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The Land-use Evolution and Impact Assessment Model: A Comprehensive Urban Planning Support System

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IntroductIon

Flooding is one of the most common natural disasters resulting in threats to life and property throughout the world (Sharma and Priya 2001). Flooding occurs when heavy and continuous rainfall exceeds the absorbing capacity of the soil or the flow of the water is greater than the normal carrying capacity of a stream channel. Statistically, streams equal or exceed the mean annual flood level once every 2.33 years (Leopold et al. 1964) and cause streams to overflow their banks onto flanking lands. Flood often accompanies other natural disasters such as brief torrential rain, monsoonal rain, cyclones, hurricanes, or tidal surges (Brakenridge et al. 2004). In addition, increasing impermeable layers, such as roads, residential buildings, and industrial complexes, reduce the land’s natural ability to absorb water, which increases runoff as well as disturbs the natural water flow, thus increasing the risk of flooding (Ramroop 2005).

In Trinidad, flood is one of the major hazards affecting the country every year and during all seasons (Ramroop 2005). In recent years, the number of flood occurrences has increased throughout the country. In addition to the previously mentioned common causes, factors contributing to flood occurrences in Trinidad are particularly indiscriminate dumping into streams and improper or illegal hillside land development and agricultural practices (WRA/MIN. Env. 2001). Flood damages can be categorized as physical damages to houses and infrastructure, casualties of people and livestock as a result of drowning, spreading of diseases, scarcity of clean drinking water because of water contamination, and damages to food crops (Mileti 1999). According to Mileti (1999), flood hazards severely impede the economy of the United States; translated into the context of Trinidad, damage caused by flooding events in 1993, 2002, and 2006 are $580,000, $3,300,000, and $2,500,000, respectively (WRA/MIN. Env. 2001, Brakenridge et al. 2003, Brakenridge et al. 2007).

After a decade of economic growth, mainly driven by the energy sector (IMF Country Report 2005), housing development in Trinidad has increased considerably even in flood-prone areas. Economic values of houses have increased with the use of costly fixtures, which further add to the losses. Unfortunately, flood insurance has not kept up with housing development and insurance providers lack the tools to properly predict potential losses and recommend mechanisms to benefit both parties in the insurance market. The insurer, more often than not, is an agent in a chain of transfer of premiums in return for potential compensation. This kind of risk transfer is depicted in Figure 1.

However, potential clients are not readily purchasing flood insurance policies because of high premiums (Browne and Hoyt 2000, Miller 1997, Preist et al. 2005). Thus, implementing flood insurance for private households with affordable premiums is in the best case difficult and in the worst case plainly not profitable (Miller 1997). For these reasons, it is very important to classify areas based on their flood risk. Geographic information systems (GIS) can be used to categorize flood-risk zones by analyzing complex spatial data sets from different sources (Gangai et al. 2003). In this study, GIS forms the basis for a private household flood-insurance system for Trinidad to calculate premiums based on household exposure to flood risk and to speed up the underwriting process.

Abstract: Floods, among the most severe natural perils causing risk to life and property in every corner of the world, have become more frequent in recent years because of increasing alterations of the environment. Damages caused by floods create great loss to individuals. Without insurance, it is difficult to recover from the impacts. In some countries, though, insurance companies charge premiums based on region rather than on the location of the individual property. In the case of Trinidad, this general way of premium calculation is in practice combined with standard property insurance. By integrating geographic information systems (GIS) to the flood-risk assessment of each and every individual private house, a more equitable premium can be calculated. This is exemplified in this study, where a GIS-based flood insurance system was developed for Trinidad to handle flood insurance for private houses. The system uses flood and house information from a GIS database and client-provided information to calculate reasonable premiums. This benefits both clients and providers of flood-insurance policies.

INTRODUCTION

GeoFIS Flood Insurance System for Trinidad: A Case Study for San Juan Downstream

F. Canisius and C. Nancy

Figure 1. Insurance Model
Flood-prone Areas in Trinidad

Trinidad is situated at the southernmost end of the Caribbean island chain located at latitude 10.5° N, longitude 61.5° W, and is approximately 5,126 km² in size. The climate of Trinidad is tropical wet, with an average rainfall of 2,200 mm (WRA/MIN. Env. 2001) and its monsoonal character results in high-intensity rainfall and subsequent frequent flooding (Bryce 2007).

The flood history of Trinidad shows that the frequency and intensity of flooding events is increasing (Bryce 2007). Based on information collected from newspaper articles (Maharaj 2006), the Water and Sewerage Authority (WASA), and the Office for Disaster Preparation and Management (ODPM), we mapped more than 100 locations in Trinidad that have been flooded in 1986–2006 (see Figure 2). In four locations, floods have occurred ten or more times within the past 20 years. More than 30 of these locations are in high-density settlement areas and floods in these areas cause significant economic damages. Typically, they occur in brief storms associated with sheet or surface flow (Baban and Kantarsingh 2005).

It is widely documented (e.g., Chan 1997, Smith 1991, Baban and Canisius 2007) that alluvial planes prone to flooding also are often densely populated and contain highly built-up areas vulnerable to flooding. Figure 2 shows that this holds true for Trinidad as well.

Functionality of GeoFIS

Based on Figure 2, significant areas in Trinidad are flood prone and coincide with residential developments. Therefore, a need exists for introducing a flood-insurance system for Trinidad to cover financial losses caused by flooding. The adaptation of the British flood-insurance system has proven unsuitable, for many householders who are living out of a flood-prone area would have to pay higher insurance premiums. This is because UK insurers traditionally determine flood-risk premiums on the basis of administrative boundaries/postcode bands rather than on particular addresses (Ordnance Survey 2007).

The GeoFIS flood-insurance system simplifies the process of risk assessment of private households by integrating GIS, allowing insurers to verify and evaluate the flood-risk level of a property and to fix a premium. Based on a GIS, the operator may zoom in on the house to be insured for a visual clarification. There are five main components to this system (see Figure 3): (1) spatially identify a particular property located in a flood-prone area; (2) analyze the vicinity of flood boundaries to predict future chances for flooding; (3) classify the flood-risk level of the house based on the flood-prone area and considering previous flood-event statements by clients and number of insurance claims; (4) estimate area, age, and number of stories of the house and calculate the house’s value, including other house information, such as construction of the house and permanently installed fixtures; and (5) calculate the premium based on the flood-risk class.

Flood-risk Analysis

To classify flood risk, a house’s location is identified to determine whether it is located inside or outside the flood zone. If the house is identified as lying in a flood zone, the flood-recurrence interval...
is analyzed in a second step. If the house is located outside the flood zone, the likelihood for flooding is determined by calculating the elevation difference between the property and the nearest flat plain, where river and drainage channels pass through.

Three ArcView Avenue scripts implement the outlined approach: (1) identification of a property location on a floodplain, (2) calculation of the distance to the floodplain, and (3) determining the floodplain in the first place:

To identify whether a house is located inside a floodplain, first retrieve the address polygon using the address ID. Next create x and y coordinates for the retrieved address polygon and create a point feature for it. Then intersect the created house point with the flood boundary and determine whether the house is located inside the flood boundary. Finally, check the flood-recurrence interval of the house that was identified inside the flood boundary.

If the house is located outside the flood boundary, then determine the elevation difference between the house elevation and the nearest flood boundary elevation. Obtain the elevation of the house by intersecting the house point with the average elevation. Then find the elevation of the flood boundary by intersecting the flood polygon with the buffered house polygon by the calculated minimum distance and obtain the smaller value of the two. Next create a point as described previously to intersect the point with the average elevation and determine the elevation of the flood boundary. Finally, calculate the elevation difference by subtracting the elevation of the house from the elevation of the flood boundary.

The location of a house in a floodplain, where river and drainage channels pass through, is identified in the following steps. First, find that the house is located in a floodplain by intersecting the house point calculated in (1) or (2) with the floodplain polygon. Then intersect the river or drainage channels polygon and retrieve the flat plain polygon to ensure that the river or drainage channel crosses the identified floodplain.

**ASSESS HOUSE VALUE AND CALCULATE INSURANCE PREMIUM**

In the assessment of the house value, its size, age, and number of stories are used. With the assessed house value, the value of permanent fixtures (built-in dishwasher, hot-water heaters, shelving and cabinetry, plumbing fixtures, stoves, ovens, refrigerator, and air conditioner) and the construction of the house (varieties of wall, floor, roof, and window) are added to calculate the total value of the house. Using MS Access, derive the area of the house and multiply the derived area by the number of stories to obtain the total area of the house. Next, multiply the total area of the house by the market price of square feet. At this point, considering the age of the house, add the percentage of the house value and calculate the total value of the house. The area, number of stories, age, and total value of the house are subjected to verification by the client. Extra tables and procedures are encoded to update market prices and changes in the variability of the price of square feet, permanently installed fixtures, and construction of the house, and the percentage of the premium, the percentage of the discount of the flood-risk classes, and the percentage of the house value with regard to the age of the house.

**Case Study of San Juan Downstream**

We selected San Juan as a study area for GeoFIS; it is the third largest city of the country and undergoes sizable developments, even in floodplain areas.

**Data Collection**

Flood data, houses, roads, rivers, elevation data, and aerial photos (shown in Figure 4) were collected from the Department of Surveying and Land Information, University of the West Indies. The 1994 and 2003 aerial photos were used to update house data and to estimate the number of stories and the ages of houses. A site visit was performed for some ground truthing. This included getting experts to estimate the square-foot market value. In addition, personal-level information about the client and the house from the application files was obtained.

**Acquire Area, Age, and Number of Stories of House**

To calculate the area of each house, we updated our files based on a 2003 aerial photograph mosaic that we created using ERMapper software. The house data then were digitized and updated using ArcView (see Figure 5A).
To determine the age of a house, we employed multidate aerial photographs. A RGB color composite was developed using multidate aerial photographs obtained in 1994 and 2003 (red: 1994, green: 2003, blue: 1994). We then classified houses as either less than ten years old (green color house in Figure 5B) or more than ten years old (white color in Figure 5B).

To identify the number of stories of a house, we developed a stereo model using two consecutive aerial photographs taken directly one after the other with about 60 percent overlap of the area. This was done by DVP digital photogrammetry software, adjusting interior, relative, and absolute orientations. The height of the house was measured from the 2003 stereo model (Figure 5C). A height of less than 3.5 m was considered a single story and each 2.5 m above a single story was considered one additional story. These houses' heights were further confirmed during field visits to the study area. The area, number of stories, and age of the house were subjected to cross-check with the information provided by the house owner before calculating the house value.

**INSURANCE ASSESSMENT**

With the GeoFIS flood-insurance system, insurance premiums for a house are calculated based on its flood-risk class in relation to the house’s location (see Figure 6). To identify the flood-risk classes, the following four criteria were used: (1) The house is located inside the flood boundary; (2) the flood-recurrence interval of the flood boundary is less than or equal to five years; (3) the elevation difference between the house elevation and the elevation of flood is less than two meters; and (4) a waterway crosses flat land (less than 1 percent slope). If flooding in a particular area is very frequent (the flood-recurrence interval of the flood boundary is less than or equal to five), the houses in the flood boundary are classified as very high or high risk. In our study area, flooding is very frequent; therefore, the houses in the flood boundary are classified as very high risk. This procedure is summarized in Figure 6.

When we applied our criteria to actual flooding data (Figure 7 and Table 1), we found that 1.47 percent of very low risk, 7.59 percent of low risk, 17.8 percent of medium risk, and 36 percent of very high risk classes were flooded in the past. These percentages are encouraging, although we would obviously prefer to get a better handle on those judged to be low risk. We assume that a significant number of these houses were flooded because of other reasons such as improper drainage or drainage blocks that were not considered in this study.

<table>
<thead>
<tr>
<th>Flood-risk Class</th>
<th>No. of Houses</th>
<th>No. of Flooded Houses</th>
<th>% Flooded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>681</td>
<td>10</td>
<td>1.47</td>
</tr>
<tr>
<td>Low</td>
<td>580</td>
<td>44</td>
<td>7.59</td>
</tr>
<tr>
<td>Moderate</td>
<td>680</td>
<td>121</td>
<td>17.8</td>
</tr>
<tr>
<td>High</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Very high</td>
<td>100</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td><strong>Total number of houses</strong></td>
<td><strong>2041</strong></td>
<td><strong>211</strong></td>
<td><strong>10.34</strong></td>
</tr>
</tbody>
</table>

**DISCUSSION**

The GeoFIS flood-insurance system was developed to determine the flood risk of private properties. The system requires high-resolution satellite and aerial imagery to derive a detailed flood map, which would be expensive to implement for the entire country. However, in Trinidad, the frequency of flooding, subsequent financial loss, and rapid development of built-up areas mandate that this system be implemented.

According to the Federal Citizen Information Center (FCIC) in the United States, about 25 percent of all flood-insurance claims come from outside the Federal Emergency Management Agency (FEMA) classification of high-risk areas. Available flood maps of Trinidad do not have the necessary resolution to truly represent the actual probability of flood danger of each individual private home. Ramroop (2005) recommends that the National Emergency Management Association (NEMA) be authorized to
develop maps of flood-prone areas. SAR data is one possible source for the development of flood maps (Canisius et al. 1998). Non-governmental organizations (NGOs) in Trinidad also showed their interest in developing flood maps using hydrological models.

The system will require regular updates. For instance, in the ten-year period from 1994 to 2003, the Bamboo Grove settlement increased by about 20 percent and the expansion of a highway may have changed floodplain conditions. This updating, however, will not affect the core function of the system, where separate lookup tables are used for variable parameters.

CONCLUSION

Insurance is a business of transferring risk. Understanding insurance in general and using GIS data in particular provides valuable input to realistically analyzing flood risk. Higher accuracy in risk assessment will help to prepare for likely increases in flood events that will enable all parties to make use of flood insurance for their advantages. The GeoFIS flood-insurance system was developed by integrating GIS into a general-purpose home-insurance system to improve processing and calculate fair premiums based on the flood-risk class of each property. Not only is this system useful for premium calculation but it also educates and prepares the entities of the insurance market about future flood perils.

The system has classified five flood-risk classes; they are: very high, high, moderate, low, and very low. By this classification, the system has provided clients a fair premium discount according to the vulnerability of their houses. This system offers advantages for both parties of the flood-insurance market: Clients can obtain the flood insurance and pay premiums based on the vulnerability of the flooding of their respective homes; insurers, on the other hand, can promote and sell their flood insurance to those homeowners who promise a long-term profit.

About the Authors

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Ms. Sophia Nancy received her BSc. in Information Systems and Management from University of London, UK and she is a licensing specialist at Adobe Systems Inc. Ottawa, Canada.

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References


Figure 7. Flood-risk Classification of the Houses


Maharaj, A. N. 2006. Methodology for identifying and mapping flood prone areas in Trinidad using GIS. BSc Research Project, University of the West Indies, Trinidad and Tobago.


St. Kitts Land Resource Analysis

Edsel B. Daniel, Derek L. Bryant, James P. Dobbins, Ilis Watts, Alan P. Mills, and Mark D. Abkowitz

Abstract: Facing successive losses in the sugar industry and the imposition of a 39 percent price reduction in its primary export market, the Government of St. Kitts and Nevis (GoSKN) decided to cease the production of sugar for export at the end of the 2005 production period. As part of the transition away from sugar production, a land resource analysis project was undertaken to complete a preliminary land-suitability analysis for proposed alternative activities. This evaluation included data collection and environmental analysis showing the magnitude and location of areas suitable for alternative agriculture, ecological preservation, and commercial or industrial activity. Geographic information systems (GIS) provided suitable technology to enable comprehensive environmental analysis and presentation of results. This project provided additional benefits by serving as a pilot project for demonstrating the value of GIS in Caribbean resource management and by building the foundation for a national GIS. This paper presents project results and describes the utility of the analysis in the selection of preferred long-term land uses and an overall sugar adaptation strategy for St. Kitts. It also highlights a few examples of similar island nations in the Caribbean and Asian/Pacific regions under comparable economic circumstances where these methods can be applied.

INTRODUCTION

Over the past 350 years, the Federation of St. Kitts and Nevis has built its economy around agriculture, focusing primarily on sugarcane production. Preferential market arrangements with Europe have played a significant role in keeping the sugar industry active as world sugar prices declined. A changing global economy has created the opportunity for new, more viable markets and increased competition. The World Trade Organization (WTO) rulings against preferential market arrangements has dealt a severe blow to the Caribbean sugar industry, not only for the Federation, but for other eastern Caribbean islands (e.g., Dominica, St. Vincent, and St. Lucia) with similar preferential arrangements for other agricultural products such as bananas. The resulting fluctuation in commodity prices and reduced European Union trade preferences have made the islands’ reliance on single-crop agriculture an economic vulnerability. To address such vulnerabilities, these island governments have focused on diversifying their economies, a trend that includes a growing number of island nations from the Caribbean to Asia and the Pacific (e.g., Malaysia) for similar reasons (SLG 2000, FAO 2001, Gunasena 2001, SLG 2006, GML 2006, GMR 2006).

The Government of St. Kitts and Nevis (GoSKN) decided to close the sugar industry on the island of St. Kitts and vigorously pursue its economic diversification by emphasizing more viable alternatives, such as tourism and nonsugar agriculture (e.g., field crops and livestock). Like other island governments, the major challenge of this situation is adopting careful planning that ensures that the island’s land resources previously utilized by these crops are optimized for the long-term economic, social, and environmental sustainability of the country. With the assistance from the UK Department for International Development (DFID), a land resource analysis was commissioned to identify the most suitable land for the various nonsugar uses under consideration. The results were compared with the economic and social goals of the government’s transition plan to develop a strategy, area by area, of preferred long-term land use.

This paper documents how geographic information technology (GIS) is utilized to perform this land resource analysis. The method adopted and data used for performing this analysis and final results are discussed. The discussion also highlights a few examples of other islands in the Caribbean and Asian/Pacific regions with similar scenarios where these methods can be applied. The paper concludes with a series of recommendations for further work and improvements in other areas that relate to land management issues in St. Kitts.

BACKGROUND OF ST. KITTS

Location and Environmental Characteristics

St. Kitts (also called St. Christopher) is part of an independent twin island federal state with the island of Nevis. These islands are located in the northeast Caribbean Sea (see Figure 1). St. Kitts has a land area of 168 km². Soils throughout the island are extremely fertile and have been used primarily for sugar production. Figure 2 provides a general layout of St. Kitts.

Agricultural and Economic History

First colonized by the British in 1623, St. Kitts has been an important sugar producer for 350 years. St. Kitts and Nevis achieved independence in 1983 and currently are members of the British Commonwealth, the Organization of Eastern Caribbean States, and the Caribbean Community (CARICOM).

Sugar was the traditional mainstay of the St. Kitts economy until the 1970s. Since then, the combination of improved international connections at the airport and cruise dock have made tourism the island’s main source of revenue. The government has subsequently sought to nurture tourism with development...
projects valued at more than $700 million (Douglas 2005). The contribution of the agriculture sector to real GDP declined from 15.6 percent in 1980 to 5.2 percent in 2004. Despite the thrust toward tourism, however, agriculture is expected to play a vital role in the economic future of St. Kitts.

St. Kitts and Nevis have a total cultivable land area of about 22,000 acres, of which some 12,000 actually are cropped. The climatic conditions are suitable for a wide variety of crops, but sugarcane occupies about 80 percent of the cropped area (see Figure 3), despite its declining acreage since the early 1980s.

Agriculture and Land-use Policies

After the closing of the sugar industry, the Physical Planning Department (PPD) and the Department of Agriculture (DoA) have spearheaded the planning for the agricultural transition. This effort includes the preparation of a National Physical Development Plan (NPDP 2005), which spans the years 2005 to 2020 and provides a blueprint that has been adopted for the future development of the island of St. Kitts. The plan recommends policies, strategies, programs, and projects that can be implemented to realize defined economic, social, and land-use goals at a sector, settlement, and national level (PPD 2005).

Several policies have been established by the development plan that affect the potential for postsugar agriculture, including:

- The reservation of lands between the 500-foot to 1,000-foot contour as priority areas for agricultural diversification and
- Provision of community grazing pastures for villages to distribute to individual herders.

The plan also proposes alternative economic activities and corresponding land areas to be allotted to each activity (see Table 1) that must be considered in planning for postsugar development.

<table>
<thead>
<tr>
<th>Acres</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,250</td>
<td>Rum distillery and tourism center</td>
</tr>
<tr>
<td>5</td>
<td>Food-processing and packaging operations</td>
</tr>
<tr>
<td>5</td>
<td>Hydroponics operation</td>
</tr>
<tr>
<td>5,000</td>
<td>10 MW cogeneration of electricity, production of ethanol from cane juice and for animal feed</td>
</tr>
<tr>
<td>100</td>
<td>Small-scale food production</td>
</tr>
<tr>
<td>1,000</td>
<td>Vegetable cropping, etc., by commercial farmers</td>
</tr>
<tr>
<td>50</td>
<td>Peanut production</td>
</tr>
<tr>
<td>1,500</td>
<td>Beef cattle production</td>
</tr>
<tr>
<td>1,500</td>
<td>Small ruminant production</td>
</tr>
</tbody>
</table>

Methodology

The methodology used for the land-suitability assessment is based on the guidelines set forth by the Food and Agriculture Organization of the United Nations (FAO 1976, 1983, 1985,
These guidelines have been widely used in determining the physical suitability of lands in support of land-use planning and development of alternative land uses. Some examples of studies that employ this method include work by Kilic et al. (2005) and Ozcan et al. (2003) in Turkey, Kalogirou (2002) in Greece, Gaiser and Graef (2001) in Niger and Brazil, and Igú et al. (2000) in Benin.

The FAO method allows the user to determine the suitability of land parcels for potential land uses by rating a series of land quality and characteristic factors. Examples of these factors include available soil nutrients, land slope, and the amount of precipitation a land parcel receives. The factors incorporated into the evaluation are selected based on their relevance to the study area. These factors then are evaluated based on the requirements for individual land uses (e.g., pineapple production versus livestock grazing). This evaluation involves classifying each land parcel as highly suitable, moderately suitable, marginally suitable, or unsuitable for each factor in each land-use being evaluated. The ratings then are aggregated using a weighting system corresponding to the relative importance of each factor to each land use. This aggregation yields land-suitability scores for each potential land use, which then can be used to create suitability maps for the land area under consideration.

The potential land uses under consideration in this study were taken from recommendations made by CARDI (2005) and the St. Kitts and Nevis DoA (2001, 2005) for postsugar agriculture. Because of insufficient data for the needs of the individual crops under consideration, potential land uses were grouped according to similar environmental requirements (see Table 2). These groupings were formulated under the guidance of senior-level staff at the DoA (Jackson 2005, Stanley 2005).

In creating the list of factors for use in determining land suitability for each land-use group, there was a need to balance the inclusion of factors with data availability. For example, soil pH and nutrient availability are two factors commonly included in land-suitability assessments. These data are not available for soils in St. Kitts, however, and both factors had to be excluded from the list. Further discussion on data availability is presented in the “Data Management” section that follows. The factors used in this study are summarized in Table 3. These factors were verified as being important to land-suitability assessments in St. Kitts by means of interviews with senior DoA officials and through field reconnaissance of potential agriculture lands with members of the PPD and former senior staff of the St. Kitts Sugar Manufacturing Corporation (SSMC). Note that because the amount of precipitation received by an area on St. Kitts is proportional to the area’s elevation, variances in precipitation have been accounted for in the evaluation factors for crop agriculture. The focus of this study was placed on rain-fed, rather than irrigated, agriculture based on the absence of additional water resources, irrigation technology, and irrigation infrastructure in St. Kitts for the foreseeable future (Thomas 2005).

### Table 2: Evaluated Land-use Groups

<table>
<thead>
<tr>
<th>Land-use Group</th>
<th>Crops/Land Uses Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineapples</td>
<td>Pineapples</td>
</tr>
<tr>
<td>Field Crops</td>
<td>Canistear, cassava, sweet potato, yam</td>
</tr>
<tr>
<td>Fruit Tree Crops</td>
<td>Sugar apple, custard apple, cardamol, guava, Indian jujube, wax apple</td>
</tr>
<tr>
<td>Vegetable Crops</td>
<td>Onions, bananas, cucumber, tomato, sweet/hot pepper, string beans</td>
</tr>
<tr>
<td>Pasture/Grass Crops</td>
<td>Grass for feeding livestock (e.g., guinea grass) or sugarcane</td>
</tr>
<tr>
<td>Livestock Production</td>
<td>Beef, pork, or mutton (goats and sheep)</td>
</tr>
</tbody>
</table>

### Table 3: Land Quality/Characteristic Factors Evaluated

<table>
<thead>
<tr>
<th>Crop Agriculture</th>
<th>Livestock Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Precipitation</td>
<td>1. Elevation</td>
</tr>
<tr>
<td>2. Soil Type</td>
<td>2. Flood Hazard</td>
</tr>
<tr>
<td>3. Elevation</td>
<td>3. Land Slope</td>
</tr>
<tr>
<td>5. Land Slope</td>
<td>5. Proximity to Water Storage Facilities</td>
</tr>
<tr>
<td>7. Wind Hazard</td>
<td>8. Soil (Ease of Mechanization/Cultivability)</td>
</tr>
</tbody>
</table>

To define the critical levels for each factor listed in Table 3 (i.e., what levels constitute highly suitable versus moderately versus unsuitable), surveys were conducted of senior-level staff at the DoA. This approach allowed for the benefit of applying local agriculture knowledge to the model. Similar surveys were planned for local farmers and various agricultural personnel, but were eliminated because of project time constraints. The surveys asked participants to list values of each factor, for each land-use group, under the headings “highly suitable,” “moderately suitable,” and “unsuitable.” The classification corresponding to “marginally suitable” from the FAO methodology was dropped from the survey to decrease the burden of survey participants and because of difficulty in obtaining meaningful and precise data for more than three suitability classes. A second component of the surveys was to determine the relative importance of each model factor. The survey participants were asked to label each factor as “very important,” “moderately important,” or “less important” in determining the suitability of a land parcel for a given use.
To aggregate factor ratings for each land-use group, the results of the survey were transformed into quantitative values. Critical level ratings were given values of 2, 1, and 0 for “highly suitable,” “moderately suitable,” and “unsuitable,” respectively. Relative importance results were transformed to values of 3, 2, and 1, corresponding to “very important,” “moderately important,” or “less important,” respectively. The use of the 0-to-2 scale for critical level ratings, as opposed to the 1-to-3 scale of relative importance, assured that factors rated as unsuitable for a given land area would not artificially increase the suitability score of that parcel.

The factor ratings were aggregated for each land parcel by multiplying the factor rating by the factor importance and summing for all factors, as seen in the following equation:

\[ \sum_{i=1}^{n} R_i \times I_i = \text{Land Suitability Score} \]  

where \( R_i \) is the critical factor rating of the \( i \)th factor and \( I_i \) is its corresponding importance. The result of this aggregation is land-suitability index values for each land parcel, which were used to create suitability maps using GIS technology.

GIS was utilized for overlaying spatial data representing the factors listed in Table 3 to delineate the relative suitability of land parcels for each land-use group. This operation resulted in distinct

<table>
<thead>
<tr>
<th>Layer name</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Polygon layer showing mean annual rain fall distribution across the entire island; data missing from the data set was accounted for by means of extrapolation</td>
<td>St. Kitts Water Department</td>
</tr>
<tr>
<td>Soil Type</td>
<td>General soil classification</td>
<td>PPD from soils maps that were created by Lang and Caroll (1966)</td>
</tr>
<tr>
<td>Soil Cultivatability</td>
<td>Ease of mechanical land preparation according to amount of stones and boulders on site</td>
<td>PPD from soils maps that were created by Lang and Caroll (1966)</td>
</tr>
<tr>
<td>Elevation</td>
<td>A contour layer with ten-meter intervals generated from a 2002 aerial photograph; GIS processing tools were used to create a new polygon contour layer with 100-foot (30-meter) ranges</td>
<td>PPD</td>
</tr>
<tr>
<td>Land Slope</td>
<td>General slope in degrees from horizontal</td>
<td>Derived from contour layer above</td>
</tr>
<tr>
<td>Flood Hazard</td>
<td>Flood prone area determined according to local water depth resulting from a 100-year return period storm</td>
<td>Post-Georges Disaster Mitigation Project (PGDM), <a href="http://www.oas.org/pgdm">www.oas.org/pgdm</a></td>
</tr>
<tr>
<td>Inland Erosion Hazard</td>
<td>Composite erosion hazard classes including gullying and landslide/rock fall hazard of bare soil areas</td>
<td>PGDM, <a href="http://www.oas.org/pgdm">www.oas.org/pgdm</a></td>
</tr>
<tr>
<td>Wind Hazard</td>
<td>Areas of storm wind hazards for a 100-year return period</td>
<td>PGDM, <a href="http://www.oas.org/pgdm">www.oas.org/pgdm</a></td>
</tr>
<tr>
<td>Settlements</td>
<td>Inhabited areas, predominantly the residential agglomerations</td>
<td>PPD</td>
</tr>
<tr>
<td>Wells and Water Storage</td>
<td>Drinking water source locations including all reservoirs, wells, and springs</td>
<td>St. Kitts Water Department</td>
</tr>
</tbody>
</table>
land areas, each with its own land-suitability index value for each model factor. Land areas in restricted zones, such as within 60 feet (18 meters) of a ghaut or above the 1,000-foot (300-meter) contour, then were removed from the layers. The remaining land areas were grouped according to an equal-interval classification of their index values (i.e., the entire range of index values represented for each land use is broken into ranges of equal size from minimum to maximum) into categories of “unsuitable,” “moderately suitable,” “suitable,” and “highly suitable.”

**DATA MANAGEMENT**

Primary GIS data collection took place at the National GIS (NGIS) Laboratory, PPD. A total of ten GIS data sets were used, each of which is briefly described in Table 4. Other data sets with information recommended by the FAO but not available for this study were soil pH, soil nutrients, and water salinity. Additional potentially useful GIS data sets to supplement the FAO method would have been property boundaries (cadastral information), waterlines, reserved lands for major tourism and related future developments (e.g., Basseterre Valley Aquifer Park), location and extent of existing farmlands, and water-table depth. These data sets were either unavailable or in a format that could not be utilized by the project team. It also should be noted that the land resource analysis excluded the reserved areas of:

- Settlements,
- The Southeast Peninsula (reserved for tourism development),
- Forest reserve above 1,000 feet,
- Brimstone Hill area (UNESCO World Heritage site), and
- 60-foot (18-meter) buffer area around ghats.

**RESULTS**

The total land area delineated as suitable and highly suitable for the six agricultural land uses (pineapples, field crops, fruit tree crops, vegetable crops, pasture corps and livestock production) is listed in Table 5. An example suitability map for fruit tree crops is shown in Figure 4.

**Table 5. Total Land Area Rated as Suitable or Highly Suitable by Land Use Group.**

<table>
<thead>
<tr>
<th>Evaluated Land Use Group</th>
<th>Suitable Areas</th>
<th>Highly Suitable Areas</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineapples</td>
<td>56.9</td>
<td>47.4</td>
<td>104.3</td>
</tr>
<tr>
<td>Field Crops</td>
<td>66.5</td>
<td>38.9</td>
<td>105.5</td>
</tr>
<tr>
<td>Fruit Tree Crops</td>
<td>27.9</td>
<td>75.4</td>
<td>103.3</td>
</tr>
<tr>
<td>Vegetable Crops</td>
<td>64.2</td>
<td>15.5</td>
<td>79.7</td>
</tr>
<tr>
<td>Pasture Crops</td>
<td>38.3</td>
<td>38.6</td>
<td>76.9</td>
</tr>
<tr>
<td>Livestock Production</td>
<td>25.8</td>
<td>3.2</td>
<td>29.0</td>
</tr>
</tbody>
</table>

*aAll values are given in km2.*

Suitability results were compared with the proposed land uses under the National Physical Development Plan (PPD, 2005) (see Figures 5) and the DoA’s (2005) proposed land uses for lands under sugar cane. Example results from this analysis, for fruit tree crops, are shown in Figures 6 and 7.

The objective of performing these comparisons is not to recommend the quantity and location of specific agricultural land uses. The goal is to highlight how current proposals for national land use (e.g., housing tourism, industrial, residential, commercial, agriculture, etc.) compare with suitable lands for alternative non-sugar agriculture uses. This comparison identifies and quantifies these overlaps. Subsequent studies can then utilize these results in a benefit-cost analysis to facilitate decision making on competing land uses. A more elaborate discussion of this finding is provided in the “Discussion” section below.
DISCUSSION

The land resource analysis results show that a wide variety of agriculture is compatible with the environmental conditions present in St. Kitts. Land-use suitability indexes calculated for each crop grouping are skewed toward higher, or more suitable, values. This result indicates that most land areas are capable of successfully producing each of the crops under consideration. There is a relatively wide envelope of area where the croplands can be potentially developed. Fruit tree crops would be successful throughout the agriculture belt, between the mountain reserve and coastal hinterland, apart from between Cayon and Basseterre. Pasture crops would be most successful just below the mountain reserve land. Vegetable and field crops have a narrower band than fruit crops but could still be widely distributed throughout the island. Pineapple crops are similarly suited to growth over large areas of the island.

Land in St. Kitts appears to be slightly less suitable for the production of livestock. Table 5 indicates that there is less land categorized as suitable or highly suitable for livestock than there is for the other evaluated land uses. The primary reason for this lower compatibility is that animal production facilities (e.g., grazing area, feed lots, etc.), unlike crops, have restrictions on their placement within a given proximity to residential areas. In this analysis, at the recommendation of senior-level DoA staff (Stanley 2005), a buffer of a quarter mile was used to separate livestock grounds from populated areas for reasons of aesthetics and human health. Most of the area classified as moderately suitable or unsuitable occurs around settlements such as the capital city of Basseterre or on steeply sloping lands near the 1,000-foot (300-meter) contour land development limit.

Comparing the results of the suitability analysis with PPD/DoA-proposed land uses shows tree crops to be the most suitable crop type for former sugar lands. The land-suitability map for pasture crops shows that the areas most suitable for this type of agriculture are at elevations that may not support beef production. The sloping lands will compromise the quality of the beef by making the livestock too muscular. Such lands would be more suitable for dairy production. An important observation is the high level of agreement between the suitable livestock lands and the DoA’s proposed livestock assignments for sugar lands. This agreement demonstrates a level of consistency between the land-suitability modeling results and GoSKN’s proposed land uses for the sugar lands, serving as a rough validation of these results.

The comparison of suitable lands and proposed land uses illustrate some of the basic types of analyses that can be performed with the results produced under this project. However, the potential for using these layers in agricultural and economic planning is fully realized when they are incorporated into the various plans for economic development, with regards to the transition from sugar agriculture and the more general national economy. Using economic indicators, and by setting average yield amounts for highly suitable and suitable categories, the area of land needed to make an enterprise viable can be calculated. This would aid land-use decision making by presenting alternatives complete with projected financial results. Using the maps presented here, decision makers can identify preferred areas of cultivation or livestock production, strategically zone areas, and assist in identifying large-scale enterprise locations and/or smallholder plots for community farming. The GIS layers produced by this study and the data they contain could be further utilized in economic planning by using them in concert with additional data layers, such as transportation infrastructure and processing-plant locations to determine the cost of transporting goods. Such analyses would allow for analysis of a wide range of costs and environmental impacts.

While this study was focused on the island of St. Kitts, it provides a template for broader and generic application in other island states throughout and beyond the Caribbean with similar agriculture or land-use diversification efforts. In the Caribbean, the island states of Dominica, St. Lucia, and St. Vincent had simi-
lar economies based primarily on a single crop (i.e., bananas). Like St. Kitts, these islands have experienced declining EU preferential markets, forcing a restructuring of their economies. For example, the government of St. Vincent and the Grenadines (SVG) has been making attempts to diversify its economy by reviving the production of arrowroot and expanding the amount of land area under root crops. This plan for agricultural diversification is complicated, however, by informal or squatter settlements in which residents illegally occupy publicly owned land.

In 2005, the government of SVG (2009) estimated the number of squatters to be 16,000, large enough to threaten the welfare of the island’s forest reserve and watershed management system. Consequently, in addition to the fundamental issues of land access and arability, shifts in agricultural policy must account for the location of illegal settlements, the factors that drive them, and potential impacts to the island’s already endangered natural resources. In an effort to address these central issues, SVG is committed to make arable land available to landless farmers and introduce appropriate land management policy SVG (2009).

Other islands around the world face similar challenges of diversification away from monoculture. For example, in the Indian Ocean, Mauritius has depended strongly on sugar as a crop. Although at this time, it still invests and relies heavily on the bulk sugar industry, it, too, has been confronting issues of diversification and allocation of resources (Julien 1998, GMR 2006). In Asia, changing land use resulting from new trade regimes guided by regional and international agencies (e.g., WTO) presents itself in states in which agricultural production now encompasses the expansion of crops such as fruits, tree nuts, and vegetables (Singh 2001, GML 2006). Like St. Kitts and the previously mentioned Caribbean island states, these kinds of expansion will require the identification of potential land areas and evaluation of the suitability of these lands to maximize production of these crops. For example, in its quest for economic diversity, the government of Malaysia (2006) has seen agricultural land use increased from 5.9 to 6.4 million hectares during the period of 2000–2005. This increase was largely because of the expansion of production in oil palm, coconuts, vegetables, and fruits. Despite this drive for increased agricultural production, however, a total of 163,000 hectares of agricultural land remained idle because of absentee or aging landowners and difficulties in consolidating native and customary land units. It is the government’s goal and expectation to increase agricultural land use at an average rate of 1.5 percent by maximizing the yield and allocating these lands for expanding oil palm cultivation; large-scale production and precision farming systems will be implemented in new production zones for fruits, vegetables, and livestock (GML 2006).

Another trend in the Asian region that presents similar land-allocation issues is the development of urban and peri-urban agriculture (UPA), which offers an alternative for achieving food security (FFTC 2006). Rapid population growth in this region, exceeding 3.5 percent in some Asian countries, and the accompanying urban development and industrialization is projected to result in a decline in suitable agricultural land availability (Gunasena 2001). To combat diminishing availability of traditional farmland, a number of Asian island countries have begun experimenting with UPA. The Japanese experience with UPA reveals that about 1.1 million hectares of farmland exist in “urban-like areas” and are producing about $10 billion worth of agricultural products or 29 percent of the national gross agricultural outputs (Tsubota 2007). To sustain and increase these benefits, Japan, like St. Kitts, faces the challenge of identifying arable land and resolving land-use conflicts. In Japanese urban areas, land is a scarce and valuable commodity and the decision to allocate these areas to agricultural production rather than other socioeconomic uses (e.g., tourism, housing) is extremely complex. According to Tsubota (2007), Japan struggles with zoning and land-planning issues that require addressing competing interest for scarce land resources. He further notes that other countries pursuing UPA, such as the Philippines, Indonesia, Vietnam, and Nepal, also are facing similar problems.

These brief examples of current global agricultural trends highlight scenarios of competing agriculture and socioeconomic interests for scarce land resources similar to those faced in St. Kitts. With adequate land characteristics and GIS resources, it is possible for these island states to adopt and apply the methods demonstrated in this study to guide decisions and solutions that will address these issues. The key is for these island states to develop the necessary GIS capabilities and gather the necessary spatial data (e.g., soil, rainfall, etc.). Land and planning authorities in these islands are taking the lead by implementing a variety of GIS-based projects or making GIS a major part of their activities and decision making. For example, the Physical Planning Department in St. Vincent, with support from the EU, is implementing a National Land Information Management project that is targeted at land titling, land registration, land-use planning, agricultural zoning, state land management, and land valuation and taxation. Central activities in this project include GIS training for key government staff, utilizing GIS for mapping agricultural land to determine potential land use, developing local area land-use maps to regularize and manage the available lands, and revamping the administration/registration of land titles (SVG 2009). In Malaysia, Samat (2006) notes that land-use allocation still is being conducted in a rather ad hoc manner, often on the basis of the knowledge of a few decision makers and local planners. However, he also revealed that GIS is becoming a useful tool for land-use planning in Malaysia. The Ministry of Housing and Lands in Mauritius also have utilized GIS to optimize the identification of quality lands for sugar agriculture (Jhoy 1998) and currently are implementing a Land Administration and Management System that will modernize land administration and management systems on the island (GMR 2009).
CONCLUSIONS AND RECOMMENDATIONS

By combining GIS and scientific criteria setting with local expert judgment, a viable method for delineating areas of successful nonsugar agriculture was produced using existing information. While specific areas have been quantified based on suitability, an added project benefit has been the ability to map these locations across the island. These maps also support the comparison of land resource analysis results with the focus areas identified in the NDP and the DoA strategic plan for postsugar production in the former sugar lands. Such evaluations provide useful input to the process for determining lands where specific agricultural uses could be allocated.

While care has been taken to use the most up-to-date and accurate maps, the dynamic nature of the natural and built environments suggests that changes may have occurred since the digital source data were captured (e.g., flood events changing ghts or construction of new housing developments). Also, the values used for environmental parameters are from published sources, but the dynamics of climate, and the summary resolution of the data, inevitably means that microtemporal and spatial variations have not been mapped. The time available to do the analysis in this report was restricted, precluding the collection of quantitative environmental data from the field.

With additional time and resources, a sensitivity analysis could be performed to enhance confidence in the results. In addition, more detailed data relating to, for example, soil types, can be included to enhance the quality of the analysis. Also, further refinements of the criteria used and comparison with other economic, social, jurisdictional, and environmental information can help to more precisely quantify conditions of suitability.

Another potential refinement to the analysis involves the definition of reserve areas (e.g., ghts and residential areas, tourism development areas, and mountain reserves). There may be other areas that the government would prefer not to be considered in the land resource analysis that were not specifically addressed by the governmental agencies involved in this study (e.g., runway approach, coastal protection, near industrial areas, new developments such as White Gate Development and Basseterre Valley Aquifer Park). Given the parameters, these areas could easily be integrated into an enhanced study.

In terms of environmental monitoring, more time to gather and update information from scientific studies and key stakeholders on the island would improve the analysis and refine the results for decision making. In particular, an updated soil survey (identifying soil type, pH, chemistry, and conductivity) would be quite beneficial. A study of existing water resources would be a useful addition as well, covering current agricultural, residential, industrial, sewage, and tourist consumption, along with requirements for conserving the natural environment. Such a study should include the logistical and economic viability of irrigation for producing specialist, high-yield, high-value crops. Finally, modeling of key habitats of St. Kitts’ fauna and flora, identifying the location and nature of historical and cultural sites, and landscape analysis (e.g., to conserve the aesthetics of the natural and cultural environments) are three additional areas of data that could be incorporated to ensure a more holistic analysis. Once the physical parameters have been identified, the results can be integrated with human and economic information, such as land ownership, settlement, and strategic planning zones, to refine the mapped areas. With or without any of these refinements, the protocol defined in this paper is a useful template for comparing physical parameters for cropping to define suitable areas and provide a vital information feed into strategic government decision making and planning.

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A Data Model and Internet GIS Framework for Safe Routes to School

Ruihong Huang and Dawn Hawley

Abstract: Safe Routes to School projects are government and public participation efforts that require a variety of data on walking and bicycling safety and security measures of the environment. Urban planners, transportation engineers, and public health researchers have developed a host of walkability/bikeability indexes. However, safe route to school-oriented data specifications, storage solutions, evaluation methods, and information distribution mechanisms are not available. This paper proposes a GIS data model and an Internet GIS framework to satisfy these needs. The data model supports convenient storage and retrieval of diversified walking/bicycling safety-related data and facilitates the development of various safety indexes. The Internet GIS framework provides a series of Web-based functions such as walkability/bikeability evaluation, safe route-oriented network analysis, data communication, and Web mapping to satisfy the information needs of all users. The GIS data model and Internet GIS framework are implemented in a Safe Routes to School information system for the Sechrist Elementary School in Flagstaff, Arizona.

BACKGROUND

In 1969, approximately half of all students walked or bicycled to schools. But now, less than 15 percent of children do so; more than half of the students arrive at schools by private automobiles (FHWA). Problems accompanying this change include childhood obesity, traffic congestion, air pollution, and pedestrian safety issues. (NHTSA 2004, Frank et al. 2005, Lopez et al. 2006, Hurvitz 2005, Crawford 2006, McMillan 2005, 2007). To address these issues, the Congress passed federal legislation to establish a National Safe Routes to School Program (SRTS) in 2005. The SRTS program is administered and guided by the Federal Highway Administration (FHWA) of the U.S. Department of Transportation (USDOT). The FHWA recommends that SRTS efforts in the United States incorporate, directly or indirectly, the five components, often referred to as the five Es: engineering, education, enforcement, encouragement, and evaluation.

Information about walking and bicycling facility conditions of neighborhoods around schools is key to the implementation of the five Es. For example, urban planners and public health authorities need the information to assess neighborhood walking and bicycling safety conditions, transportation engineers need the information for roadway and intersection improvement, law enforcement officers need the information to respond to unsafe factors, law makers need the information to initiate new policies, parents need the information to understand their neighborhood safety and security conditions, and children also may need the information to guide their walking and bicycling activities.

Walking and bicycling safety data collection and assessment have been conducted by various interested parties such as urban planners, transportation engineers, and public health administrators. A significant trend in such data collection is to provide environment attribute information to planners and to evaluate new environmental and policy initiatives (Sallis et al. 1998, Ewing et al. 2003, Frank and Engelke 2001, Leslie et al. 2007). For example, Schlossberg et al. (2006) use street networks around transit stops and schools to quantitatively analyze local walkability and provide useful planning and evaluation tools for transportation planners interested in enhancing the local walkable environment. However, a good deal of existing pedestrian safety data collection activities are orientated to an adult walking environment (McMillan 2007, Schlossberg et al. 2007). For instance, Leslie et al. (2007) measure features of the built environment that may influence adults’ physical activities and develop indexes of walkability at the local level. GIS technology has been used in some data collection activities to obtain spatial measures of urban form, transportation facilities, and resource accessibility (Schlossberg et al. 2007, Leslie et al. 2007).

Transportation engineers focus on individual transportation facilities at restricted locations. For example, a transportation project targeted at improving a specific street intersection or a segment of sidewalk surface may collect data in the geometry, traffic flow, pedestrians, and accidents at the construction site before and after the implementation of engineering measurements. Walking and bicycling safety checklists often are used for such project-specific data collection.

While walking and bicycling safety data collection is a common practice for urban planning and transportation engineering projects, similar activities dedicated to SRTS are rarely seen in literature. Because most of the current data collection practices are not school-trip oriented, direct participants of SRTS programs, including children, parents, and schools, are not involved, and their concerns are not reflected. To date, there are no standards or specifications to guide comprehensive data collection for SRTS. Given that SRTS is a widely embracing public participating effort involving participants from a wide range of areas, including schools, parents, children, planners, engineers, public health organizations, and law enforcement institutions, keeping everybody informed is essential to the success of an SRTS program.

An Internet (or Web-based) geographic information system
(GIS) has the potential to satisfy the broad information needs for SRTS. This paper presents a data model for a GIS database and a framework for Internet GIS applications that satisfy SRTS data collection, evaluation, analysis, and distribution. An SRTS database can support convenient storage of diversified walking and bicycling safety measures and facilitates evaluation of walkability and bikeability conditions. Built on the GIS database, Internet GIS provides advanced online information services such as collection and dissemination of walking and bicycling safety data as well as safe route planning. It also provides a means of communication between different parties involved in an SRTS project. An Internet GIS, therefore, can serve as a platform on which every party can play a role in SRTS.

WALKABILITY AND BIKEABILITY INDICATORS

Supposedly, good urban form can lead to a reduction of total transportation costs and automobile usage, resulting in more livable communities (The Victoria Transportation Policy Institute 2007). McMillan (2005, 2007) maintains that urban form is a primary factor affecting children’s travel behavior to school. Schlossberg et al. (2006) not only believe that urban form is a factor that affects students’ transportation modes but also suggest that it can help predict school travel modes. Furthermore, Schlossberg (2007) proposed a series of urban form measures based on TIGER files in a GIS. These urban form measures fall into three categories containing a total of 13 measures: quality (e.g., minor road density, minor/major road ratio), proximity (e.g., pedestrian catchment area, impeded pedestrian catchment area), and connectivity (e.g., intersection density, dead-end density). In studying general walkability of local communities, Leslie et al. (2007) propose a walkability index of Census Collection District (CCD) based on four environmental attributes: dwelling density, connectivity (using road centerline and intersection data), land-use accessibility and diversity of uses (entropy of land-use mix), and net area retail (shopping centers). They also argue the importance of objective measures of walkability factors in urban areas. McMillan (2007), however, pays more attention to perceptual aspects of urban forms and safety by surveying caregivers for their perceptions of a number of variables, including neighborhood safety, traffic safety, household transportation options, sociocultural norms, attitudes, and sociodemographics. Although land use was regarded an important factor of neighborhood walkability in the study of Leslie et al., it is excluded from considerations for school trips by other researchers because the school is the only destination (McMillan 2007, Schlossberg 2007).

Transportation engineers are more interested in safety conditions of transportation facilities, especially roadways and intersections, and they have proposed a host of indexes for walking and bicycling safety. Examples of these indexes include Pedestrian Level of Service (PLOS) (Sarkar 1993, Dixon 1995, Gallin 2001, Chu and Baltas 2001, Balts and Chu 2002), measure of pedestrian environments (Khisty 1994), pedestrian environment factor model (1000 Friends of Oregon 1993), pedestrian potential index and deficiency index (Portland Pedestrian Master Plan, City of Portland 1998), Level of Service (LOS) (Botma 1995), Bicycle Safety Index Rating (BSIR) (Davis 1987), roadway condition index (RCI), Bicyclist Stress Level (Sorton and Walsh 1994), Intersection Hazard Score (IHS) (Landis 1994), Bicycle Level of Service (BLOS) (Landis, et al. 1997), Bicycle Compatibility Index (BCI) (Harkey et al. 1998), intersection BLOS (Landis et al. 1997), Compatibility of Roads for Cyclists (CRC) (Noel et al. 2003). Some of these indexes focus on roadways and others emphasize intersections. Indexes usually are calculated as the weighted sum of a number of objective or subjective safety factors:

\[ I = \sum_{i=0}^{n} w_i x_i \]  

where \( I \) is walkability or bikeability index, \( x_i \) is the measure of the \( i \)-th safety factor, and \( w_i \) is the weight of the \( i \)-th factor. A factor usually is measured on a scale of 0 to 4 or 5. For example, Khisty (1994) proposed seven qualitative performance measures of pedestrian environments: attractiveness, comfort, convenience, safety, security, system coherence, and system continuity. Each measure is scored on the scale from 0 to 5, depending on the level of satisfaction, and the relative importance of each measure was determined from survey responses. Gallin (2001) determined the pedestrian LOS by scoring and weighting a total of 11 factors. Each factor is scored 0 to 4 and the weights range from 2 to 5. For example, the “path width” factor is scored as 0 if no pedestrian path is present, 1 if the path width is 0 to 1 meter, and up to a maximum of 4 if the path width is more than 2 meters. Table 1 summarizes commonly identified factors for all the walkability and bikeability indexes reviewed previously.

To accommodate the walking and bicycling safety factors shown in Table 1 and to develop a GIS that satisfies information demands from all parties involved in an SRTS project, a comprehensive GIS data model is needed to facilitate storage of walking and bicycling safety measures and computation of walkability and bikeability indexes. The following section presents a data model that satisfies these needs.

GIS DATA MODEL

A data model is a blueprint of a database. A good data model should support convenient storage of all necessary data, minimize redundancy, facilitate information retrieval, and be flexible to adapt to future changes. Figure 1 is a logical schema of a GIS data model that supports walking SRTS data storage and facilitates walkability and bikeability assessment.

This data model describes the structure of a GIS database that facilitates both spatial and nonspatial data storage for SRTS. The spatial data, enclosed in the dashed-line box in Figure 1, consists of base feature classes including street centerlines, census data,
**Table 1. Summary of Walking and Bicycling Environment Factors**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Environmental Measure</th>
</tr>
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</table>
| Regional        | **Quality (street classification analysis):**  
|                 | Minor roads (mi)  
|                 | Major roads (mi)  
|                 | Minor road density (street miles per area)  
|                 | Minor-major road ratio  
|                 | **Proximity (pedestrian catchment area):**  
|                 | Pedestrian catchment area (ratio)  
|                 | Impeded pedestrian catchment area (ratio)  
|                 | Distance to school  
|                 | Route directness (ratio of the straight-line distance from home to school to the network distance from home to school)  
|                 | **Connectivity (intersection analysis):**  
|                 | Intersection density  
|                 | Dead-end density  
|                 | Intersection/dead-end ratio  
|                 | Impedance-based intersection density  
|                 | Impedance-based dead-end density  
|                 | Impeded intersection/dead-end ratio  
|                 | Change in intersection/dead-end ratio  
|                 | **Environmental/social:**  
|                 | Population density (by census tract)  
|                 | Dwelling density (by CCD)  
|                 | Block size  
|                 | Land-use mix  
|                 | Commercial density  
|                 | Accessibility to opportunities  
|                 | Accessibility to transit  
|                 | Attractiveness (e.g., tree cover)  
|                 | Physical barriers (e.g., slope)  
|                 | Crime rate  
| Roadway         | Sidewalk presence  
|                 | Sidewalk width  
|                 | Sidewalk continuity  
|                 | Sidewalk quality (pavement condition)  
|                 | Outside lane width  
|                 | Shoulder or bike lane width  
|                 | On-street parking (percentage of road segment)  
|                 | Planting strip (yes/no)  
|                 | Attractiveness (favoring environmental factors such as landscape)  
|                 | Eyes on the street (security)  
|                 | Street lighting  
|                 | Geometric measures (curves)  
|                 | Terrain (maximum slope of segment)  
|                 | Motor vehicle volume  
|                 | Motor vehicle speed (limit)  
|                 | Number of through lanes  
|                 | Number of commercial driveways  
|                 | Crash records  
| Intersection     | Crosswalk presence  
|                 | Crosswalk width  
|                 | Crosswalk length  
|                 | Width of the outside through lane  
|                 | Traffic control (no/stop sign/signal/pedestrian signal/push button)  
|                 | Median islands (presence)  
|                 | One way (yes/no)  
|                 | Traffic volume  
|                 | Vehicle speed  
|                 | Roadway width  
|                 | Crash records  
|                 | Number of lanes  
|                 | Curb radii  
|                 | On-street parking (yes/no)  
|                 | Right-turn-on-red allowance  
|                 | Surrounding development type  
|                 | Sight distance  

vegetation coverage, properties, land use, photo points, etc. The spatial data set forms the basis for walking and bicycling safety data acquisition and storage. Except for photo points, most of the feature classes shown in Figure 1 are public data and, therefore, available from the local government. If this data model is implemented in an ESRI geodatabase, special topological rules, such as street centerlines must not cross properties, may be applied to certain features as needed. Region-based walkability/bikeability indexes, such as proximity, connectivity, as well as social and environmental indexes, can be derived from feature classes of the spatial data set.

The street centerline feature class makes up the backbone of the database because roadway-based and intersection-based walking and bicycling safety measures are related to it in this data model. This feature class contains attributes, such as segment length, speed limit, and CFCC, which are available in TIGER line files. Properties that are pertinent to walking and bicycling safety are stored in a related table named “Streets,” which contains fields including number of lanes (Lanes), Average Daily Traffic (ADT for traffic volume), speed limit (Speed in mph), the left and right outer lane widths (OLWL and OLWR in feet), percentage of street segment for left-side and right-side on-street parking (OSPL and OSPR), whether it is a one-way street (One way: 0 = no, 1 = yes), and the existence of a median (Median: 0 = no, 1 = yes). A subjective measure of comfort (Comfort) is used in the “Streets” table as a comprehensive measure of perceptual safety and amenity factors. The “Comfort” is scored 0 through 4 by which 0 represents the lowest level of comfort and 4 the highest level. A basic network topology can be established based on the street centerline and intersection feature classes to support network analyses based on shortest-path algorithms.

Walking and bicycling safety measures can be recorded along roadways and at intersections. Roadway safety measures, based on sidewalks and bike lanes, are stored in table “Side Lane”—a combination of sidewalk and bike lane. Fields of this table include a primary key ID, a foreign key Street ID referring to the street centerline, the percentages of starting and ending points along a street segment (Start pct, End pct), right side/left side of a street segment based on the physical direction of the street segment in GIS (Side), the type of lane (0 = sidewalk, 1 = bike lane), the width (in feet), surface condition (0 to 4), and the type and width of buffer zone (e.g., none, paint, curb, plants, street furniture zone).
that separates this lane from vehicle lanes (see Figure 2).

Measures of intersection safety are recorded in the crosswalk table. A crosswalk is related to an intersection point and a street segment to cross in this data model. Safety measures for crosswalks include the length, width, the greater curb radius, traffic control method (uncontrolled, stop sign, traffic lights, push button, guarded), existence of safety islands (0 = no, 1 = yes), and paint quality (0–4).

Based on this data model, a Microsoft Access database is developed to satisfy the needs for walking and bicycling data storage and for the development of safety indexes for regions, roadways, and locations. A field walkability and bikeability audit program for GPS-enabled portable computing devices is developed to assist field data collection (shown in Figure 3).

A simple edge-node network topology is enabled by the relationship between street centerlines and intersections in this data model. Because roadway walkability and bikeability indexes are associated with street centerlines and intersections, the best path that minimizes risks can be resolved by a shortest-path algorithm. It should be noted that establishing a high resolution network based on sidewalks and crosswalks is extremely difficult. Sidewalks often are discontinuous and crosswalks are incomplete. If a sidewalk is missing or discontinuous, the pedestrian has to walk on the street alternately, so that excessive nodes have to be added to the network to connect every broken sidewalk segment to street segments. More importantly, unlike driving, walking cannot be restrained to specific lanes. Pedestrians, especially children, can randomly cross open streets while walking in a residential area.

Figure 3. Snapshots of Field Walkability and Bikeability Audit Software

A FRAMEWORK FOR INTERNET GIS

An SRTS project is a collaborative effort of many parties from both government and the public. Accurate and timely information about walking and biking conditions in the neighborhood around schools can be used by various parties to promote safely walking or biking by children. For example, it can help schools plan the safest routes for walking and bicycling; it can allow administrators to monitor student walking and biking activities; it can inform authorities of emerging unsafe factors and help them make decisions in response to walking environment changes; and it may encourage parents to let their children walk or bike to school. Based on the data model discussed in a previous section, a framework of Web-based GIS is proposed for data collection, analysis, and information dissemination (see Figure 4). This Web-based GIS can serve as a platform for safe routes to school projects, in which every involved party can play a role.

This framework adopts a client-server Internet GIS architecture. The clients consist of all SRTS-involved parties who use Web browsers to access information services provided by the GIS server. The GIS server consists of three GIS-functional modules and four Web portals. GIS modules include a walkability/bikeability assessment module, a network analysis module, and a Web mapping module. A Web portal is a site that provides a single function via a Web page or site. Web portals in this Web-based GIS are used for online data entry and communication, which include a field data entry portal, a walking/biking activity monitoring portal, a walking/biking safety concern reporting portal, and a public opinion surveying portal. This Internet GIS framework adopts a thin-client architecture so that all data processing and map creation are performed by the server and a client can simply use a Web browser to manipulate and view data. The following paragraphs explain the structure and functions of each module or portal.

Figure 4. Structure of a Web-based GIS for SRTS Programs by Which Every Involved Party Plays a Role
Walkability/Bikeability Assessment Module
This module assesses the walking and bicycling safety conditions of neighborhoods, roadways, and intersections. Various walkability and bikeability indicators discussed previously can be computed based on safety measures associated with various transportation facilities in the database. It should be noted that with the help of the public opinion survey portal, perceptual safety and security indexes of transportation facilities and neighborhood environment can be obtained. These perceptual indexes then can be used to determine coefficients or relative weights of various walkability/bikeability measures. Moreover, with the perceptual safety or security indexes, regression models can be established for pedestrian and bicyclist LOS indexes (Landis et al. 1997, 2001). Assessment results, in turn, can be stored in the database and published online in map or tabular format.

Network Analysis Module
Based on roadway and intersection walkability or bikeability measures in the database, this module performs the following tasks using path-finding algorithms that minimize total risks:

- Identifies walkable/bikeable areas,
- Finds the best route between any location and a school,
- Plans the best walking school bus routes and stop locations given student home locations, and
- Plans school bus routes and locates stops given student home locations.

Overall, this module can attract a wide audience. For example, it can help parents and children find the best route to school. It may encourage more parents to select walking or bicycling as children's school trip mode. It also can assist the school to plan school bus routes and stops, and aid Parent-Teacher Associations (PTAs) to organize walking school buses or other walking/bicycling activities. Furthermore, it can be used by multimodal planners for traffic analysis and alternative development.

Web Mapping Module
A Web mapping module is an essential part of the system that creates maps dynamically on user requests and delivers the maps online. Examples of Web mapping include:

- General Web maps for interactive information query,
- Walkable or bikeable area map for school trips,
- Pedestrian or bicyclist roadway safety maps,
- Pedestrian or bicyclist intersection safety maps, and
- Best walking/bicycling path maps.

All these maps are interactive so that they can be zoomed, panned, and queried by online users.

Field Data Entry Portal
This portal facilitates online updating of walking and bicycling safety data collected by the field auditing instruments shown in Figure 3. Data collected by field auditing instruments are encoded in XML documents that then are uploaded to the central GIS database through this portal by users with administrative privileges.

Walking/Biking Monitoring Portal
This portal of the Web-based GIS allows students to periodically log their walking and biking activities. Student walking and biking activities then can be queried and displayed in maps for specified time periods. The module not only can enable school authorities to obtain timely information of walking and biking activities of students, but also can be used by organizations such as PTAs to organize walking and bicycling competition programs.

Public Opinion Surveying Portal
The wonder of a Web-based GIS is its public accessibility. This portal provides various online surveys (e.g., http://zenith.geog.nau.edu/GIS/srts/survey.html). An important survey is to collect road safety or comfort level indexes to determine weights for walking and biking safety measures or criteria. Experts and residents can be invited to participate in the survey. Safety or security concerns of parents about the walking and bicycling environment may be collected by another survey. Public opinion also may be collected from online discussion areas in this portal to provide additional information to SRTS project personnel.

Safety Concern Reporting Portal
This portal provides an unsafe or unsecure factor reporting mechanism for the public to report unexpected unsafe conditions. Upon receiving a case, the system administrator is responsible for updating the information in the GIS database after verifying the reported cases.

IMPLEMENTATION
The data model and framework have been implemented in an experimental online information service for SRTS for the Sechrist Elementary School in Flagstaff, Arizona (see Figure 5).
Pedestrian Catchment Area (PCA) Ratio and Intersection Density

A PCA is the walkable area within a network given an origin or destination location. This area can be derived from service area analysis with a GIS. A PCA ratio is the ratio of a PCA to a theoretical walkable area in a homogeneous space (a circle). Schlossberg (2007) suggests a PCA ratio of 0.5 to 0.6 for a walkable environment, and indicates that a ratio below 0.3 would reflect an inaccessible environment for walking. With a PCA ratio of 0.26, this school district is virtually unwalkable. This inaccessibility is because of the valley bottom location on one hand and the low street connectivity of the urban area on the other hand. Connectivity can be measured by intersection density. Schlossberg (2007) suggests that an intersection density of less than 100 per square mile indicates an unwalkable neighborhood. The Sechrist School district has a very low intersection density of 68 per square mile.

The Mount Elden neighborhood is connected to the network only at its southwest corner. Although most of this neighborhood is within one-mile direct distance from the school, it is totally out of the one-mile walking area (see Figure 5). If a walking link is established between the northwestern corner of the neighborhood and the Fort Valley road, the neighborhood would become mostly walkable and the PCA ratio can be increased to 0.32. Supported by network analysis and walkability assessment modules, alternative planning scenarios can be developed by the GIS.

Pedestrian Level of Service (PLOS)

To demonstrate the capability for roadway walkability assessment, the system calculates the pedestrian level of service (PLOS) for every street segment using the following formula proposed by Landis et al. (2001):

\[
PLOS = -1.2021 \ln \left( \frac{W_s}{Vol_{15}} \right) + 0.253 \ln \left( \frac{Vol_{15}}{L} \right) + 0.0005 \ SPD^2 + 5.3876
\]

where \(W_s\) represents outer lane width (feet), \(W_i\) is width of shoulder or bike lane (feet), \(ORS\) is percent of segment with on-street parking, \(W_l\) is buffer zone width (feet), \(W_s\) is sidewalk width (feet), \(L\) is total number of through lanes, \(SPD\) is average running speed of motor vehicle traffic (mi/hr), and \(Vol_{15}\) is average traffic during a 15-minute period. In addition, \(f_p(=0.20)\), \(f_b(=5.37)\), and \(f_s(=6.03W_s)\) are effect coefficients of their corresponding variables. Equation (2) measures three categories of walking safety factors: the lateral separation, traffic volume, and traffic speed. Coefficients of these factors were established based on step-wise regression analyses of real-time observations in walking events.

Most of the variables in Equation (2) are directly available from the GIS database, except the 15-minute traffic volume (\(Vol_{15}\)). However, this variable can be derived from the average daily traffic (ADT) by the following formula (Barsotti 2002):

\[
Vol_{15} = \frac{(ADT \times D \times Kd)}{(4 \times PHF)}
\]

where \(D(=0.565)\) is directional factor, \(Kd(=1/11)\) is peak to daily factor, and \(PHF(=0.92)\) is peak hour factor. Values of these factors are available in the Highway Capacity Manual (TRB 1994). Scores of LOS are stratified into six classes labeled by letters as shown in Table 2 (Landis et al. 2001).
Vehicle count data are available for a number of locations in the neighborhoods for years 2000 to 2003 (2003 Annual Traffic Volume Report of the City of Flagstaff). For unmeasured residential streets, an ADT of 2,000 vehicles per day is assumed in calculating PLOS. Figure 7 is a snapshot of the interactive online roadway PLOS map. Roadway safety measures and PLOS values can be identified in the online GIS.

**Pedestrian Intersection Safety Index (PISI)**
Intersection safety for pedestrians can be assessed by the Pedestrian Intersection Safety Index (PISI) of Federal Highway Administration (FHWA 2006):

\[
PISI = 2.372 - 1.867SIG - 1.807STP + 0.335LNS + 0.018SPD_{85} + 0.006(ADT \times SIG) + 0.238COM
\]

where \(SIG\) is a binary variable for traffic signal–controlled crossing (0 = no, 1 = yes), \(STP\) is a binary variable for stop sign–controlled crossing (0 = no, 1 = yes), \(LNS\) represents total number of through lanes on street being crossed, \(SPD_{85}\) is the 85th percentile speed of street being crossed (mph), which may be estimated as the posted speed limit plus four to eight miles per hour (Fitzpatrick et al. 2003), \(ADT\) is the average daily traffic count in thousands, and \(COM\) is a binary variable for predominant commercial land use (0 = no, 1 = yes).

This GIS computes PISI for each crosswalk at an intersection and attributes the average of all crosswalks PISI to the intersection. Figure 8 is a snapshot of the PISI map. Crosswalk properties and intersection ISI values can be interactively identified by this Web-based GIS.

**Network Analysis**
Roadway and intersection walking and bicycling safety indexes can be incorporated into transportation networks to support safe path analysis in GIS. This is illustrated in Figure 9, in which the safest path from a student’s home to the school was found with turn-by-turn trip directions. Network analysis also can be performed to find the best path given multiple locations for origins or destinations such as in organizing a walking school bus.

**CONCLUSION**
This paper presents a GIS data model and an Internet GIS framework for an SRTS information service. The data model can be used to guide the development of GIS databases for walking and bicycling safety data storage, retrieval, and analyses. It also provides a framework to guide data collection for SRTS projects. An Internet GIS is a Web-based application that provides online GIS services to allow the public as well as multiple agencies to seek SRTS-related information. The Internet GIS framework
proposed in this paper consists of three GIS functional modules and four Web portals. The walkability/bikeability assessment module computes various walking and bicycling safety indexes at neighborhood, roadway, and intersection levels, while the network analysis module performs safe routes planning based on safety indexes. The Web mapping module presents query and analysis results in interactive maps and various other formats. The four Web portals expand online data communication to include field data uploading, online surveys, walking/bicycling safety concern reporting, and trip logging. The proposed system is flexible enough to incorporate data ranging from engineering standards to user perceptions. An Internet GIS based on this data model and framework can provide a public participation platform in which every SRTS-involved party, including children, parents, teachers, urban planners, transportation engineers, and law enforcement officers, can play a role.

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Modernizing the Register of Deeds in Dane County, Wisconsin

J. David Stanfield and Jane Licht

Abstract: Efforts around the world to improve property registration systems have devised various indicators of how well these systems are functioning. This article uses a case study of the Dane County, Wisconsin, Register of Deeds to develop four indicators of the performance of the Register of Deeds and to explore the effects of major investments in information technology on that performance.

INTRODUCTION

Property registration systems have been studied extensively, as countries have attempted to find ways to make property markets work better. The United Nations Economic Commission of Europe (1996, 9) observed:

A system for recording land ownership, land values, land use and other land-related data is an indispensable tool for a market economy to work properly, as well as for sustainable management of land resources. All industrialized nations with a market economy maintain some sort of land register system that fulfills the above requirements.

Most analyses of registration systems, however, look at them either from the point of view of the users to calculate transaction costs in order to make changes in the procedures of registration and thus make land markets more dynamic, or from the perspective of the requirements of a market economy (see Burns et al. 2003) to make institutional recommendations in countries moving toward a market economy. Such a focus on system creation and organization is useful in exploring options for the design of such systems.

However, once established, land registries perform more or less well. How to evaluate this performance once the offices and system are established is important for improving that performance over time. As Adlington (2002, 2) observed:

. . . despite the significant resources being invested by the donor community for modernizing land administration infrastructure, there is little systematic discussion of the key elements of such a system and of what constitutes effectiveness within particular socio-economic, cultural and temporal contexts.

The International Federation of Surveyors (FIG) addressed this performance monitoring question in a paper on benchmarking cadastral systems, with the objective of making comparisons across systems (see Steudler and Kaufmann 2003). Such an approach is difficult to use, however, because of the different institutional and legal contexts in which registration/cadastre systems function. A more useful approach for monitoring performance is to develop indicators of performance of a single system over time. As part of the policy to shift the Land Registry in the United Kingdom to an independent executive agency, specific indicators were established to show government whether the new Land Registry was meeting goals of gradually improving efficiency and effectiveness (HM Land Registry Executive Agency 1996). John Manthorpe prepared an analysis of these performance indicators (2000).

With the growing interest around the world in making property registries self-financing, client-oriented, and efficient, this UK approach could prove useful. Even more useful would be a set of indicators that could be applied to a single registration office and not the entire system as in the UK. To test this notion, we have taken the Dane County Register of Deeds as a case study to explore the question whether meaningful and useful performance indicators can be developed in a non-UK context.

These indicators then are used to analyze the costs and benefits of the introduction of information and communication technologies into the operations of the Register of Deeds. The second question is whether there has been a simple shift from people-related expenses to technology expenses or has technology introduction generated some net benefits?

BACKGROUND

Dane County, Wisconsin, is the location of the state capital, the largest campus of the University of Wisconsin System, the Madison metropolitan area, and numerous businesses. The population is approximately 458,000 people (Dane County, Wisconsin, 2005). In 2004, there were approximately 180,000 properties (land parcels and condominium units) in the county, of which
approximately 174,000 were housing units. There were 2,887 farms in Dane County in 2002, containing a total of 415,310 acres of cropland. In 2004, there were 39 sales of agricultural land continuing in agricultural use, averaging 83.6 acres per sale at an average price of $6,765 per acre. There were 38 sales of agricultural land diverted to other uses, averaging 58.7 acres per sale, with an average price of $23,839 per acre (Wisconsin Agricultural Statistics Service 2005).

The total value of real estate in the county was approximately $36 billion in 2004, up by 11 percent from 2003, an indicator both of the large asset base of the county and of the rapidly rising property values in the region. In 2004, the total value of properties that changed ownership was approximately $350 billion. Documents that describe property transactions are recorded at the Dane County Register of Deeds (ROD), which is the authoritative source of information about real property transactions.

The property market in Dane County is most active for residential parcels or condominium units. Table 1 shows the number of residential sales and median prices for 2000 through 2004 as tabulated from listings by Realtors working in the county, and linked with the South West Wisconsin Realtor Association.

Condominium sales have been increasing more rapidly than houses, and the median prices have been increasing rapidly for both types of residences.

Returning to the Register of Deeds, over the six-year period 1999–2004, there have been an average of 17,087 deeds recorded yearly (see Table 2), including sales, intrafamily transfers, and other types of transfers. Most of these deed transactions reflect sales of urban properties.

Sales deeds, however, are just one type of transaction. Mortgage-related transactions are quite numerous. An average of almost 70 percent of all documents recorded over the past six years have been mortgages or satisfactions of mortgages, with the year 2003 experiencing a very high number of such documents recorded.

Table 1. Residential Sales in Dane County 2000–2004

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SALES</th>
<th>MEDIAN PRICE</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Houses-Number</td>
<td>%</td>
</tr>
<tr>
<td>2000</td>
<td>4375</td>
<td>82.1%</td>
</tr>
<tr>
<td>2001</td>
<td>4902</td>
<td>81.4%</td>
</tr>
<tr>
<td>2002</td>
<td>5261</td>
<td>81.3%</td>
</tr>
<tr>
<td>2003</td>
<td>5620</td>
<td>79.8%</td>
</tr>
<tr>
<td>2004</td>
<td>5775</td>
<td>75.6%</td>
</tr>
</tbody>
</table>

(Source: South West Wisconsin Multiple Listing Service Corporation)

Note: This information is based in whole or in part on data supplied to the South Central Wisconsin MLS Corporation by Realtors. The SCWMLS does not guarantee and is not responsible for its accuracy. Data maintained by the SCWMLS does not reflect all real estate activity in the market.

There were nearly 150,000 real estate-related documents recorded in the ROD in 2004, but more than 236,000 documents recorded in 2003—showing that there are large variations year to year.

Using the estimate of 180,000 real estate units in the county, the turnover rate is close to 75 percent to 80 percent of the total number of properties each year on the average, and in some years the rate is more than 100 percent, depending on the rate of new mortgaging and the desire of property owners to refinance new mortgaging when interest rates drop as they did in 2002–2003.

The Dane County ROD charges a fee of $11 for the first page of a document that is submitted for recording, plus $2 for each additional page. This fee is set for all 72 RODs of the state.

“Satisfactions” are mortgage satisfactions. “Plats” are mainly subdivision survey plans with a few assessor, cemetery, and transportation project plats included. “Condo plats” are condominium plats that are maps showing the locations of units and their dimensions, and common areas of condominium-type buildings. “Condo dec” are condominium declarations, which are documents that set up the governance of condominiums.

“Certified survey” refers to certified survey maps. “Misc. docs” includes affidavits, agreements, judgments, lis pendens, restrictions, resolutions, power of attorney, federal tax liens, etc. “HT 110” is the form used for the termination of a decedent’s property interest.

Other revenues for the Dane County ROD come from document copying, and, of growing importance, are the revenues from fees charged for access by various types of clients to the digital information maintained by the ROD. The ROD also has a “vital records” section, where it maintains records of births, deaths, and marriages that occur within the county. About 7 percent of the fees generated by the ROD come from the copies provided to the public of birth, death, and marriage certificates.

Because the Register of Deeds is an institution of fundamental importance for the operation of property markets and the
management of $36 billion in assets in the county, how well this institution functions is of interest. We use the following indicators of ROD management to try and evaluate it.

For a properly functioning ROD, we would expect:

• The number of recorded documents by one staff person should increase over time, showing improving ROD staff productivity.

• The total cost per document recorded should decrease over time, showing increasing ROD economic efficiency.

• The surplus of revenues over costs should increase over time, showing that the ROD is meeting client needs and is operating efficiently.

• The increased availability of property information from the ROD should lead to a reduction in fees charged the participants in property transactions by private companies for verifying title.

Staff Productivity

Table 3 shows the staffing levels and the number of real estate documents the ROD has recorded by year. With the addition of only two full-time staff people since the 1990–2003 period, the ROD handled almost double the number of documents on the average in the 2001–2004 period. The average number of documents recorded increased by nearly 92 percent. The general trend in real estate activity is upward, but there are also significant peaks and valleys. The Dane County ROD has been able to “ride the storms” of periods of heavy recording (most frequently because of refinancing of mortgages, dropping interest rates).

The average number of documents recorded per staff member increased more than 71 percent from the four-year average of 1990–2093 in comparison with the four-year average 2001–2004.

Although some of this increase in staff productivity came from an increase in the use of short-term employees in recent years, much of the increased productivity comes from important investments made in the intervening period in information and communication technology (see Land Information Bulletin (1998), for a description of these investments).

In the 1980s, the ROD had already invested in an in-house mainframe software program that produced microfiche images of recorded documents and microfiche indexes for retrieval of those documents. By 1995, the switch to a client-server PC-based system with document imaging was well under way, financed by a $300,000 grant from the State of Wisconsin Land Information Program. The office transformation continued with the acquisition of 26 workstations, two scanners, one 88-platter jukebox, three laser printers, a 12-megabyte file server, a database server, an image server, a print server, and a modem.

In 2000, the ROD offered “Laredo,” an online system providing access to its index and images. In 2001, the ROD upgraded its imaging and indexing systems, resulting in increased speeds of indexing, scanning, and access. In 2003, the ROD recorded the first document electronically, and it now accepts digital filing of mortgages, assignments of mortgage, and satisfactions of mortgages and subordination agreements from eight major lending institutions.

Table 2. Number of Documents by Type Recorded at the Dane County ROD, 1999–2004

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DEEDS</td>
<td>16,263</td>
<td>14,941</td>
<td>16,071</td>
<td>17,274</td>
<td>18,856</td>
<td>19,117</td>
<td>102,522</td>
<td>17,087</td>
</tr>
<tr>
<td>MORTGAGES</td>
<td>40,985</td>
<td>32,035</td>
<td>53,529</td>
<td>72,442</td>
<td>85,441</td>
<td>54,136</td>
<td>338,568</td>
<td>56,428</td>
</tr>
<tr>
<td>LAND CONTRACTS</td>
<td>325</td>
<td>238</td>
<td>204</td>
<td>239</td>
<td>195</td>
<td>193</td>
<td>1,394</td>
<td>232</td>
</tr>
<tr>
<td>SATISFACTIONS</td>
<td>41,235</td>
<td>25,945</td>
<td>44,969</td>
<td>71,290</td>
<td>87,002</td>
<td>46,708</td>
<td>317,149</td>
<td>52,858</td>
</tr>
<tr>
<td>PLATS</td>
<td>62</td>
<td>48</td>
<td>41</td>
<td>42</td>
<td>60</td>
<td>45</td>
<td>298</td>
<td>50</td>
</tr>
<tr>
<td>CONDO PLATS</td>
<td>68</td>
<td>83</td>
<td>97</td>
<td>91</td>
<td>130</td>
<td>137</td>
<td>606</td>
<td>101</td>
</tr>
<tr>
<td>CONDO DEC</td>
<td>95</td>
<td>102</td>
<td>124</td>
<td>117</td>
<td>153</td>
<td>164</td>
<td>755</td>
<td>126</td>
</tr>
<tr>
<td>CERTIFIED SURVEY</td>
<td>383</td>
<td>352</td>
<td>369</td>
<td>353</td>
<td>323</td>
<td>330</td>
<td>2,110</td>
<td>352</td>
</tr>
<tr>
<td>MISC DOCS</td>
<td>21,889</td>
<td>21,919</td>
<td>30,367</td>
<td>39,131</td>
<td>43,699</td>
<td>27,702</td>
<td>184,707</td>
<td>30,785</td>
</tr>
<tr>
<td>HT 110</td>
<td>622</td>
<td>547</td>
<td>638</td>
<td>664</td>
<td>664</td>
<td>609</td>
<td>3,744</td>
<td>624</td>
</tr>
<tr>
<td>REAL ESTATE TOTAL</td>
<td>121,927</td>
<td>96,210</td>
<td>146,409</td>
<td>201,643</td>
<td>236,523</td>
<td>149,141</td>
<td>951,853</td>
<td>158,642</td>
</tr>
</tbody>
</table>

(Source: Dane County Register of Deeds, 2005)
Table 3. Register of Deeds Staffing and Workload by Year

<table>
<thead>
<tr>
<th>YEAR</th>
<th>STAFF</th>
<th>No. of Real Estate Documents Recorded (1)</th>
<th>No. of Documents Recorded per Staff Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>16.5</td>
<td>61,044</td>
<td>3,700</td>
</tr>
<tr>
<td>1991</td>
<td>16.5</td>
<td>72,173</td>
<td>4,374</td>
</tr>
<tr>
<td>1992</td>
<td>16.5</td>
<td>115,621</td>
<td>7,007</td>
</tr>
<tr>
<td>1993</td>
<td>16.5</td>
<td>133,066</td>
<td>8,065</td>
</tr>
<tr>
<td>1994</td>
<td>17.8</td>
<td>94,953</td>
<td>5,334</td>
</tr>
<tr>
<td>1995</td>
<td>18</td>
<td>75,223</td>
<td>4,179</td>
</tr>
<tr>
<td>1996</td>
<td>18</td>
<td>94,745</td>
<td>5,264</td>
</tr>
<tr>
<td>1997</td>
<td>17.5</td>
<td>98,346</td>
<td>5,620</td>
</tr>
<tr>
<td>1998</td>
<td>17.5</td>
<td>147,754</td>
<td>8,443</td>
</tr>
<tr>
<td>1999</td>
<td>18.5</td>
<td>121,927</td>
<td>6,591</td>
</tr>
<tr>
<td>2000</td>
<td>18.5</td>
<td>96,210</td>
<td>5,201</td>
</tr>
<tr>
<td>2001</td>
<td>18.5</td>
<td>146,409</td>
<td>7,914</td>
</tr>
<tr>
<td>2002</td>
<td>18.5</td>
<td>201,643</td>
<td>10,900</td>
</tr>
<tr>
<td>2003</td>
<td>18.5</td>
<td>236,523</td>
<td>12,785</td>
</tr>
<tr>
<td>2004</td>
<td>18.5</td>
<td>149,141</td>
<td>8,062</td>
</tr>
<tr>
<td>90-93 avg.</td>
<td>16.5</td>
<td>95,476</td>
<td>5,786</td>
</tr>
<tr>
<td>01-04 avg.</td>
<td>18.5</td>
<td>183,429</td>
<td>9,915</td>
</tr>
<tr>
<td>% Change</td>
<td>+12%</td>
<td>+92%</td>
<td>+71%</td>
</tr>
</tbody>
</table>

Staff are cross-trained so that real estate staff can help with customer service in Vital Records and Vital Records staff can help with indexing in the Real Estate section. Vital Records documents received by the Register of Deeds are not included in this table, nor are documents relating to personal property. The number of copies of vital records produced for clients ranged between 11,800 and 13,100 during the past four years. *(Source: Dane County Register of Deeds, 2005)*

Figure 1 shows the overall trend toward increasing numbers of documents recorded per staff person, but also that there appears to be a five-year cycle of increasing and then decreasing the numbers of documents recorded.

Cost of Recording Each Document

The staff levels have remained relatively constant since 1990, increasing by just two persons in 15 years. The year-to-year variation in the number of documents recorded is partly absorbed by the increased reserve capacity of the technology installed in the mid-1990s and also through the hiring of short-term staff when the workload increases and dismissing of such staff when the workload drops.

Figure 1. Documents Recorded Per Register of Deeds Staff Person by Year

Have the investments in ICT and flexible staffing simply shifted the costs from permanent staff to investments in technology using machines in place of people?

Table 4 shows the costs of the Register of Deeds operation, including capital investments, by year. A major capital investment of $300,000 was made in 1994 and amortized over five years, as shown in the “Projects” column for 1994–1998. The Register of Deeds retains some of its revenues, up to $17,000 per year, for its own investments in capital improvements.

In nominal terms, the average expenses for the years 1990–1993 have increased nearly 75 percent when compared with the average expenses for the years 2001–2004. Yearly inflation totaling about 45 percent over the period 1990–2004 is partly responsible for this increase in costs. There have been net positive increases in total Register of Deeds costs, in response to the 92 percent increase in workload (number of documents recorded).

Table 5 shows the trends in the total operating costs per recorded document by year, to see whether there has been an increase in economic efficiency during the past 15 years. The total costs for each year have been adjusted for inflation by expressing those costs for each year in 2004 dollars.

While 2004 showed an increase in costs to the levels of the early 1990s, the average costs for the four years 2001–2004 were 33 percent lower than the average costs for the four years 1990–1993, net of inflation. Economic efficiency has tended to improve substantially.

Revenues in Relation to Expenses

Register of Deeds revenues traditionally have come in part from the fees charged for the recording and copying of documents. As the number of documents recorded increases, the fees generated increase. About 49 percent of the Register of Deeds fees come from this document-based fee.

In recent years, however, with the development of digital databases available online and a reputation for accurate and reliable information, private companies have reached agreements with the Register of Deeds for access to the databases for a fee.
Private sector interest in access to Register of Deeds information also has been stimulated by a change in the law in the early 1990s that eliminated the minimum prices that title insurance companies could charge for their services. That legal change allowed title insurance companies to compete for clients on the basis of service provided and price. The number of title companies (six) doubled in less than five years. Today, more than 70 firms and 200 individual customers regularly do business in the Register. Most of them have not invested in costly title plants because they can get reliable and timely access to recorded documents from the Register. These are Laredo online subscribers who access the Register’s index and images of recorded documents nearly every day. Other customers purchase information from time to time in Tapestry or buy document copies in the office. The fees generated from access licensing amount to about $162,000 per year, or about 4 percent of the total Register revenues (see Table 6).

Fees charged for services produce about 59 percent of the Register total revenues. These fees have “paid” for the expenses of the ROD in every year since 1990, even those years when the major investments were made in information and communication technology. The major investments in that technology are repaid approximately every two years from fees for services that have been made possible by those investments. A substantial part (41 percent) of Register revenues, however, comes from being assigned 20 percent of the transfer fee charged

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PERSONAL SERVICES</th>
<th>SUPPLIES</th>
<th>REPAIR</th>
<th>PROJECTS</th>
<th>OTHER</th>
<th>TOTAL EXPENSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>$468,681</td>
<td>$41,526</td>
<td>$11,358</td>
<td>$60,071</td>
<td>$14,262</td>
<td>$595,898</td>
</tr>
<tr>
<td>1991</td>
<td>$529,729</td>
<td>$52,010</td>
<td>$10,592</td>
<td>$2,974</td>
<td>$9,821</td>
<td>$605,126</td>
</tr>
<tr>
<td>1992</td>
<td>$653,499</td>
<td>$93,863</td>
<td>$9,661</td>
<td>$1,616</td>
<td>$1,135</td>
<td>$759,774</td>
</tr>
<tr>
<td>1993</td>
<td>$749,889</td>
<td>$97,960</td>
<td>$19,680</td>
<td>$2,645</td>
<td>$17,354</td>
<td>$887,528</td>
</tr>
<tr>
<td>1994</td>
<td>$737,146</td>
<td>$80,443</td>
<td>$11,294</td>
<td>$61,979</td>
<td>$14,390</td>
<td>$905,252</td>
</tr>
<tr>
<td>1995</td>
<td>$749,198</td>
<td>$81,098</td>
<td>$24,631</td>
<td>$62,986</td>
<td>$11,618</td>
<td>$929,531</td>
</tr>
<tr>
<td>1996</td>
<td>$781,072</td>
<td>$76,774</td>
<td>$39,415</td>
<td>$78,463</td>
<td>$8,015</td>
<td>$983,739</td>
</tr>
<tr>
<td>1997</td>
<td>$787,680</td>
<td>$88,271</td>
<td>$22,677</td>
<td>$86,225</td>
<td>$14,685</td>
<td>$999,538</td>
</tr>
<tr>
<td>1998</td>
<td>$875,107</td>
<td>$95,843</td>
<td>$35,759</td>
<td>$60,000</td>
<td>$22,467</td>
<td>$1,071,875</td>
</tr>
<tr>
<td>1999</td>
<td>$861,583</td>
<td>$100,017</td>
<td>$31,368</td>
<td>$43,470</td>
<td>$35,437</td>
<td>$1,095,622</td>
</tr>
<tr>
<td>2000</td>
<td>$856,834</td>
<td>$81,324</td>
<td>$22,563</td>
<td>$0</td>
<td>$34,901</td>
<td>$995,622</td>
</tr>
<tr>
<td>2001</td>
<td>$933,421</td>
<td>$112,112</td>
<td>$25,206</td>
<td>$33,621</td>
<td>$45,864</td>
<td>$1,150,224</td>
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<tr>
<td>2002</td>
<td>$996,005</td>
<td>$90,370</td>
<td>$14,047</td>
<td>$83,373</td>
<td>$42,187</td>
<td>$1,225,982</td>
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<tr>
<td>2003</td>
<td>$1,063,705</td>
<td>$112,749</td>
<td>$11,571</td>
<td>$83,356</td>
<td>$69,251</td>
<td>$1,340,632</td>
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<tr>
<td>2004</td>
<td>$1,013,348</td>
<td>$89,158</td>
<td>$10,124</td>
<td>$84,073</td>
<td>$63,045</td>
<td>$1,259,748</td>
</tr>
</tbody>
</table>

(Source: Dane County Register of Deeds, 2005)

Table 4. Total Operating Costs of the Register of Deeds by Year

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Expenses Per Document in 2004 Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>$14.13</td>
</tr>
<tr>
<td>1991</td>
<td>$11.51</td>
</tr>
<tr>
<td>1992</td>
<td>$8.66</td>
</tr>
<tr>
<td>1993</td>
<td>$8.54</td>
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<tr>
<td>1994</td>
<td>$11.85</td>
</tr>
<tr>
<td>1995</td>
<td>$14.97</td>
</tr>
<tr>
<td>1996</td>
<td>$12.27</td>
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<tr>
<td>1997</td>
<td>$11.68</td>
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<tr>
<td>1998</td>
<td>$8.32</td>
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<tr>
<td>1999</td>
<td>$9.76</td>
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<td>2000</td>
<td>$11.19</td>
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<td>2001</td>
<td>$8.30</td>
</tr>
<tr>
<td>2002</td>
<td>$6.32</td>
</tr>
<tr>
<td>2003</td>
<td>$5.80</td>
</tr>
<tr>
<td>2004</td>
<td>$8.45</td>
</tr>
<tr>
<td>90-93 avg.</td>
<td>$10.71</td>
</tr>
<tr>
<td>01-04 avg.</td>
<td>$7.22</td>
</tr>
<tr>
<td>% Change</td>
<td>-33%</td>
</tr>
</tbody>
</table>

(Source: Dane County Register of Deeds, 2005)

Table 5. Expenses Per Recorded Document (in 2004 Dollars)
### Table 6. Sources of Revenues for the ROD, 2001–2004

<table>
<thead>
<tr>
<th>SOURCES OF ROD OFFICE REV-</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>4 Year Averages</th>
<th>Average Percents</th>
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</thead>
<tbody>
<tr>
<td>Vital Records(4)</td>
<td>$153,253</td>
<td>$186,657</td>
<td>$185,064</td>
<td>$197,264</td>
<td>$180,559</td>
<td>4.2%</td>
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<tr>
<td>UCC/FTL</td>
<td>$15,964</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Estate Recordings(5)(6)(7)</td>
<td>$1,647,823</td>
<td>$2,318,347</td>
<td>$2,866,722</td>
<td>$1,657,855</td>
<td>$2,122,687</td>
<td>49.3%</td>
</tr>
<tr>
<td>Real Estate Photocopies/FAX</td>
<td>$65,541</td>
<td>$68,987</td>
<td>$77,811</td>
<td>$68,219</td>
<td>$70,139</td>
<td>1.6%</td>
</tr>
<tr>
<td>Real Estate Indexes/Online and Images(1)</td>
<td>$85,116</td>
<td>$151,920</td>
<td>$241,196</td>
<td>$168,590</td>
<td>$161,705</td>
<td>3.8%</td>
</tr>
<tr>
<td>CSM paper</td>
<td>$253</td>
<td>$584</td>
<td>$535</td>
<td>$569</td>
<td>$485</td>
<td>0.0%</td>
</tr>
<tr>
<td>TOTAL ROD Fees</td>
<td>$1,967,949</td>
<td>$2,726,495</td>
<td>$3,371,328</td>
<td>$2,092,496</td>
<td>$2,539,567</td>
<td>59.0%</td>
</tr>
<tr>
<td>20% of Transfer Fees to ROD</td>
<td>$1,394,086</td>
<td>$1,674,285</td>
<td>$1,872,316</td>
<td>$2,115,670</td>
<td>$1,764,089</td>
<td>41.0%</td>
</tr>
<tr>
<td>County General Fund—ROD(3)</td>
<td>$3,362,036</td>
<td>$4,400,780</td>
<td>$5,243,644</td>
<td>$4,208,166</td>
<td>$4,303,656</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

(1) Customer account established 10/1/96.
(2) Folded into “Real Estate Recordings” after 2001.
(3) Includes general fees plus 20 percent of transfer fees.
(4) $7 out of every $12 fee for birth certificates goes to the state for the Child Trust Fund to fight child abuse.

The remaining $5 per certificate fee is shown in this line item. There is no fee for filing vital records; the fees are charged for providing certified copies of vital records after they are filed.

(5) $5 out of $11 fee for the first page of every recorded document goes to the County Land Records Fund.
(6) $2 out of $11 fee for the first page of every recorded document goes to the State Land.
(7) The remaining $4 for the first page of every document and the $2 fee for all subsequent pages are shown in this line item.
(8) The transfer fee is $0.30 per $100 value of the property.

(Source: Dane County Register of Deeds, 2005)
by the county on every real estate ownership transfer transaction. This fee is 0.3 percent of the value of the transferred property ($0.30 per $100 of value). Value is determined based on the declared sale price for sale transactions, although Department of Revenue auditors review all such declarations for their correspondence to known real estate prices.

Table 7 shows the trends in revenues and their relations with expenses over the past 15 years.

Table 7. Register of Deeds Revenues and “Surpluses” by Year

<table>
<thead>
<tr>
<th>YEAR</th>
<th>REVENUE</th>
<th>SURPLUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>$1,049,392</td>
<td>$453,494</td>
</tr>
<tr>
<td>1991</td>
<td>$1,208,749</td>
<td>$603,623</td>
</tr>
<tr>
<td>1992</td>
<td>$1,818,286</td>
<td>$1,058,512</td>
</tr>
<tr>
<td>1993</td>
<td>$2,078,130</td>
<td>$1,190,602</td>
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<td>1994</td>
<td>$1,744,357</td>
<td>$839,105</td>
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<td>1995</td>
<td>$1,553,899</td>
<td>$624,368</td>
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<td>1996</td>
<td>$1,886,188</td>
<td>$902,449</td>
</tr>
<tr>
<td>1997</td>
<td>$1,924,399</td>
<td>$924,861</td>
</tr>
<tr>
<td>1998</td>
<td>$2,522,837</td>
<td>$1,433,661</td>
</tr>
<tr>
<td>1999</td>
<td>$2,414,233</td>
<td>$1,342,358</td>
</tr>
<tr>
<td>2000</td>
<td>$2,167,978</td>
<td>$1,172,356</td>
</tr>
<tr>
<td>2001</td>
<td>$3,376,727</td>
<td>$2,226,503</td>
</tr>
<tr>
<td>2002</td>
<td>$4,400,780</td>
<td>$3,174,798</td>
</tr>
<tr>
<td>2003</td>
<td>$5,243,644</td>
<td>$3,903,012</td>
</tr>
<tr>
<td>2004</td>
<td>$4,208,166</td>
<td>$2,948,418</td>
</tr>
<tr>
<td>90-93 avg.</td>
<td>$1,538,639</td>
<td>$826,558</td>
</tr>
<tr>
<td>01-04 avg.</td>
<td>$4,307,329</td>
<td>$3,063,183</td>
</tr>
<tr>
<td>% Change</td>
<td>180%</td>
<td>271%</td>
</tr>
</tbody>
</table>

(Source: Dane County ROD, 2005)

While there are year-to-year variations, there are strong trends for revenues to exceed expenses by substantial amounts over the 15-year period, particularly after the year 2000. Revenues increased more than 180 percent since 1990. Following a decline in surpluses in the years of the large IT investment, the rising trend in surpluses became impressive by 2004, increasing 271 percent since 1990 (using four-year averages as in previous tables).

Very active land markets, a positive “client orientation” in the Register, and a digital information system accessible online have combined to produce these positive results.

Benefits for the Public
About 70 percent of the Register’s document-recording load is presented by title insurance companies. In a typical sale, there are two title policies—an owner’s title policy, of which the deed is the foundation, and a loan policy—of which the mortgage is the foundation. Therefore, of the various recorded documents involved in the average transaction, both the buyer and the seller typically pay for a title insurance policy. The seller pays for the new owner’s policy and the buyer (who is the new owner) pays for the mortgage policy. About 11 percent of all recorded documents for the period 1999 through 2004 were ownership transfers (mostly sales) or land contracts, a total of 103,916 such transactions during those five years, with the yearly average being 17,319 such transactions (see Table 2).

Fees for title insurance have changed dramatically since 1990. In 1990, the fees that title insurance companies could charge were regulated and a minimum fee was established by law. In that year in Dane County and in other large counties with more competition among the title insurance companies than the smaller counties, the cost of title insurance for a $100,000 home (the average home cost for Dane County in that year) was $575. For a “reissue” used for refinancing mortgages where the title company had already done the title work several years earlier, the cost was approximately $430. For an average home sale in 1990, the total cost of title insurance was about $1,000. Title companies in northern Wisconsin typically would charge an additional $300, a practice allowed by law. They did so because the value of the properties tended to be less, they did not have the volume of work as in the south, and title work in the less urbanized county offices was very labor-intensive.

In 1990, the cost of title insurance in Dane County occasioned by the sale of a $200,000 home was $975 and $730 for a reissue of a mortgage for such a home.

In 2005, the average home in Dane County was worth $200,000 but the basic title insurance cost for a $200,000 home was about $400 and $275 for mortgage reissues. Assuming that there will be approximately 17,000 sales in 2005 (the average number over the past five years) and approximately 40,000 mortgage refinancings, Table 8 shows that there would be a total savings of $35.7 million for those engaged in the main transactions carried out in 2005.

The changes in the ROD management of information and its network of clients have meant dramatic savings for the borrowers.

Replicability?
How replicable is this experience in other places? The Dane County financial accounting and reporting system has enabled the authors to do most of these calculations. Without such a system, evaluating a county agency would be extremely difficult.

For the past 25 years, the Register of Deeds has developed a “culture” of modernization of its services, with the first major improvement being the shift to microfiche for archiving and accessing records, to computerizing the grantor-grantee and tract indexes, and in recent years a shift to a Web-based property records system. This latest phase of a full digital environment lays the basis for improving efficiency of services in the future, the reduction of costs of archiving and retrieving documents, and the greater security of information storage.

As far as the shift to digital information processing is concerned, in Dane County, there is a very supportive IT environment. There is good vendor support for the Register’s indexing and imaging system in coordination with the County Information
Management Division that purchases all computer hardware and handles installation. These two groups work together to give the Register reliable service, which is key in the Register of Deed’s ability, in turn, to provide reliable service to its customers.

The Wisconsin Land Information program is also a vital element in the Register’s success story. Some of the financial support from this program was used to purchase its first indexing and imaging system and the associated hardware in the mid-1990s. That support allowed the Register to begin to offer online access to customers in 2000. The revenue from that service is used to pay for indexing/imaging software lease and for hardware upgrades. For example, in 2000, the Register abandoned its jukebox storage system and moved to massive hard-drive storage space, an upgrade that requires less cost for maintenance and provides faster image retrieval.

The County’s Land Information Office (part of the Wisconsin Land Information Program) offers AccessDane that provides links to the Parcel Information program (tax assessment information) and DCIMap (a user-friendly GIS) via the Internet, two excellent and useful programs that save many county offices numerous customer phone calls and staff resources.

The Register of Deeds of Dane County presently is working with the Wisconsin Department of Revenue (along with the rest of the county registers in the state) to accept the electronic version of the Wisconsin Real Estate Transfer Return Form required with every instrument of conveyance; this will allow the Register to accept deeds electronically. This method saves time and money for everyone. It will become an important safety valve as the years roll on and the office continues to record more documents under the county executive’s strict rule of no additional staff.

The Register’s Web-based systems provide the opportunity for the office to continue to serve its customers at a remote location should some natural or human-made disaster strike. The office is also preparing its Continuity of County Operations Plan to develop a strategy to strengthen and improve record preservation and public access now and in future years.

### CONCLUSIONS

The real estate markets in Dane County have been producing dramatically increased numbers of documents to be recorded by the Register of Deeds, increasing approximately 92 percent since 1990 through 2004. In the mid-1990s, the Register of Deeds introduced new management procedures and new ICT.

Using four indicators, the paper presents data about how well the Register of Deeds has met the challenge of a dramatically increasing workload:

- Has staff productivity increased during the past 15 years?
  The data show an average increase of 71 percent of documents recorded per staff person since 1990.
- Has the cost per document recorded decreased over time, showing increasing economic efficiency?
  The expenses per recorded document declined by approximately 33 percent since 1990.
- Is the Register meeting client needs, has an adequate fee structure, and is operating efficiently, as measured by the surplus of revenues over expenses?

<table>
<thead>
<tr>
<th>Table 8. Estimated Savings from Reducing Costs of Title Insurance—2005</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimated Savings from Reducing Costs of Title Insurance—2005</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Cost of insurance—sales, new owners</td>
</tr>
<tr>
<td>Cost of insurance—mortgages, sales</td>
</tr>
<tr>
<td>Cost of mortgage refinancing</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
</tr>
</tbody>
</table>

(1) Assuming the average number of yearly sales to be approximately 17,000. To arrive at an estimate of the number of refinanced mortgages, we subtracted the average number of sales from the average number of mortgages. See Table 2.

(2) These figures are only indicative, for there are many different situations that involve different title insurance rates.

(Source: Table 2 and estimates of title insurance costs from ROD)
While there are year-to-year variations, revenues have exceeded expenses by substantial amounts over the 15-year period studied, particularly after the year 2000. Overall, revenues increased more than 180 percent since 1990. Following a decline in surpluses in the years of the large IT investment, the rising trend in surpluses became impressive by 2004, increasing 271 percent since 1990. Because surpluses increased more than revenues, the Register has probably improved its management efficiency. The improved services offered because of the investments in information and communication technology have opened up new sources of revenues in recent years, indicating that the Register has found new ways to satisfy the needs of its main clients.

- Have fees charged the participants in property transactions by private title insurance companies for verifying title declined over time?
  The increased availability of property information from the Register through its offering of title-search capabilities via computer-assisted searches should contribute to a reduction in fees. Over the past 15 years, these fees have dramatically declined. Certainly a change in the law removing minimum title insurance fee requirements was also an important contribution to this reduction in fees. Another possible contributing factor is the title insurance company shift from highly trained and qualified title search staff to more clerical staff, thus reducing their costs and the fees they charge. The improved access to archives by the introduction of IT and the improved access policies of the Register have been important factors in the dramatic reductions in charges to the public for title searches.

Other Registers of Deeds in Wisconsin have made similar investments. Out of 72 county registers, 70 have computerized imaging and indexing systems. Twenty-eight registers are offering online access and ten are able to accept documents for recording electronically.

What about such organizations in places without a highly active real estate market, which operates through the formal registration system, and without a highly developed support network for IT? Might they benefit from making the investments in technology and management of the type undertaken in Dane County?

The “environment” of the Dane County Register in Madison, Wisconsin, is very favorable. There is a widespread effort to introduce ICT into public-sector and private-sector organizations and to change access of the public to land information in Dane County. Technical support services for IT are readily available. The very active real estate markets produce significant revenues for the Register, which facilitate securing adequate budgetary resources and offering more services, thus increasing revenues. Dane County financial management systems enable monitoring the actions of county agencies and rewarding capable managers.

How “replicable” the specific experiences of the Register of Deeds might be in other contexts is a question to be assessed by those interested in Dane County’s efforts and in the indicators that can be used to monitor the modernization process.

About the Authors

Jane Licht received a Master’s degree in Land Resources with an emphasis on land information systems from the University of Wisconsin at Madison, and has a Wisconsin Real Estate Broker’s license. She became Register of Deeds of Dane County in 1989. She is past president of the Wisconsin Register of Deeds Association, past president of the Wisconsin Land Information Association, past member of the Wisconsin Land Information Board, and a current member of the Dane County Land Information Office.

J. David Stanfield has a Ph.D. in Communication from Michigan State University, an M.A. in International Relations and Organization from American University, Washington, D.C., and a B.S. in Mathematics from Ohio State University. He worked for the Land Tenure Center, University of Wisconsin, Madison, for several years, and now is working with Terra Institute, Mount Horeb, Wisconsin, on land tenure, management, and administration.

References


Endnotes

1 Land sales figures include only averages of arm’s-length transactions. Sales made under other than normal market conditions (such as family sales or foreclosures) are not included.
Sales are reviewed by the Wisconsin Department of Revenue, Bureau of Equalization. With each sale of a parcel of land, the buyer is required to file a Wisconsin Real Estate Transfer Return, documenting the parcel size, sale price, present use, and intended use of the property. State appraisers inspect the site and verify the transfer return. The sales data are a summary of the Wisconsin Real Estate Transfer Returns.

2 Estimated from the transfer fees charged during 2004 by Dane County, with an average of $183,000 per property transferred.
Evaluating Spatial Impacts of Changes to Coastal Hazard Policy Language

Ana Puszkin-Chevlin and Ann-Margaret Esnard

Abstract: There has been a concerted effort in the United States and elsewhere toward hazard mitigation planning and related GIS-based community vulnerability assessments. However, “what is exposed” often is assessed independently of spatially implicit policy language revisions. In 2006, the definition of Florida’s Coastal High Hazard Area (CHHA) was changed for the third time since its establishment in 1985 without a thorough spatial impact assessment of the proposed changes. Our GIS analyses show that the latest definition change results in removal of vulnerable coastal lands from the CHHA (e.g., coastal areas adjacent to the ocean, but situated at higher base elevations). Overall, spatially-implicit changes in policy language, however subtle, need to be quantitatively assessed for unintended impacts. Adoption of scientific language, concepts, and standards into policy requires thorough assessment, for standard measures and benchmarks may translate awkwardly into policy mandates.

INTRODUCTION

Coastal land in the United States is managed through a complex and often disjointed web of federal, state, and local programs and regulations that attempt to balance goals of community development, environmental protection, coastal hazard mitigation, and respect for property rights. The high economic value and appeal of coastal tourism, recreation, homes, ports, marinas, and transportation access present obstacles and challenges for instituting environmental and hazard mitigation policies and regulations. State coastal hazard policies in Florida seek to standardize local environmental regulations, but at the same time must allow sufficient flexibility to adapt to local geographies and constituencies (May 1994, Deyle and Smith 1998).

Against this backdrop of requisite uniformity and flexibility in policy, there has been a concerted effort in the past decade toward Community Vulnerability Assessments (CVAs): baseline vulnerability assessments that identify hazard threats (floods, earthquakes, wildfire, hurricane storm surge, and wind) and assess risk and exposure. GIS technology has served as a common platform for CVA assessments at local, regional, and country-wide scales. CVA takes into account physical characteristics such as building construction and age, as well as social parameters that hinder the abilities of individuals, households, or communities to respond and recover from natural disasters. However, such baseline assessments largely inventory physical, social, economic, and environmental factors, and according to Thomalla et al. (2006, 45), “still concentrate on what is exposed instead of understanding the processes and dynamics of exposure and responses.”

It has become clear from recent hurricane response experience and emerging research on variable levels of storm impacts (Puszkin-Chevlin 2007a, FDCA 2006) that vulnerability also can be engendered in how policies are (re)formulated and applied. Revision and recalibration of policies and regulations can impact community vulnerability, directly or indirectly. However, in the urban planning academic discipline, policy language revision and review often is viewed primarily as content analysis—a reflection of sociopolitical processes. The research that we present here examines the semantics of policy language using GIS.

The underlying premise of our paper is threefold: (1) Proper analysis of proposed policy language can prevent failure during implementation and subsequent revision, a typical pattern noted in incremental policy development (Puszkin-Chevlin and Esnard 2009); (2) policy language must be assessed against numerous geographic characteristics of the coast (i.e., land use, building age, and asset value, and geomorphology) for sound coastal management; and (3) geographical analytical tools, and not just policy content analysis, can offer important insights on hazard policy impacts.

BACKGROUND

A 2007 “themed” issue of the Journal of Coastal Management explored the role of geography, including geographical/spatial investigation methods, in understanding coastal processes and informing coastal management policy and practice issues (Fletcher 2007, Fletcher and Smith 2007, Hodge and Johnson 2007, and McFadden 2007). McFadden (2007) argues that geographic science has been overshadowed by the governance aspects of coastal management. The author also reasoned that concerns for stakeholder representation and conflict resolution have primacy and, as a result, science has an increasingly marginalized position within integrated coastal zone management. These themes also appear in scholarly research by Birkland (1987), Deyle (1994), and Puszkin-Chevlin (2007a). Birkland noted that this is particularly evident in hurricane mitigation research, compared to earthquake research where scientific data forms the basis of policy response.

Fletcher and Smith in the same issue argue that coastal use is a reflection of the physical geography and the political and legal constructs that control development and regulate activities. Integrative paradigms, which include GIS spatial analysis, contribute to the understanding of coastal processes and are use-
ful to policy making. Furthermore, such analyses are more value neutral, not guiding policy toward particular social objectives. As such, scientific geographic analysis can be employed to advance diverse and conflicting policy objectives.

Van Kouwen et al. (2008) identified challenges of matching Decision Support System (DSS) tools with knowledge and process aspects of integrated coastal zone management and decision making. The authors acknowledge that policy-related research is not sufficiently linked to the formal policy-making process itself. Getting policy makers to participate in the process of building DSS is offered as one possible solution. This is part of knowledge building for more relevant DSS tools for coastal zone management.

In reviewing the current literature, there appears to be a gap in scholarly documentation on the use of geospatial investigation methods such as GIS, CVA tools, and DSS tools for a priori or a posteriori assessments of spatially implicit changes in coastal policy language. If this analysis is being reported, it is within government agencies and planning departments, and rarely published in the academic press. The GIS application presented here is an assessment of the impact of changes in the policy language of Florida’s Coastal High Hazard Area (CHHA) boundary definition (adopted in 2006). It illustrates how relatively simple GIS-based analysis of proposed policy language could have illuminated unintended impacts on community vulnerability, and allow for revision and adjustment prior to adoption. This can be useful to multidisciplinary research and practitioner teams of planners, policy analysts, GIS analysts, hazard mitigation specialists, scientists, and designers of coastal management decision support systems.

**POLICY CASE**

In Florida, a state long known for mandating local comprehensive planning, coastal land planning and hazard mitigation policies are legislated in a broad framework of directives known as Florida Statute (FS) 163.178 and administrative laws known as 9J-5. Among them is the requirement that localities designate a Coastal High Hazard Area (CHHA)—an area that requires special planning consideration because of the risk of damage from wind and water during a tropical storm event. Parcels within the CHHA zone are subject to more stringent development regulations, which until the 2006 policy revision included a restriction on zoning changes that increased development densities above and beyond what was depicted on the local future land-use map (FLUM).

Designation and boundary delineation of such CHHAs date back to the passage of the Growth Management Act in 1985 and have been central and controversial components of coastal planning initiatives (DeGrove 1992, Chapin et al. 2006). As of 2007, there have been two boundary definition changes. First was the change from a locally defined area of risk (1985–1994) to a uniform state-wide definition based on emergency management professionals’ criteria of the category-one evacuation zone (1994–2006). However, the emergency management department of each county had latitude in determining the boundaries of the areas that must be evacuated for a category-one hurricane. Generally, they identified a prudent, contiguous, planimetric zone away from the ocean or gulf coast shoreline. Furthermore, emphasis was placed on ease of communication of the boundary with the public. We refer to this definition as the “Old CHHA” throughout the document.

<table>
<thead>
<tr>
<th>Criteria used to define the Old CHHA in the study area were, for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Indian River County: (i) entire barrier island; (ii) western boundary of the Category 1 storm surge (based on SLOSH data); and no rivers (Indian River Comprehensive Plan, 2005);</td>
</tr>
<tr>
<td>• Martin County: (i) areas west of the Atlantic Ocean to the Intracoastal Waterway; (ii) all mobile and manufactured home parcels; and (iii) residential parcels within half a mile from Indian River, the North and South Fork of St. Lucie River, and the Loxahatchee River (Martin County Comprehensive Plan, 2004); and</td>
</tr>
<tr>
<td>• St. Lucie County: (i) entire barrier island; (ii) entire Category 1 storm surge (based on SLOSH data); and (iii) all mobile home parks (St. Lucie County Comprehensive Plan, 2004).</td>
</tr>
</tbody>
</table>

The current (2009) definition, (adopted in 2006) which we refer to as the “New CHHA,” is the area below the category-one storm surge line established by the Sea, Lake and Overland Surge from Hurricane (SLOSH) computerized storm surge model. This most recent change (New CHHA) was prompted in part by Hurricanes Charley, Frances, Jeanne, and Dennis that crisscrossed Florida in 2004 and related debates about: (1) the impacts and fairness of the regulation on coastal communities; (2) a desire to ground the definition of vulnerability in scientifically defensible models; and (3) which type of professionals should control the statutory definition of the CHHA. Nonetheless, the New CHHA continues to raise questions and concerns among land-use planners, hazard mitigation specialists, and public officials (Compton 2006) and has left many unanswered questions about the implications of the change for additional coastal (re) development and increased vulnerability of people and property. A thorough assessment of the 2006 legislative boundary change was not undertaken by any state agency, despite such concerns and a specific recommendation by a CHHA Study committee (http://www.dca.state.fl.us/fdcp/dcp/chhsc/workshops.cfm) for additional analysis (Florida Department of Community Affairs 2006). An analysis thus was independently undertaken by a university-based research center.

As researchers, we believe that this case study provides a useful model for assessing the spatial impacts of coastal hazard policy delineations. The change in policy language, from the “category 1 hurricane evacuation zones” to the “area below the elevation of the category 1 storm surge line as established by SLOSH” may have appeared innocuous to legislators and policy
analysts unfamiliar with hazard mitigation and coastal management. In fact, the reuse of the term *category one* in context with *hurricane* and *storm surge* may have obfuscated the difference. It is precisely the subtlety of the word change that is central to the issue of community resiliency. As noted, the Old CHHA definition was a contiguous area with a western boundary set in relation to a distance from the ocean for evacuation purposes. In contrast, the new definition is based on a topographic elevation with respect to potential storm surge. While legislators left the “category 1 hurricane” wording from the Old CHHA definition, the category-one hurricane evacuation zone and the category-one SLOSH storm surge embody nearly opposite notions of prudence to risk. The spatial application of the former delineates all the areas deemed so risky they must be evacuated for even a weak hurricane. The spatial application of the latter identifies the very limited land that would be impacted by just one factor of a weak category-one storm.

The changes to Florida’s CHHA delineation also offer an ideal case for application of GIS to evaluate impacts of changes in policy language given: (1) its geographic dimension (i.e., change from category-one hurricane evacuation to a topographically based zonal boundary criteria), (2) its temporal dimensions (i.e., three boundary definition iterations over the past 20 years), and (3) the desire to examine characteristics of land use and built age in relation to vulnerability and redevelopment pressure.

**STUDY AREA**

Florida’s three Treasure Coast counties (as shown in Figure 1) were selected based on the rapid growth and ongoing development pressure experienced in the past two decades along the coast—a trend representative of coastal counties in the United States and elsewhere. The counties’ geography, including the presence of three major rivers and the location of the coastal ridge, introduce additional features worthy of analysis. The Treasure Coast counties also provide examples of (1) built-out, (2) newer developments, and (3) older coastal cities and villages that might desire redevelopment in an attempt to control sprawl. Studies by Chapin et al. (2006) and Puszkin-Chevlin (2007a, 2007b) have documented the local political, historical, and contextual factors contributing to Florida’s coastal asset accumulation and the important determinants that shape development outcomes along Florida’s coastline. These studies grounded our understanding about the unique development history of each coastal county, and place the intercounty and intracounty comparative assessments of land parcels (including use, size, value, tenure, and year built) in context.

Although the study’s focus on Florida may be viewed as overly narrow, we believe that the GIS-based assessment approach employed in this research has broad applicability and transferability to other regions that maintain current parcel level data. Thus, we provide the specific data points by county not as a key finding, but rather to illustrate how GIS analysis revealed issues of increased vulnerability created by the change in policy language. GIS was a particularly effective tool for depicting the changes in the geographic expanse of the Old CHHA and New CHHA, and for mapping and analysis of the distribution and characteristics (e.g., land use and year built) of parcels removed and gained because of revision of CHHA boundary definition.

**GIS ANALYSIS AND ASSUMPTIONS**

This section provides a summary of the main steps used (see Figure 2), assumptions made and lessons learned regarding data sources, selecting appropriate geographic extents, categorizing and grouping parcel uses, and use of appropriate GIS functionality.

At the onset of our project we mapped the category-one storm surge and observed that because of rivers, tributaries, and canals, the areas extended up to eight miles inland for the study area counties. Knowing that the CHHA regulations were intended to limit development in areas proximate to the Atlantic Ocean or Gulf of Mexico, this key initial finding suggested that the boundary designation may not encompass the intended geography.

To keep the focus on coastal resiliency impacts, a similar assessment was completed for a subarea within three miles of the coastline. This three-mile area allows one to hone in on the impact of changing the CHHA definition because it eliminates areas that may be included in the “new” SLOSH-oriented definition, but would not experience significant surge water rise because of their inland location.

We also identified complications of implementing the new boundary. The SLOSH category-one hurricane storm surge perimeter line does not coincide with parcel boundaries, creating many split parcels. No policy language had been crafted to address this issue. For this assessment, we designated parcels out of the CHHA-based on whether the parcel’s center point was outside the SLOSH category-one storm surge area.
The most challenging aspect of the analysis was Step 4 (shown in Figure 2)— unpacking the net values (the difference in acreage of parcels between the old and new definition) resulting from the total values (Step 3). This was a critical piece of analysis, for the small net value changes camouflaged that many parcels were being added and many others were being removed. The location of the added and removed parcels had different vulnerability characteristics.

To better illustrate the implications of the new SLOSH-based policy language to hazard vulnerability, in Step 5 we compared the geography covered by New and Old CHHA to a widely accepted benchmark, the National Flood Insurance Program’s VE flood zones (i.e., areas inundated by 100-year flooding, with velocity hazard wave action). We maintained that the state policy should at least meet the thresholds established by the federal government. We also mapped the SLOSH for the category-three storm surge.

Additionally, we acknowledged that tax parcels engender different vulnerability characteristics depending on whether they are developed and the type of development. In Step 6, we assess the impact of the change on potential development, redevelopment, and resiliency. We examined the land use and age of structures on the affected parcels with the following assumptions:

- Land held for recreation or conservation uses by government and nonprofit conservation entities are not likely to be developed. Undeveloped land held by public entities for conservation purposes have lower vulnerability, for there are few to no built improvements on the land.
- Vacant land held by private entities will be developed at market values that can support development costs profitably. Privately held vacant land has low vulnerability, but may contribute to community vulnerability in the future when it is developed. Additional new development increases exposure; new development also is typically built to modern hurricane standards that may be very resilient.
- Older structures or buildings that do not maximize the developable square footage are likely to experience redevelopment pressure as property values increase. Thus, building age serves as a proxy for redevelopment potential.

The gained and removed parcels were categorized by general land use (i.e., residential, commercial, governmental, institutional, vacant, and recreational) and year built (i.e., pre-1970, 1970–1979, 1980–1989, 1990–1999, and post-2000). The parcel data used for this analysis was obtained from the Florida Department of Revenue (FDOR). This allowed for use of common attributes (e.g., parcel use codes, size of parcels, year built) for all counties in the study area.

When using parcel data, analysts also need to understand the difference between the tax parcels and land acres. While the acreage quantifies the size of the land parcels, the tax parcels represent improved real estate assets on the parcel of land. Thus, in the case of condominium or co-op buildings (land-use codes 04 and 05), one will find many tax parcels correlated to a particular acreage, in comparison to a multifamily rental residential building (land-use codes 03 and 08). Additionally, grouping or categorizing the parcel uses into broader land-use categories leaves room for variable interpretation by the analyst and had to be carefully brainstormed by the project team. In the case of open space, for example, special attention was paid to public and private ownership, and public ownership was scrutinized as government agencies may have conflicting land-use objectives. We aggregated land-use codes for vacant residential, commercial, industrial, and institutional properties (land-use codes 00, 10, 40, and 70, respectively), and segregated them from recreational and public open space (land-use codes 82, 95, and 97).

Because each coastal region has a unique group of stakeholders, research teams should assess these variables in their local context and incorporate knowledge of local government officials and stakeholders. For example, local sources may know if a vacant parcel is already slated for construction or perhaps under
consideration for purchase by a conservation group. There may be rental properties in the process of condominium conversion. The diversity of professionals consulted also is important. Local coastal engineers can provide information on beach management practices and/or inlet dredging projects that impact storm surge water flow, while transportation planners may know about pending road and bridge improvements.

**RESEARCH FINDINGS**

The New CHHA Changes Shape

As previously noted, the most striking difference between the two boundary definitions is the shape of the regulated area (Figures 3 to 5). Because category-one storm surge areas could extend up to eight miles inland along these waterways, the New CHHA generally incorporates more inland properties that were not part of the evacuation zone (i.e., the Old CHHA). However, the difference in the size and shape varied significantly by county. In Martin County, the New CHHA boundary results in a net increase of 28 percent (7,621 acres), because the new definition picks up low-lying inland riverine areas (see Figure 3). In St. Lucie County, we note a net decrease of land of 9 percent (1,509 acres), because small parts of the barrier island and some mobile home parks on the mainland drop out (see Figure 4). In both these counties, the changes appeared to be largely explained by whether a county had included "storm surge" or "mobile home park" language in their pre-2006 definition of the category-one hurricane evacuation. In Indian River County, we observe a slight net increase in acreage of 4 percent that could not be explained by these factors. Upon closer review, it became clear that small net difference resulted from riverine areas replacing coastal areas located on higher elevations of the coastal ridge (see Figure 5).

**REMOVED AND GAINED PARCELS: PERCEIVED VERSUS REAL**

The net differences in parcels and acreage between the Old CHHA and the New CHHA is only one descriptive parameter, and must be understood in the context of the number and specific location of the impacted properties, as many were gained and others removed—especially in key coastal areas. For example, in Martin County, the net impact of the change is 4,248 acres of land, but the redefinition actually impacts 10,778 acres, as 7,513 acres were gained and 3,265 were removed. Similarly, there is a locational shift in parcels that are gained or removed from the CHHA.

The GIS map for Indian River County depicts the total impact, distinguishing between the removed and gained parcels, and showing the spatial location and distribution (see Figure 6). Thus, it became clear how the language depicting the CHHA as the "area

<table>
<thead>
<tr>
<th>Parcels and Acres Impacted within VE Flood Zone</th>
<th>Three-mile boundary</th>
<th>Old CHHA boundary</th>
<th>New CHHA boundary</th>
<th>Absolute Change</th>
<th>Percent of Absolute Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martin</td>
<td>778</td>
<td>735</td>
<td>638</td>
<td>97</td>
<td>13%</td>
</tr>
<tr>
<td>St. Lucie</td>
<td>901</td>
<td>851</td>
<td>757</td>
<td>94</td>
<td>11%</td>
</tr>
<tr>
<td>Indian River</td>
<td>639</td>
<td>636</td>
<td>448</td>
<td>188</td>
<td>30%</td>
</tr>
<tr>
<td>Total # of Parcels</td>
<td>2,318</td>
<td>2,222</td>
<td>1,843</td>
<td>379</td>
<td>17%</td>
</tr>
<tr>
<td>Martin</td>
<td>5,248</td>
<td>5,118</td>
<td>4,657</td>
<td>461</td>
<td>9%</td>
</tr>
<tr>
<td>St. Lucie</td>
<td>6,055</td>
<td>6,043</td>
<td>5,940</td>
<td>103</td>
<td>2%</td>
</tr>
<tr>
<td>Indian River</td>
<td>1,506</td>
<td>1,503</td>
<td>1,237</td>
<td>266</td>
<td>18%</td>
</tr>
<tr>
<td>Total Acres</td>
<td>12,810</td>
<td>12,664</td>
<td>11,834</td>
<td>830</td>
<td>7%</td>
</tr>
</tbody>
</table>

Figure 3. CHHA Boundary Comparison: Martin County
below the category 1 storm surge” had the unintended impact of including low-lying riverine areas (land typically shielded from development through wetland regulation) and exempting land parcels in proximity to the ocean that sit on higher bluffs or the coastal ridge feature. The CHHA no longer was a contiguous area along the coastline. Rather, as higher elevation areas were exempted, it created holes similar to a “Swiss cheese” effect. Thus, while portions of the land may be elevated, they can be left isolated if surrounding low-lying areas are inundated or connecting roadways and bridges are damaged. The shortcomings of defining the CHHA boundary using SLOSH are illustrated in Figure 7 by adding layers depicting the road and highway network to the previously generated maps. In the area marked, the access roads traverse areas below the storm surge. This impacts approximately 919 parcels.

**ASSESSMENT AGAINST RELEVANT VULNERABILITY BENCHMARKS**

The newly defined CHHA covers 379 fewer VE flood zone parcels than the old definition, a decrease of 17 percent for the entire study area (see Table 1). In contrast, the Old CHHA definition applied to all these properties. The greatest change occurs on the barrier islands in Indian River County and on Jupiter Island.
in Martin County. These are areas of clear coastal flood hazard risk.

As climate research indicates that stronger storms may become increasingly common with an increase in ocean water temperatures, it was important to examine how SLOSH models for stronger storms might better depict a coastal high hazard zone. In Indian River, for example, at the widest point, the storm surge from a more intense category-three storm would extend to the first 7,300 feet of mainland west of the Intracoastal. In St. Lucie County, like in Martin, the category-three storm surge area would increase the number of parcels in the CHHA and include the entire barrier islands. The land within the SLOSH category-three model better represented the NFIP's VE zone. A comparison of the size of the SLOSH areas for category-one and category-three storms helped clarify the arbitrariness of the selected threshold measure.

It is important to note, however, that the NFIP VE zone is one benchmark of risk and resiliency and it focuses on water inundation and damage caused by wave impact. However, waterfront and proximate parcels on the barrier island and mainland shoreline also face the strongest winds of a hurricane landfall. In 2004, when the study area was hit by Hurricanes Frances and Jeanne, the coastal-most zone delineated by Florida's Coastal Construction Control Line experienced damage to 288 major structures (Florida Department of Environmental Protection 2004). Research on hurricane wind speed decay suggest that parcels even just slightly inland have advantages, for wind speeds decrease 10 percent to 20 percent from the landfall site because of the rougher topography of the land and vegetation (Schwerdt et al. 1979, Kaplan and DeMari, 1995). This bolsters the argument that land-use policy should attempt to limit asset development on barrier islands. To highlight the wind vulnerability issue, we compared the New CHHA definition to a high-wind-zone map provided by Citizen's Insurance Company and found that the new CHHA area was a fraction of the size of the latter. Overall, the New CHHA deemphasizes the distance from the ocean in favor of a topographical definition focused simply on inundation risk. Is this a prudent demarcation of coastal vulnerability?

**Changes in Land Use and Inventory Characteristics**

As one of the public concerns about the new policy was that it would encourage additional coastal asset accumulation, we investigated how the boundary change differentially impacted parcels with different land uses and parcels with structures of different ages (Williams and Phillip 2000). The breakdown of land uses among parcels that are added and removed from the CHHA confirms and strengthens the conclusion that the New CHHA could allow up-zoning on nearly 850 acres of vacant privately owned land removed from the Old CHHA. The New CHHA boundary also opens the door for up-zoning of some already developed residential areas and commercial parcels.

The only land-use categories that experience an increase in acres subject to the New CHHA regulations are recreational use and government-owned facilities, and this is limited to Martin County. However, increasing the amount of recreation and conservation land in the CHHA has no benefit in terms of directing development away from vulnerable coastal areas or limiting asset accumulation because this land is not likely to experience any development.

The new definition contains fewer properties in each year-built decadal range. However, because of the development chronology of the study area, which moved steadily inland and included a coastal building boom in the early 1980s, the inventory of the New CHHA boundaries included 45 percent fewer pre-1980 properties and 58 percent fewer properties constructed in the 1980s. In aggregate, the change in the boundaries would remove more than 5,700 structures built before 1980 and 2,300 structures built between 1980 and 1989 from the CHHA. See Figure 8 for a snapshot of Indian River County.

In Florida's real estate market, these properties are viewed as reaching obsolescence as consumer preferences for style and design features have shifted markedly toward newer construction. By comparison, only 744 tax parcels constructed after 2001 would be removed, a decrease of 32 percent. The take-home message is that to the extent that the New CHHA designation contributes to the removal of up-zoning restrictions from such older properties, it could encourage property redevelopment at densities beyond what currently is planned in the Future Land Use Map (FLUM). This has a mixed impact on vulnerability. Redevelopment can remove structures built to older and lax construction standards, but it also can increase the number and value of assets at risk.

**Conclusions**

In coastal management, there often is a gap between planning objectives and implementation. It can be challenging to craft politically palatable policy and regulatory language, and select the
standards and thresholds that effectively operationalize the objectives. This case study highlighted the importance of scrutinizing small, seemingly benign-appearing incremental policy changes that occur both inside and outside the context of hazard-planning documents. The desire to minimize ambiguity with quantitative thresholds and ground regulatory policy in scientifically defensible data lead planners to adopt and apply concepts and models (in this case, SLOSH) with a limited understanding of their applicability, impact, and limitations. Thus, in an effort to define zones of geographic vulnerability with a numerically measurable parameter, parcels that are proximate to the ocean, subject to the high winds, and have limited road access get dropped from the CHHA zone. The spatial analysis offered by the CHHA case study revealed that the new boundary definition (adopted in 2006) creates a sort of “Swiss cheese” spatial boundary, with elevated areas excluded from development regulations while adjacent parcels are included. The analysis also highlighted the importance of comparing outcomes of policy language against both recognized standards (such as the NFIP VE zones) and equally valuable data gleaned from disaster experience, such as the high water mark or debris line.

Our assessment of the quantitative and spatial differences between the Old and New CHHA, therefore, compel us to question whether the SLOSH category-one storm surge is an appropriate boundary criterion. Moreover, while the use of the term SLOSH model appears to lend the new boundary an image of scientific creditability and accuracy, it does not distinguish risk factors precisely at the parcel level or address the full range of hazard risk. The scale at which the model estimates storm inundation is relatively coarse in comparison to the plat maps delineating parcel boundaries.

Finally, the case study illustrated how relatively simple GIS analysis elucidates impacts more clearly and visually. As noted, GIS offered the advantage of simultaneously illustrating the total number of impacted parcels as a composite of the geography added and removed from the CHHA. In contrast, numerical data presented in graphs and bar charts typically illustrate the net impact in an oversimplistic manner. Presenting the removed and gained parcels would require that the bar chart include positive and negative values, making it difficult to visually ascertain the net difference and never clarifying the spatial distribution of the added and removed parcels. GIS ground truths the impacts of policy change contextually in surroundings familiar to the stakeholders and government leaders. It facilitates a priori or a posteriori assessments of coastal policy changes by planners and policy makers. GIS has been effectively used in gathering data needed to develop Community Vulnerability Assessment (CVA), but it now must also be incorporated into decision support tools that can evaluate policy alternatives.

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References


Endnotes

1 Old CHHA Definition (1994-2006): FS 163.3178 (2)(h) “Designation of high-hazard coastal areas, which for uniformity and planning purposes, are herein defined as category 1 evacuation zones. However, application of mitigation and redevelopment policies, pursuant to s380.27(2), and any rule adopted there under, shall be at the discretion of local government.”
New CHHA Definition (as of June 2006): Change introduced by HB 1359 “The coastal high hazard area is the area below the elevation of the category 1 storm surge line as established by a Sea, Lake and Overland Surges from Hurricanes (SLOSH) computerized storm surge model.”

SLOSH was developed by the National Weather Service to calculate potential surge heights from hurricanes.
GIS in Hazard Mapping and Vulnerability Assessment on Montserrat

Lavern Ryan

Abstract: This paper presents a description of how a geographic information system (GIS) was implemented in hazard mapping and vulnerability assessment on Montserrat. GIS has proved to be an effective tool in disaster management. It is needed at all stages of disaster management, particularly mitigation, preparedness, response, and recovery. Employing standard GIS techniques and incorporating data from other sources, it allowed for the visualization of a disaster situation effectively, thus reducing the loss of life and property. The demand for quick and accurate information and mapping where hazards exist can be met by a GIS.

INTRODUCTION

The British Government, the United Nations Development Programme (UNDP), and other international organizations have cooperated with the government of Montserrat in its massive efforts to rebuild socially and economically after its volcanic destruction in 1995.

In this connection, the Physical Planning Unit (PPU), in collaboration with the Department of Lands and Survey (L&S), has developed a GIS-based Land Information System (LIS) for effective planning and better management of land resources. LIS provides the basis for the development of a National Data Warehouse (NDW), which is effectively utilized for the better management of various public utility services and other resources of the country.

Moreover, GIS based LIS has proved to be an effective tool in disaster management. It is needed at all stages of disaster management, particularly mitigation, preparedness, response, and recovery. The demand for quick and accurate information and mapping where hazards exist can be met by the LIS. It allows for the analysis and visualization of a disaster situation, effectively reducing the loss of life and property.

This paper describes how GIS based LIS was implemented in hazard mapping and vulnerability assessment on Montserrat. It demonstrates the overall methodology adopted to achieve these objectives and gives an idea of the future potential of its application in the management of catastrophes.

Study Area

Montserrat, part of the Leeward Islands in the eastern Caribbean and overseas territory of the United Kingdom, is approximately 39.5 square miles in area. It lies approximately 27 miles southwest of Antigua (see Figure 1) and 1,150 miles north of the equator. This volcanic island is approximately 12 miles long and seven miles wide at its broadest point, with geographic coordinates of 16° 45’ N, 62° 12’ W.

Montserrat has severely suffered in the recent past, particularly when a major volcanic eruption in June of 1997 completely destroyed nearly two-thirds of the island, including its airport, seaport, and the capital, Plymouth. Such devastation has had an unfavorable impact on its economic, social, environmental, and institutional infrastructures, resulting in an immediate migration of nearly 62 percent of its population to the United Kingdom, the United States, and other countries (see Figure 2).

The island has since been divided into two zones (see Figure 3): the safe area and the unsafe area. The safe area has

1 Safe area covers the north of the island, which is separated by an imaginary line recommended by the volcanic scientists. This area, as compared to the southern part of the island, is considered at minimal risk of volcanic activities.

2 Unsafe area covers mainly the south and southeast areas of the island, which are in close proximity to the volcano, considered at high risk and thus excluded from all kinds of development and human activities.
been undergoing rapid development in terms of expanding road networks and the construction of buildings, all in an effort to provide facilities for the steadily re-increasing population. The unsafe area however, has been excluded from all development and human activities.

**VOLCANIC HAZARD ON MONTSERRAT**

Based on the seventh meeting of the Scientific Advisory Committee (SAC) on Montserrat Volcanic Activity that took place on August 28 to 30, 2006 (MVO 2006), it was concluded that the continued rapid growth of the lava dome posed a serious hazard to the nearby occupied communities. These hazards were pyroclastic flow from dome collapse and column collapse, rock avalanches from the collapse of the crater walls, and explosions with ash and rock fallout (see Figure 4).

The SAC advised that “the likelihood of these hazards is strongly controlled by the rate of extrusion, with high rates more likely to initiate both collapses and explosions.” In this particular setting, a large dome almost reached the point where it was capable of overtopping the crater rim, and potentially being able to send pyroclastic flows in multiple directions. Figure 5 shows populated areas [1–3] at risk. The dashed line is the estimated southern boundary that can be reached by a pyroclastic surge produced by a collapse of 12 million cubic meters of dome material; the northern boundary of this is the solid line between Areas 1 and 2. The northern boundary of Area 2 indicates the limit, if 20 million cubic meters were to be produced by a collapse. The northern boundary of Area 3 marks the northern limit of any conceivable pyroclastic flows.

Thus, the role and importance of GIS was highlighted in this grave situation. It was important that the vulnerable population be highlighted if there were to be a collapse of 12 million cubic meters of material or more. The Disaster Management Coordination Agency found it beneficial to use GIS in ensuring mitigation measures were enforced.

**Workflow**

Using standard GIS techniques, the impressions prepared by the SAC, showing population Areas [1–3] in Figure 5, were transformed into GIS-ready “polygon shapefiles.” After scanning and georeferencing the image, digitizing was carried out. These polygons then were overlaid on an aerial photograph of the area at risk (see Figure 6).

Based on the resulting images this map produced, it was decided that persons who fell within the 12M cubic meter and 20M cubic meter polygons be evacuated from their homes and relocated further north. This occurred successively in January and February of 2007. As a result of this evacuation, the safe area boundary line shifted further northward on two occasions, causing

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3 The SAC is responsible for assessing the hazards and risks associated with the Soufrière Hills Volcano, Montserrat.
Analysis

Based on the advice of the Montserrat Volcano Observatory (MVO), the DMCA requested that changes to the map be made as the situation at the volcano changes. It is useful to highlight the way in which the boundary of the safe and unsafe areas shifted during the course of the year 2007. As seen in Figure 9, the unsafe area increased in January 2007 (A), increased even further in February 2007 (B), but decreased significantly by September 2007 (C). This is a direct result of the ongoing activity at the volcano.

Additional data was incorporated from the Land Information System (LIS), as shown in Figure 7. The names of owners were extracted to enable the Disaster Management Coordination Agency (DMCA) to personalize the emergency evacuation notice to those persons who were vulnerable and to ensure that these persons complied.

Police checkpoints were put in place on the ground to ensure that no unauthorized personnel entered the newly designated unsafe area. The GIS also was used to map these police checkpoints to ensure that all the routes in and out were covered by security (see Figure 8).

The MVO provides scientific advice to the civil authorities on the volcanic activity and the associated hazards and risks.
Soufrière Hills Volcano.

The MVO reported on January 3, 2007, that the dome was observed to have overtopped the crater wall. By January 4, 2007, there were simultaneous pyroclastic flows and ash venting, which reached an estimated 8,000 feet. Moreover on January 8, 2007, a pyroclastic flow entered Belham Valley (Area 1 in Figure 5), an area close to the occupied communities.

On February 7, 2007, a new lobe was discovered on the southwestern side of the dome, and there also was an increase in rockfall activity. On March 12, 2007, large pyroclastic flows went down the Tar River, which drains and dissect the Soufrière Hills in an eastern direction (a location in the designated unsafe area), and the spine that was growing on the northeastern side of the crater was lost.

Early in April of 2007, the dome growth terminated, and by May of 2007, the MVO noted that all measurable activity was low. After a period of low activity, the safe/unsafe boundary was restored in September of 2007.

The government of Montserrat, the DMCA, and the MVO now have adopted a Hazard Level System. The purpose of the system is to improve management of the ongoing eruption and to provide important information to the residents of Montserrat.

The Hazard Level System divides the southern two-thirds of Montserrat into six zones with two Maritime Exclusion Zones (see Figure 10). Access permission for each of these zones depends on the hazard level.

The hazard levels, which range from 1 to 5 (see Figure 11), are set by the National Disaster Preparedness and Response Advisory Committee (NDPRAC) on the advice of the MVO.

**CONCLUSIONS**

The application of GIS in hazard mapping and vulnerability assessment on Montserrat has provided the disaster managers and the government of Montserrat with the necessary tools to manage a crisis on the island more efficiently. We have seen that hazard mapping is a quick way to inform residents of impending danger.

Moreover, GIS has proven a useful tool for the management of disasters and the relocation of residents during an emergency for it allows the potential for better decision making in an urgent situation. GIS techniques can be used to analyze and visualize an emergency situation, thus allowing decision makers to make informed decisions based on data they can see.

GIS further provides the means for different governmental
Figure 10. Hazard Level System

Figure 11. Maps Showing Hazard Levels 1 through 5
agencies to participate in a full range of emergency management activities. Data is brought into one focus, helping to identify what needs immediate attention, what can wait, and what can be delegated. Having knowledge ahead of time can benefit those on the front line, such as the police, fire, and medical departments.

Emergency crisis events impact more than just people and facilities. They also have an impact on the environment, crops, and livestock. This GIS tool has given the government of Montserrat impetus to continue to manage all limited resources (environmental, ecological, etc.) on the island in a sustainable fashion.

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References

The Land-use Evolution and Impact Assessment Model: A Comprehensive Urban Planning Support System

Zhanli Sun, Brian Deal, and Varkki George Pallathucheril

Abstract: The mechanism of urban growth and its interaction with socioeconomic and environmental systems still are poorly understood. Consequently, policy makers and planners often face tremendous difficulties in decision making with lack of vision into the future of urban growth. The Land-use Evolution and Impact Assessment Model (LEAM) has been developed as a comprehensive urban planning support system in a regional scale. LEAM incorporates ecological, geographic, and environmental theories into a single hierarchical framework, yet it is designed as an open architecture. LEAM is unique for all subsystems are explicitly and separately modeled. Submodels are developed by experts, who have substantive knowledge relating to a particular system, using an icon-based graphical modeling tool, STELLA. These contextual submodels then are linked to form the main framework of the dynamic model that run simultaneously on each grid cell of raster GIS map(s) in a Spatial Modeling Environment (SME). The overall model then is created in an open and distributed manner. A land-use decision support system for the St. Louis metropolitan region using the LEAM approach has been developed.

INTRODUCTION

Urban growth and the resultant sprawling patterns of development are causing social, economic, and environmental strains on U.S. communities (Schmidt 1998). According to the Sierra Club, undesirable urban growth, also known as urban sprawl, has become one of costliest problems in America. With growing concerns about the negative impacts of these development patterns, public agencies and policy officials are seeking principles and tools designed to manage land-use change under the flag of “smart growth” or “sustainable growth.”

During the past two decades, spatial analysis tools, geographic information systems (GIS), and remote sensing (RS) technologies have been widely deployed to monitor, analyze, and visualize the urban growth phenomena. Maps and satellite images, however, are limited to static displays of past and current data sets. They portray the current state of the system, with neither the reasons for it nor any possible future outlooks. Although GIS-based tools provide useful analysis and have been widely used to assist urban planners, the static mapping concepts on which they are built are clearly insufficient to study the dynamics of urban growth (Hopkins 1999). The causal mechanisms associated with land-use change remain relatively poorly understood, in part because of the complexity of urban systems. Consequently, policy makers and planners often are faced with the difficult tasks of making land-use decisions without sufficient analyses or vision.

Very recently, computer-based urban system simulation models are being employed to forecast and evaluate land-use change (Batty and Xie 1994, Birkin 1994, Landis 1994, Engelen et al. 1995, Wu and Webster 2000, Waddell 2002). These models represent a spatial and dynamic approach that enables planners to view and analyze the future outcomes of current decisions and policies before they are put into action. These models have the ability to help improve our fundamental understanding of the dynamics of land-use transformation and the complex interactions between urban change and sustainable systems (Deal 2001). These spatial dynamic modeling techniques are becoming essential elements in the Planning Support System (PSS) literature (Hopkins 1999, Kammeier 1999).

To date, however, spatial dynamic urban modeling is still in its infancy. Few models have been built that are able to represent the complex dynamics of urban land-use change that are consistent with observable data (Almeida 2003). As a result, few such models are operational and are used to assist urban planning practices.

In this paper, we present a comprehensive dynamic spatial urban simulation model, the Land-use Evolution and Impact Assessment Model (LEAM). LEAM originally was developed as a research project by an interdisciplinary team of researchers at the University of Illinois with support from the National Science Foundation. After a successful full-scale pilot application in Peoria, Illinois, LEAM has been selected to assist planning practices in the St. Louis metropolitan area, as part of the Department of Defense (DOD) encroachment analysis and as part of the Smart Growth initiative introduced by the state of Illinois. Described here is a bistate application of LEAM consisting of the five counties in southwestern Illinois and the five counties in east central Missouri that make up the St. Louis metropolitan region. In the following sections, the conceptual framework and relevant features of the LEAM simulation environment is described, followed by the results of the St. Louis metropolitan regional application.

LEAM DESIGN

LEAM is a new modeling environment designed to support regional planning practices. Understanding the interactions between
An Ecological Approach

LEAM builds on a body of work on large-scale ecosystem models that have seen a recent resurgence (Deal 2001). The theoretical underpinnings of LEAM are based on integrated, multidisciplinary, ecological, and engineering approaches to modeling spatial dynamics.

Applying ecological concepts and methods to urban research has roots that trace back to the 1920s when R. E. Park and E. W. Burgess developed a concentric, static urban structural model based on the ecological equilibrium theory. In the 1960s, J. Forrester further advanced the urban ecology ideas by adding a dynamic component. This was manifested in his urban dynamics model based on concepts of “industrial dynamics” and “industrial ecology” (1961, 1970). However, the ecological approach has not been applied systematically to urban problems until very recently when urban ecology began to emerge as a new branch of environment science, which studies urban ecosystems.

Urban ecology broadens the concept of traditional ecology to consider human systems as a major actor in ecosystem analysis. Its goal is to promote a sustainable urban environment through the study of the interactions between human and environmental systems. Urbanization impacts studied include feedbacks on human society as well as on the natural environment. LEAM models not only are the drivers of urbanization, including biophysical factors and socioeconomic factors, but also model the impacts and feedbacks that urbanization has on itself and on other systems.

New theory, tools, and research methods in ecological systems have the potential to improve the dynamics of change in urban environments. A variety of sophisticated computational and theoretical tools exist for characterizing urban systems at a conceptual level, and for visualizing and understanding these characterizations. An integrated platform for a high-performance spatial modeling ecosystem, called the Spatial Modeling Environment (SME; developed at the University of Maryland) (Maxwell and Costanza 1997), is utilized in LEAM. This modeling environment, which transparently links icon-based modeling tools, such as STELLA, enables users to develop LEAM models in a user-friendly, graphical environment, requiring very little knowledge of computer programming. Therefore, the combined use of SME and STELLA allows users to build LEAM collaboratively in an open architecture form.

Collaborative, Distributed, and Open Architecture Design

To build a comprehensive urban simulation model involves collaboration of scientists from multiple disciplines. Traditional approaches to complex multidisciplinary modeling require one or more programmers to “translate” substantive contextual models developed by others into computer code. The programmers separate the modelers from the actual model implementation and they often are the only ones who understand the interrelationships and nuances of the entire model. To further complicate the situation, the black-box nature of these implementations leaves the substantive experts unable to assess whether their expertise has been adequately and accurately captured. In this traditional approach, the processes of model formulating, calibrating, coding, and integration are time-consuming, error-prone, and very difficult. The entire model ends up as a black-box system to users, even to model developers. It is extremely hard to use and maintain.

With these problems in mind, LEAM was developed using an alternative strategy to this black-box approach. This strategy can be characterized by two key differences from the current set of approaches: First, this alternative strategy must involve an open model building environment rather than a black box; second, it must allow for disaggregated and distributed model building in which various subject experts can contribute directly and collaboratively in the model building process rather than working through a single programmer as “translator.” An open model building environment would allow model parameters and drivers (the local rule set) to be easily inspected and evaluated. Disaggregated and distributed model building would ensure that groups of experts can work directly on parts of the model with which they are most familiar.

Such an alternative is available in the combined use of STELLA for constructing the cellular models, which are local rules that define cells behavior, and SME for assembling and linking the cellular models spatially across the lattice. STELLA is a graphically based dynamic simulation software based on Jay Forrester’s “system dynamics” language that uses icons and symbols to communicate a model’s structure (1961). STELLA has a good mix of simplicity in manipulating model components and power of model expression. Icons include reservoirs representing stocks of resources and “pipes” and “valves” representing flows and controls between those reservoirs, each with an associated user-defined equation (Hannon 1994). Variables of interest
can be scaled and plotted in different formats to help visualize model behavior. The effects of changes made can be viewed immediately in a user-friendly, graphical environment, requiring no knowledge of computer programming. Using iconographic modeling techniques greatly increases the ease with which the model can be changed and calibrated, allowing the user to concentrate on modeling instead of computational details (Maxwell and Costanza 1997).

SME spatializes the single-cell STELLA models, applying them to a geographic area (represented in this case as a matrix of cells), and simulating the changes that take place to the state of each cell over multiple time steps. SME automatically converts the STELLA models into computer C++ code that can be run on multiple processors (and multiple computers) in parallel. The spatial simulations, as a result, are processed in distributed high-performance fashion that is transparent to users. Results can be displayed in a number of ways, including a built-in mapping and animation tool when running SME with Graphic User Interface (GUI); results also can be exported to images and GIS format files, then visualized and analyzed in image-processing software or GIS software. Other representations, such as map movies, animations that show change over space and time, summary tables, and summary maps, can be easily generated.

SME imposes constraints of modularity and hierarchy in model design, and supports archiving of reusable model components (Maxwell and Costanza 1997). In these ways, this approach eliminates black-box complexities and advances an open, disaggregated approach to spatial modeling. By applying this collaborative spatial modeling approach, LEAM is developed in an open, modular approach that promotes collaboration.

**Cellular Automata–based Model**

Under the framework of SME, a spatial region is breaking down into cells, which are analogous to GIS grid cells. The behavior of each cell object, also called local rules, is described by the STELLA model. A set of intercellular links also can be defined, representing spatial contiguity and local spatial interactions. Typically, any two cells are linked if they share a boundary, but more flexible and general linkages are possible (Costanza 2004). Essentially, SME provides a perfect platform for cellular automata (CA) modeling, which emerges as a microscopic simulation approach to model urban dynamics.

Cellular automata is a discrete dynamic system whose behavior is completely specified in terms of a local relation. In a typical two-dimensional cellular automaton, space is represented by a uniform grid, with each cell holding a discrete value as its state. The cell state changes in discrete steps and its new state is computed based on the configuration of its neighbor cells. The concept originally was conceived by John Von Neumann (1966), who is known as the “father of the modern computer,” and introduced to the public by another mathematician, Stanislaw Ulam, in the 1950s. In the 1970s, John Conway’s “Game of Life” raised a lot of attention and interest toward CA research. CA has been widely applied to chemistry, physics, computer graphics, and so on. CA establishes itself as an important tool to study complex systems. Very recently, Stephen Wolfram even defines CA as a revolutionary model tool that changes how we look at and simulate the world in his book, *A New Kind of Science* (2002).

CA is embedded with a spatial dynamic feature, which makes CA a natural tool for spatial modeling. CA application in geographic modeling dates back to the spatial diffusion model developed by T. Hagerstrand (1967), which essentially is a stochastic CA although he didn’t even use the term CA. Geographer W. Tobler (1979) first defined CA as a geographical model, although he believed some CA are too simple to be useful applied. Later on, the implication of CA to geographic modeling, including advantages and theoretical obstacles of applying CA to geographic modeling, was explored theoretically (Couclelis 1985, 1987, Batty et al. 1997, Couclelis 1997). CA is very appealing to geographic modelers because (1) a CA-based model is simple and intuitive, yet capable of simulating a self-organizing complex system; (2) the natural-born spatial dynamic feature enables modeling a spatial dynamic system in extreme spatial detail and spatially explicitly; (3) the cellular structure of CA has a natural affinity with the raster data format of remote sensing images and GIS grid maps; a CA model can be easily integrated with GIS through generalization of map algebra (Takeyama and Couclelis 1997); (4) the bottom-up approach of CA provides a new strategy of geographic modeling; and (5) CA is a computational model running in parallel that fits the high-performance geocomputation.

Since then, CA application in geography has been experiencing exponential growth, especially in urban land-use simulation. Batty was the one of earliest geographers to sketch the general framework of CA-based urban models (Batty and Xie 1994). An integrated platform, named DUEM, designed for geographic CA exploration, also was developed by Batty and his group (1999). Engelen used CA to model urban land-use dynamics to forecast climate change on a small island setting (Engelen et al. 1995). Wu presented a model that also included user decisions to determine model outcomes (Wu and Webster 1998). White’s St. Lucia model (White and Engelen 1997) is an example of high-resolution CA modeling of urban land-use dynamics and an attempt to use the standard nonspatial models of regional economics and demographics, as well as a simple model of environmental change, for predicting the demand for future agricultural, residential, and commercial/industrial land uses. An urban growth model of the San Francisco Bay Area (Clarke and Gaydos 1998) is another example of using relatively simple rules in the CA environment to simulate urban growth patterns. Li and Yeh integrated neural networks and CA in a GIS platform and successfully applied it to urban land-use change simulation in Guangdong, China (2002).

Although dozens of models have been proposed and built over the past 20 years, CA based on land-use modeling technique still is far from mature. Despite the flexibility of the CA approach, limitations remain (Torrens and O’Sullivan 2001). The hypothetical urban forms emerging from CA models with surprisingly simple local transition rules certainly are plausible. However,
urban systems evolve in much complex ways in reality. The current CA-based urban models are just too simple to capture the richness of urban systems. Consequently, most CA models still are developed as research projects, and applications are conducted more like experiments to test models. To date, few CA-based models are operational as productive tools to support regional planning practice.

To build useful operational models, modelers try to loosen the constraints of CA and extend the concept of CA, and also integrate a diversity of models, such as traditional regional socioeconomic models (White and Engelen 1997, Wu and Martin 2002). In LEAM, cells evolve in a constrained surface defined by biophysical factors, such as hydrology, soil, geology, and landform, and socioeconomic factors, such as administrative boundary and census district, instead of in a homogeneous space as in a traditional CA model. The probability of each cell change is not only decided by the local interactions of neighbor cells, but also by global information. Therefore, cells in LEAM are intelligent agents that not only can get the local information, but also can sense the regional or global information, such as social environment and economic trends. LEAM also has a hierarchical structure with multiple scale models incorporated. These models are loosely coupled in a modular framework, where the information can be exchanged between these models through aggregation or disaggregation approaches on the fly. By adapting such a strategy, LEAM can integrate cellular micromodels and regionalized macrosocioeconomic models into a single model framework.

**LEAM Framework**

LEAM consists of two major parts in the framework (see Figure 1), a land-use change (LUC) model and urbanization impact models. The LUC model part is the core of LEAM and answers the question: How does land use change under certain assumptions and policies? The second impact models part is a further interpretation and analysis of urban land-use change and answers the questions: What does the resultant land-use change pattern mean? How does it affect water quality, air quality, traffic pattern, and property value, etc.? Besides these two parts, a hidden part involving dialogue with planners and policy makers completes the workflow in a circle as feedback. This third feedback part is very important to LEAM as a planning support tool. Basically, it asks planners these questions: Are you happy with the land-
use change pattern? If not, how should policies or decisions be revised? What are the alternatives? These answers from planners would be used as the feedback input for running another scenario of the LUC model.

In the LUC model part, LEAM evaluates land-use transformation potential by explicitly quantifying the forces that contribute to land-use change. Model drivers represent the dynamic interactions between the urban system and the surrounding landscape. Each of these forces (also known as “drivers”) is developed as a contextually independent submodel that allows for calibration before being run simultaneously in the LEAM model. Vacant lands, or developable lands, can be transformed into three categories of urban cells—residential, commercial/industrial, and urban open space. Generally, driver submodels currently address urban dynamics influenced by regional economics, social factors, transportation infrastructure, proximity to city centers, facility infrastructure, neighboring land uses (where the CA model is adapted), geographic factors, and spontaneous growth. The open architecture and modular design certainly makes incorporation of extra local drivers into LEAM an easy job.

LEAM uses a 30 m × 30 m raster-based GIS land-use map based on the U.S. Geological Survey’s National Land Cover Data (NLCD). The NLCD maps are used to initialize the land-use conditions in the region of interest. The model then uses the same 30 m × 30 m resolution to simulate the socioeconomic parcel-by-parcel decision making that influences urban growth patterns (Deal 2001, Deal 2003). Each of the drivers contributes to the calculation of the development probability of each grid cell. Each driver is developed as a submodel; definitions are completed and run independent of the larger LEAM organization. Each cell’s land use is changed based on the collective influence of each of these submodels that represent actual forces present in the landscape. The influence of these changing forces is different for each study area. Consequently, each driver submodel can be weighted to provide the appropriate local influence.

This modeling process determines the overall growth potential of each land cell. This potential, also called score, defines the relative preference among cells, but it is not probability yet. A regional input-output econometric model, coupled with cellular micromodels, provides regional population change and economic trends over time. The results can be further used in allocation models to deduce residential, commercial/industrial, and open space regional demands. Based on these demands, the development potential of each cell can be adjusted to real probability to meet the regional demand. At last, a Monte Carlo stochastic simulation is conducted on the probability surface to select developable cells for urban growth. Compared to the approach that selects the top cells with highest probability as in Engelen and White’s model (Engelen et al. 1995, White and Engelen 1997), the Monte Carlo approach provides a visually more realistic pattern, avoids the unfairness in selecting because of the spatial order, and enables running the simulation in parallel mode.

Environmental, economic, and social system impacts of alternative scenarios such as different land-use policies, growth trends, and unexpected events can be modeled and tested out in the LEAM modeling environment. LEAM’s visual representation of each scenario’s outcome provides an intuitive means of understanding the potential of decisions and acts as a catalyst for discussion and communal decision making.

**CASE STUDY: ST. LOUIS PLANNING SUPPORT SYSTEM**

Like most other older metropolitan areas, St. Louis faces a great challenge of sustainable growth. With relatively slow population growth, even negative growth in its urban core, the city is continuing to sprawl. The St. Louis metropolitan region is already the third largest in the amount of land that it covers, while it ranks 14th in terms of population. According to the Census data, the urban population had a very modest 7 percent growth over the past three decades (1970–2000). However, new urbanized land mushroomed 125 percent. That means people are leaving city neighborhoods for suburban areas. Consequently, open space and valuable farmland are lost; the city core is under investment; the tax base declines; property values decline; racial segregation and economic disparities become severer and create more socioeconomic problems. Traffic congestion and air pollution also are symptoms of urban sprawl. The East-West Gateway Coordinating Council (EWGateway), the metropolitan planning organization and council of governments for the St. Louis region, forecasts continuing slow population growth for the region as a whole during the next 20 years, with some level of continuing decline in the core and expansion in the outlying counties. Can we afford to let this growth happen in such a way? What is the physical, fiscal, and governmental infrastructure needed to support future growth? What are the potential economic, social, and environmental impacts of a planning project or policy? How should we encourage economic development opportunities to maintain and build attractive, high-quality, healthy communities that provide good jobs and sustainable futures for today’s workers and for our children and grandchildren? These are some of the questions that come before the policy makers and planners of metropolitan St. Louis. Unfortunately, it is not trivial to answer these questions. To attain smart growth, smarter tools need to be deployed. Compared to other urban modeling tools, LEAM has an open architecture, which makes it easier to incorporate multiple models and build localized urban models. LEAM also is more open for inspection. Furthermore, LEAM can run in parallel model on supercomputers and can model large regions at a very fine resolution. LEAM in comparison is more open to inspection and, because it runs on supercomputers, can handle large regions at a very fine resolution. In 2003, EWGateway began to work with the LEAM research group and use LEAM as a planning tool to assist communities in making decisions that affect the economic efficiencies, health, and viability of both the local community and the region as a whole. LEAM also provides a framework for public officials and citizens to dialogue with planners and evaluate public investments through exploration of scenarios. This is also the second full-scale
application project, after the Peoria Tri-County project.

Spanning parts of the states of Missouri and Illinois on both sides of the Mississippi River, the study region includes ten counties—five counties (Clinton, Jersey, Madison, Monroe, and St. Clair) in Illinois and five counties (City of St. Louis, St. Louis, St. Charles, Jefferson, and Franklin) in Missouri (see Figure 2). This area is about 120 miles from east to west and about 90 miles from north to south. It accounts for a little more than 30 million grid cells at 30 m x 30 m spatial resolution.

At the first step, a generic LEAM run was conducted for the region. In the generic application, the land-use simulations were generated using a limited set of drivers, those for which national data sets could be used. The model parameters are either empirical or based on national average value. It is certainly not the best prediction; it can, however, serve as the basis for public discussion of regional drivers of land-use change and scenarios of interest in public workshops.

Figure 3 is a map showing the outcome of one generic LEAM simulation; new areas of development in the year 2025 are shown in green and existing areas in purple.

Based on the input of local planners and residents, the following step is to build a tailor-made LEAM model just for the St. Louis metropolitan region. This is a tough part. To develop a localized LEAM model, a significant amount of work must be done on data and models.

First, successful model runs require acquiring and processing substantially accurate data. It is impossible to get reliable results without accurate data input. Up-to-date and accurate land use is especially important to LEAM simulation. Multiple data sets from various sources have been used to produce a land-use map at year 2000, the start year of the LEAM model.

Second, each submodel needs to be refined and calibrated based on local data. For example, the input-output econometric model for projecting population and jobs has to be localized by using local data sets; the transportation model needs to be calibrated and emulate the traffic congestion caused by the bridges on the Mississippi River to plot out the local traffic pattern.

Third, a number of new submodels must be developed. The additional driver models are designed to capture the local urban growth pattern; impacts models are built to address the problems people are interested in in this region. For instance, the generic LEAM simulations used proximity to city centers as a driver of land-use change. Public review of these simulations suggested that land-use change in this region is likely to be driven by proximity to other centers such as employment, shopping, health, and cultural amenities. A spatial interaction model, also called a gravity model, is developed based on proximity, travel time precisely, to these centers. Besides adding these attractors models, a social model was developed. A social model acts as a repelling driver, which discourages growth based on vacancy rate, rental rate, income

Figure 2. Study Region
Figure 3. Map of a Generic LEAM Simulation

Figure 4. LEAM Blueprint Simulation
Figure 5. LEAM Blueprint Simulation

Figure 6. Regional Map Showing Change over Time
level, and other socioeconomic factors.

Finally, submodels need to be integrated, tested, and calibrated in LEAM framework. This localized model is termed a blueprint LEAM model. It is more powerful, capable, and accurate than a generic model. Comparing this blueprint simulation (see Figures 4 and 5) to the generic LEAM application, it is not hard to notice growth is shifted from the Illinois to the Missouri side, with much less growth happening in the urban core area. More detailed quantitative analysis and validation further proves this model produces a more realistic urban growth pattern in this region.

Armed with this blueprint model, we can take the next step to explore scenarios based on planning projects, policies, or “what if” assumptions. Here we will present two scenarios: One is the new bridge scenario showing how a transportation project affects land-use change pattern; the other is fiscal analysis showing what urban growth means to cities’ fiscal status.

**New Bridge Scenario**

Changes and enhancements to the road network in the region are likely to have an impact on land-use patterns. In this scenario, we assume the new bridge on the Mississippi River planned in the first phase of the St. Louis Long-Range Transportation Plan is implemented, and after that no changes will be made to the infrastructure. In this case, the simulation was conducted in two steps. First, we ran the blueprint model from year 2000 to year 2007, when the planned bridge is finished. Then, the bridge was added to the road network and the travel times in the region were recomputed. It will further affect proximities to infrastructure, city centers, employment centers, etc. At the same time, the economic model was run to assess the regional impact of the boost to the regional economy from this construction project. The simulation was run out to the year 2050, starting from the land-use pattern at the end of year 2007, the new development probabilities as a result of changed travel times, and new development targets from the economic model.

The results are shown in the two regional maps (see Figures 6 and 7). The first map summarizes change over time, and the second map compares change in this scenario with change in the blueprint model. The comparison map reveals how constructing the new Mississippi River Bridge is likely to pull more development (indicated in magenta) to the Illinois side of the river, while the blueprint model (in green) had more development further away to the eastern and western fringes of development in the region. Urban growth also can be aggregated to counties and compared to the blueprint simulation. It shows the extent to which development is likely to shift from Missouri to Illinois; within each subregion, the relative share of different counties does not appear to change dramatically.

Blue cells are developed cells common to both scenarios. Green cells are developed cells unique to the blueprint model. Pink cells are developed cells unique to the new bridge scenario. The red lines forming a cross in the center of the map is where the new bridge is located.

![Regional Map Comparing Change over Time in Current Scenario with Change in Blueprint Model](image-url)
FISCAL IMPACT ANALYSIS

Land-use change pattern has deeper implications. Fiscal impact is one of the further interpretations of urban growth. After considering various approaches already attempted by others, we tested a regression model based on per-capita expenditure in the year 2000 using a sample of 73 jurisdictions in the Illinois portion of the St. Louis metropolitan area. Our analysis suggests that there are no economies of scale: Per-capita expenditure increases as the number of households increase. At the same time, jurisdictions with greater population densities have lower per-capita expenditures, and jurisdictions with greater economic activity (as measured by per-capita sales tax collection) have higher per-capita expenditures.

Figure 8 shows how the model was used to predict the future (2030 in this case) expenditures and to evaluate the possible annexations because of development. The future population density, number of households, and the per-capita sales tax were calculated from the LEAM runs and plugged back to the model. Without any boundary change, the total government expenditure of the city of Edwardsville will increase by $3,238,441 from 2000 to 2030. The two annexation scenarios show greater increases in expenditures if new developed areas were annexed to the 2000 city boundary.

The St. Louis LEAM project is still an ongoing project. More detailed calibration will be conducted; more submodels will be developed; dozens of scenarios will be implemented for local planners to explore. These scenarios will significantly enhance planners’ insights into future land use and its impact. Although LEAM probably will not make decisions for planners, neither will it make planners smarter; however, it certainly will help them make smarter decisions.

CONCLUSION

Planners need better tools to understand their cities and regions not just as economic systems or as static inventories of natural resources, but also as environmental systems that are part of regional and global networks (Campbell 1996). Remote sensing and GIS are useful tools for planners, but inadequate to provide insights into possible urban futures. Urban systems, as a complex system, can be best understood by spatial dynamic modeling. Aiming to provide decision support tools for urban planners, LEAM is developed using an urban ecological approach. The LEAM environment enables users to capture stochastic influences and report the probable consequences of events in scenario format. What are the consequences of additional developments in a particular part of a community or the impacts of planned new roads? How will growth policies impact the social well-being of the existing residents? The completed work will enable planners and laypersons to assess the environmental impacts of urban land-use policies and visualize the results.

The importance of the collaborative approach and the democratization of the results in the LEAM process cannot be overstressed. This is the most important feature of the LEAM approach, which makes LEAM unique to other urban models. The LEAM dynamic urban modeling environment uses a multi-disciplinary, distributed modeling and visual output approach to assess socially significant policy scenarios affecting land-use change and its associated environmental impacts. Inefficiencies in some of the processes of developing competing computationally complex urban models may be hindering their progress toward application and utility. An open architectural approach to the LEAM environment exposes the fundamental modeling assumptions and variable interactions, increasing model transparency, transportability, validity, and user trust in the reliability of the results.

LEAM has been successfully applied to Peoria, Illinois, and planners there are using LEAM in their daily decision making; although the metropolitan St. Louis project still is under development, some scenarios have been implemented and the results verified. This demonstrates that LEAM can be a useful tool for planning decision support.

However, LEAM is not a finished product and probably will remain a dynamic work in progress. The causal mechanisms of urban system dynamics still are not well understood. Although LEAM may help to provide some insights, more sophisticated submodels are needed to address the complexity of the social, economic, and environmental issues inherent in urban system dynamics. The calibration of LEAM as with other CA models.
still is problematic, although some recent research has shed some light on possible solutions (Wu 2002, Maria de Almeida et al. 2003). How to validate the model results also is being debated. Nevertheless, the spatial dynamic modeling process and the open framework of LEAM are not only useful to planners and decision makers, but also helpful to other academic researchers.

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