PLANNING SUPPORT SYSTEMS

Integrating geographic information systems, models, and visualization tools

RICHARD K. BRAIL AND RICHARD E. KLOSTERMAN, EDITORS

Contents

Paper 11

CommunityViz: An Integrated Planning Support System

MICHAEL KWARTLER
ENVIRONMENTAL SIMULATION CENTER
NEW YORK, NEW YORK

ROBERT N. BERNARD
PRICEWATERHOUSECOOPERS
ITHACA, NEW YORK

ABSTRACT

CommunityViz™ is an ArcView GIS-based decision support system for community planning and design applications. The software is unique in that it fully integrates the words, numbers, maps, and images that planners and designers traditionally use for planning purposes into one, real-time, multidimensional environment. This is achieved by enabling ArcView GIS to modify data on the fly, linking it to real-time photo-realistic 3-D visualizations, and adding the fourth dimension (time) through the use of agent-based predictive modeling. In doing so, all types of data become mutually accountable to each other and the impacts of alternative planning scenarios and designs can be evaluated on the fly. This article outlines the development and general structure of CommunityViz, each of its three components (Scenario Constructor™, TownBuilder 3D, and Policy Simulator™), and how the software could be used in a real-world planning context.

COMMUNITYVIZ: DECISION SUPPORT SOFTWARE

CommunityViz software is a set of planning and decision support tools that integrates 2-D mapping information, 3-D visualization, and policy simulation technologies that can be applied to the planning and design issues of specific communities. CommunityViz creates an interactive, 3-D, real-time environment in which citizens and professionals alike can come to clear understandings of plans for the community. Users can propose policies and suggest design alternatives. They can visualize immediately how these changes might affect their environment—physically, economically, and socially. This interactive process enables citizens, planners, designers, and public officials to make better informed decisions and facilitate the building of consensus when controversial or complicated proposals are negotiated. CommunityViz is unique in its integration of GIS, 2-D and 3-D visualization, and multiagent simulation modeling. Figure 1 shows CommunityViz in action.

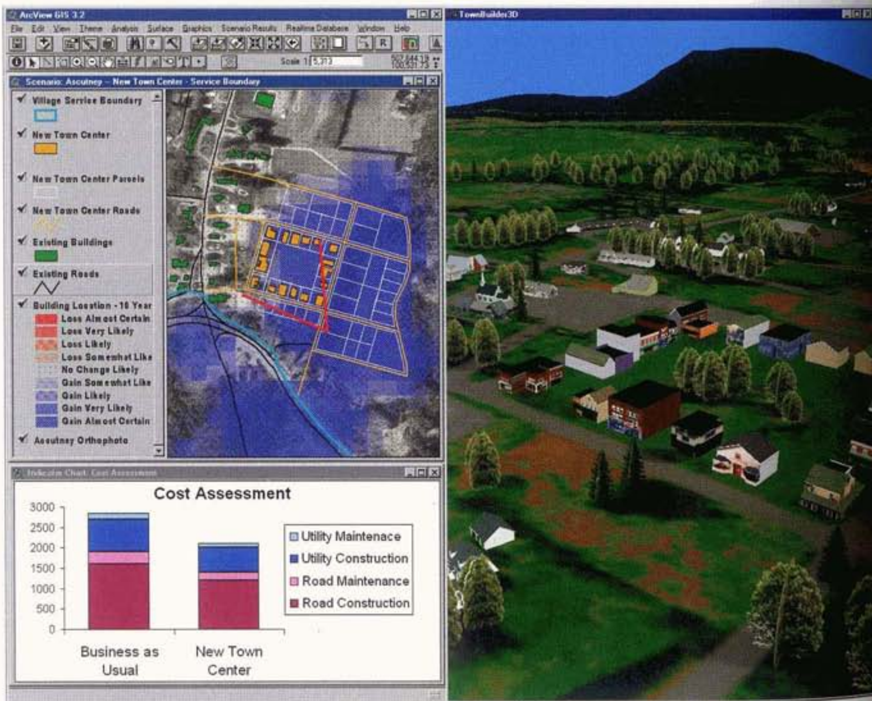

Figure 1. Typical CommunityViz. An illustration of the three modules that comprise CommunityViz, displaying a proposed policy in GIS and 3-D.

BACKGROUND

The Orton Family Foundation, a nonprofit organization based in Rutland, Vermont, contacted Coopers and Lybrand in 1996 about building computer software that would help satisfy the Foundation's mission to "help citizens of rural America define the future, shape the growth and preserve the heritage of their communities" (Orton Family Foundation, 2000). Rural areas throughout the country were slowly eroding, working landscapes were being transformed into subdivisions and "starter castles," while traditional towns and villages were being rendered obsolete as new forms of retailing emerged in the changing economy. In Vermont, a grassroots coalition consisting of government officials, planners, consultants, architects, preservationists, conservationists, and, most importantly, Vermont citizens themselves, formed to stop this erosion. Not coincidentally, it is citizen volunteers who do most of the local town planning in Vermont in the first place, without much—if any—formal training in land use planning, demography, or economics. In effect, these citizen planners are the embodiment of the Jeffersonian model of government run by an informed and engaged citizenry (Peterson 1975).

Vermont citizen planners were nevertheless at a disadvantage. Without the information and tools to (literally) envision what the future might look like, it would continue to be extremely difficult for them—no matter how committed—to grasp the inexorable land-use patterns and changes that might emerge from the simplest decisions or nonactions. These citizen planners needed new tools that would support and add new vitality to the Jeffersonian model of collaborative decision making. The planning tools required would assist citizens in learning about the potential resources in their communities, understanding the complex interrelationships between land use, the environment, and the economy, visualizing possible futures, and evaluating them against a set of policies and ordinances, as well as personal values.

THE DESIGN OF THE SYSTEM

CommunityViz represents the Orton Family Foundation's contribution to, and support and development of, work pioneered by the Environmental Simulation Center (ESC) and Coopers and Lybrand's Emergent Solutions Group (now PricewaterhouseCoopers Washington Consulting Practice, "PwC"). The Environmental Simulation Center and the Orton Family Foundation gathered together other partners to develop the software that eventually became CommunityViz. Coopers and Lybrand's experience in simulation modeling (Koselka 1997; Byrne 1998; Farrell 1998) dovetailed well with the Environmental Simulation Center's work with urban, suburban, and rural communities employing visualization and simulation in the analysis and design of plans, regulations, and policy scenarios (Bressi 1995; Dunlap 1992; Teicholz 1999). These entities were well-suited to help the Foundation realize its vision of building a software suite that would assist rural communities in planning their futures.

Under the direction of the ESC, and with the assistance of Green-Mountain Geographics (the project's GIS consultant), the remaining members of the development team were assembled. These included MultiGen-Paradigm, Inc. (MP) (now a part of Computer Associates), a leader in real time three-dimensional visualization (Chan and Zucker 1999; Delaney 2000) and Fore Site Consulting, Inc., a leader in the creation of GIS-based "spatial spreadsheets" and impact analysis tools (Faber 1997). After the team was assembled, the ESC assumed the role as project director and one of the lead designers of the Orton Family Foundation's CommunityViz planning and decision support system.

COMPONENTS

CommunityViz is a series of modules built on ESRI's ArcView GIS, which was chosen because of its widespread use by the planning agencies in small cities, towns, and rural communities. The system runs on a standalone PC, running Windows NT®, and works with ArcView GIS 3.2 and ArcView® Spatial Analyst 1.1. CommunityViz consists of three modules:

- Scenario Constructor
- TownBuilder 3D
- Policy Simulator

While each module was conceived to be able to function as a standalone extension to ArcView GIS, it was clear from the beginning that the whole was significantly more than the sum of the parts. The vision was always of a fully integrated decision support software that functioned interchangeably in two, three, and four dimensions. The software itself was conceived as a shell that had to be filled with data and information unique to the community and adaptable to the countless ways in which communities might use it. In the following sections, we describe the three major components of CommunityViz, and then explain how they work together as a complete planning support system.

MODULE 1: SCENARIO CONSTRUCTOR

AN OVERVIEW

The Scenario Constructor mediates the integration of ArcView GIS and its extensions, and TownBuilder 3D and Policy Simulator. It permits nontechnical users to interactively create land use scenarios, and evaluate those scenarios against community objectives and constraints. It measures effects, evaluates performance, and performs sensitivity analyses. It is intended to assist small cities, towns, and rural communities in assessing the immediate consequences of alternative land-use proposals in an interactive and visual context. The Scenario Builder also serves as the spatial (two-dimensional GIS) component of CommunityViz. Figure 2 depicts the spatial data exchange and dependencies between Scenario Constructor and the other CommunityViz modules.

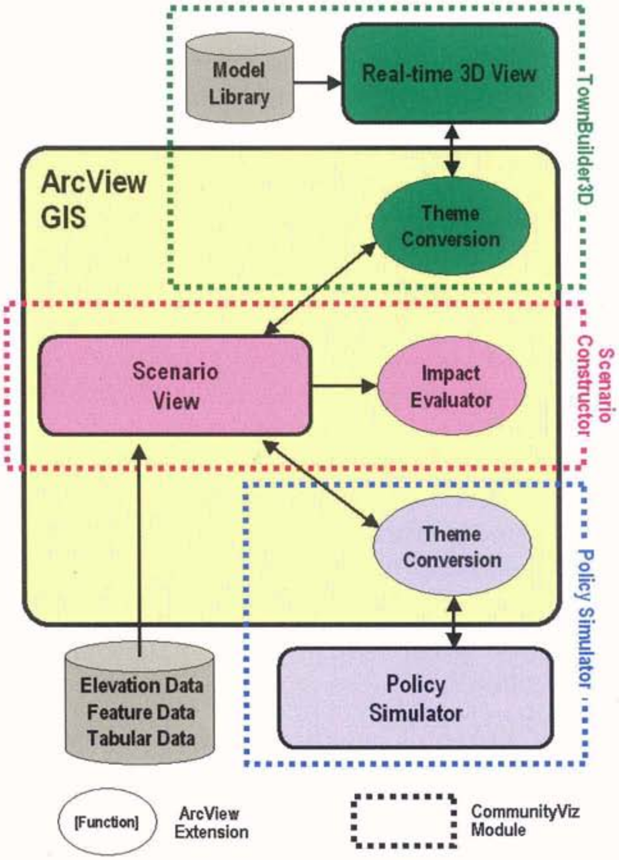

Figure 2. The Structure of CommunityViz. Three modules comprise the structure of CommunityViz. The Scenario Constructor moderates the interaction to ArcView GIS and interacts with both TownBuilder 3D and Policy Simulator.

Scenario Constructor manipulates data and tags contained in a specialized ArcView GIS document referred to as a "Scenario View." In the overall design of CommunityViz, the primary communication mechanism between program modules is spatial data. Scenario Views serve as the clearinghouse and translation center for this data. The Scenario View contains both vector and raster themes. A subset of these themes is designated as "Scenario Themes," which are vector shape themes that can be modified by the user. The Scenario Constructor ArcView GIS extension enables the user to interactively create copy, paste, drag, resize, and edit features or zones within any Scenario Theme.

The impact evaluation component of Scenario Constructor supports defining, evaluating, and tracking the performance of multiple planning alternatives. When other CommunityViz modules, such as the Policy Simulator, simulate alternative future scenarios, a new Scenario View is generated. This allows the impact analysis on any alternative generated within the overall software suite.

The Scenario Constructor evaluates impacts in real time by constantly checking user-defined indicators and benchmarks with the current state of a scenario, as it is edited. A user would set up an indicator by defining a formula that looks for and performs operations on data in the GIS. The results of these formulas are displayed as customizable indicator charts. Each time a feature in the Scenario is added, deleted, or moved, the GIS is updated, the formula is automatically rerun, and the indicator chart updated accordingly. In this manner, the user has constant feedback about actions. Scenario Constructor also allows the user to challenge or change assumptions (i.e., "variables," such as a property tax rate, cost of new construction, etc.) and perform sensitivity analyses at any point. Therefore, very sophisticated "what-if" scenarios can be quickly generated and evaluated on the fly.

FUNCTIONALITY

The Scenario Constructor's functionality also includes interactive exploration of present and proposed landscape scenarios, on-screen feature editing, and automatic calculation of attributes for each new or edited feature. The module dynamically tracks and displays indicator results as land-use proposals are modified, permitting the rapid comparison of alternative scenarios. Figure 3 presents three different indicators—open space, local employment, and school impacts—for a proposed development and as forecast by the Policy Simulator in ten years. The results are displayed in the form of easily understood bar charts. The user sees both the two-dimensional map and the indicators at the same time, permitting the visualization of planning choices on the landscape.

Figure 3. Scenario Constructor Indicators. Using the Scenario Constructor, users can generate easily understandable indicators, benchmarks, and thresholds that are used to evaluate the performance of a policy, plan, or design.

MODULE 2: TOWNBUILDER 3D

AN OVERVIEW

Displaying 2-D data in a 3-D virtual world has become increasingly important as a means to better understand the experience of "place" as information. Since we experience the world dynamically, 3-D data should be viewed in real time, where the user can explore policies, plans, and designs by moving through the world and receiving instantaneous visual feedback.

MultiGen-Paradigm (MP) designed TownBuilder 3D to explore the 3rd dimension, with real-time movement and object manipulation in a photo-realistic model. Using software originally designed for visual simulation for the gaming and defense industries, MP built on the 3-D/GIS concepts developed by the ESC (Dunlap 1995). TownBuilder 3D is capable of representing real places as photo-realistic models. The photorealistic models are created by mapping perspective corrected photographs of the building to a digital wireframe or massing model of the building. Of equal importance, it synchronizes the experiential world and the GIS world, allowing the user to seamlessly and simultaneously shift between the world of numbers and words and the 3-D experiential world; the user is thus able to move anywhere in the 3-D model's virtual world without restraint.

In addition, the landscape can be altered on the fly. Change in the 3-D world will change the GIS database for the scenario. Similarly, any change in the scenario database would be synchronously reflected in the 3-D world. Planning decisions will no longer be abstractions, but rather translatable into actions on objects in the virtual world.

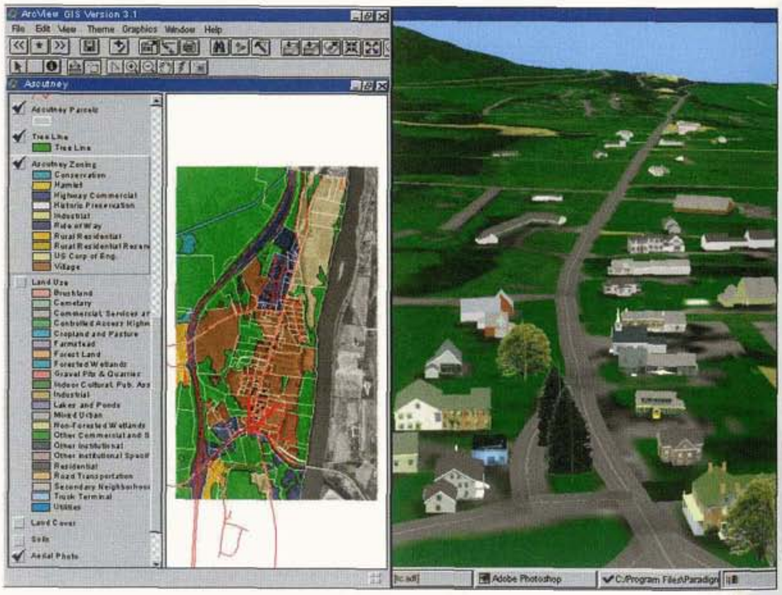

Figure 4. TownBuilder 3D View. TownBuilder 3D allows users both to seamlessly interact with and easily manipulate ArcView GIS and the 3-D view. The red avatar "view cone" locates the position of the viewer.

TownBuilder 3D has two interrelated elements. The first component builds a photo-realistic real-time database (the 3-D model), using the GIS database managed by Scenario Constructor and actual photos from the site. The second component is the runtime system that allows the user to interact with the 3-D real-time model, the GIS database, and Scenario Constructor simultaneously. By coupling TownBuilder 3D with ArcView GIS, the user can visualize proposed changes to a planning area in both 2-D and 3-D. As shown in figure 4, TownBuilder 3D is displayed side by side with Scenario Constructor on the monitor. The user can query both the ArcView GIS database and Scenario Constructor as well as locate herself on the ArcView GIS map with a "view cone" that synchronously moves as the viewer navigates through the 3-D model.

If the user manipulates the 3-D model, the Scenario Constructor module is notified, updates the GIS database, and provides the citizen planner with real-time feedback about consequences and constraints. For example, if an area were zoned for residential use, the system would notify the user that a rule-based constraint has been violated when the user tried to place a commercial building in the zone. The system can draw on the GIS knowledge that exists, enabling a user to receive a real-world visualization of proposed changes, as well as real-world constraints, via a user-determined GIS rule base.

FUNCTIONALITY

TownBuilder 3D has a broad range of automated functions, including creation of the terrain models, texture mapping of orthophotographs, and creation of 3-D models representing buildings, tree canopies, roads, rivers, fences, hedgerows, and other natural and man-made features. These photo-realistic 3-D models of buildings, roads, structures, and landscape elements are stored in and retrieved from the TownBuilder 3D Model Library. This library also stores physical information about each model, such as footprint square footage, total square footage, number of stories, tree types, etc. Cultural attributes, which are not inherent to physical objects, are assigned in the Scenario Constructor Module. For instance, a detached house could either be a residence, a residence with a shop, or professional offices. The power of TownBuilder 3D is its capacity to assemble scenarios using pre-built structures, roads, and landscape features, and its synchronicity with the other modules in CommunityViz.

MODULE 3: POLICY SIMULATOR

AN OVERVIEW

The Policy Simulator module forecasts the probable land use, and demographic and economic changes in a community given alternative governmental and community choices. The Policy Simulator takes input from a user about a course of action (or nonaction) and returns a general prediction of what the future might bring. For example, the user might be interested in predicting what might happen if the town adopted an "Urban Service Boundary." The user would add this policy to the town's existing Policy Set, and the Policy Simulator would provide its prediction of demographic, economic, and land use change over a selected period as part of an ArcView GIS feature theme or table.

The Policy Simulator differs from many other small area demographic and economic forecasting tools in that it utilizes a technique in simulation called "adaptive agent-based modeling" (Holland 1995). The "agents" in this model are not what is now referred to as Web agents, pieces of software code that perform tasks for a computer user. Instead, we are dealing with an "economic agent," an autonomous decision-making entity that has individual goals and preferences, and which interacts with and creates—through its actions—the environment in which it resides. Traditionally, computer models of urban systems have dealt with aggregate data and have been characterized as "top down." National forecasts are allocated to the states, state forecasts to regions, etc. Using equations and statistical analysis, these aggregate projections for a region are then allocated to subregions using an urban allocation model. For example, if the region were a metropolitan area, the allocation model might project population into the future for census tracts within the area (see Putman and Chan or de la Barra in this volume). These allocation models forecast demographic, economic, and land use change for aggregate areas. This kind of modeling leaves little room for interaction. If users wanted to learn how they might change their fate, these models usually cannot provide options. Figure 5 displays some of the differences between an agent based simulation model in planning and a more traditional model (based on a table in Bernard 1999).

TRADITIONAL MODELS	AGENT MODELS
Units of analysis are groups	Units of analysis are individuals
Equation-based formulas	Adaptive agents
Allocative (top-down)	Aggregative (bottom-up)
Deterministic (one future)	Stochastic (multiple futures)
Few parameters	Many parameters
Do not give explanations	Explanatory power
Spatially coarse	Spatially specific
Environment given	Environment created
You can REACT to them	You can LEARN from them

Figure 5. Traditional and Agent-Based Simulation Modeling. Traditional predictive modeling and adaptive agent-based modeling are different in several ways.

In agent-based models, however, the units of analysis (i.e., those units being modeled directly) are the specific individuals or households living in the environment. These agents are the people who live and work in the community being simulated, including residents, business owners, and employers. Policy Simulator models the specific behaviors and interactions of these individual households and persons (e.g., where Mr. Jones shops, where Mrs. Smith works) in the study area. Agents are programmed to make decisions regarding their life autonomously, based upon their own individual characteristics. Each agent has different motivations and values.

Policy Simulator is a stochastic simulation model. The decisions that the agents make are not based on a deterministic model structure. Instead, each possible alternative of a particular decision is weighted in a probability distribution, with a random number generator used to select one of the alternatives in the decision set. There is considerable variability in the behavior of agents from one simulation to the next, even if the agents are in the same perceived situation. This kind of stochastic modeling can lead to situations wherein one small change in one agent's behavior can lead to very large changes in the resulting system. For instance, in one simulation run an agent may decide to purchase a tract of land, while in another simulation run the agent may decide not to purchase the land, even if the exact same choices in exactly the same circumstances confronted the agent. Such a small decision may lead to big changes in the short- and long-term futures of the two simulations. This type of stochastic, agent-based simulation modeling is a main experimental method in the field of complexity theory (Cowan, Pines, and Meltzer 1994).

Policy Simulator's adaptive agent-based modeling incorporates cultural as well as economic values. Each policy simulation is inherently different, reflecting the contingent or existential nature of the world. Contradictions are built into the agent's belief system reinforcing the ability of the agents to learn—that is, to shift their beliefs and the decisions that come out of them. This last point is particularly important. Planning to an agreed degree is based on perceptions (e.g., the point at which an individual believes a loft is not only an industrial workplace, but also a place to live and work). Unlike many traditional equation-based simulation models, agent-based models allow the user to trace back the causes of the decisions and diagnose the decision-making process as well as understand how the agents are modeled. It takes policy forecasting out of the "black box" and makes the process more transparent.

Policy Simulator consists of several interacting submodules that assist in generating input data, calibrating and running the model, displaying the results, and developing policies in the community.

GENERATING INPUT DATA

Policy Simulator requires a great deal of data that may be difficult for communities to acquire. As it is an agent-based model and requires data about specific individuals and households in the community, it is impossible (at least in the U.S.) to acquire this information from the federal census; thus, we developed tools that deal with the issue. Information is also required about the buildings, parcels, and economic entities (businesses) in the community. Such information is available from various sources (assessor's office, Dun and Bradstreet) but again, we attempt to compensate for those communities that do not have complete data sets.

Required spatial data includes zoning, land use, parcels, and building locations. We convert these GIS layers for the user into Policy Simulator-recognized formats. Other required data includes federal, state, and local taxes (income, sales, and property). Finally, we require consumer expenditures by good type, derived from the Consumer Expenditure Survey (Division of Consumer Expenditure Surveys 1994).

Finally, Policy Simulator, and the philosophy behind CommunityViz in general, is to focus on information at a very fine-grained spatial level. Policy Simulator predicts land-use changes at a grid cell size level of anywhere from 1,000 to 25,000 square meters. Forecasting on such a small scale guarantees that the model will not be entirely accurate much of the time. However, our calibration techniques (see below) and our method of displaying results make it possible to present correct general patterns most of the time.

POLICY SIMULATOR COMPONENTS

SIMPREP AND DATA INTEGRITY

SimPrep is a submodule in Policy Simulator that permits users to create a complete set of data for use in a simulation run. One of the major difficulties we anticipated with the Policy Simulator was the fact that communities would not have the requisite data to run the program successfully. In SimPrep, a community enters general information about the demographics and economics of the area from generally available federal census data. SimPrep then generates an appropriate data set. For instance, agent-based models require specific data on individuals in the community (namely, variables such as the age, race, and beliefs). Through surveys conducted by various communities, we analyzed individual responses and gathered data on demographic, economic, and psychographic variables. From these responses, we then constructed an "agent pool" from which SimPrep creates an artificial population for a community; this population matches well with the actual residents who live there. Finally, we have a facility for users to check the integrity and viability of their data sets to see if their data preparation adequately works with the simulation.

CALIBRATION

The calibration program uses a proprietary combination of a genetic algorithm (Mitchell 1996) and simulated annealing (Kirkpatric, Gelatt Jr., and Vecchi 1983) to calibrate the approximately 30 free parameters in the Policy Simulator simulation model. The calibration program tries different combinations of the values of the free parameters, keeps track of those that work well, and gradually moves toward a solution. To work well, the number of forecasted households and jobs (for example) in the community must match with linearly extrapolated historical patterns or predetermined future numbers. In addition, the land-use changes over time can also be calibrated. Since there are many combinations of free parameters, there are many solutions as well. The calibration program notes this, and presents these results to the user.

SIMULATION

The simulation engine itself is the core component of the Policy Simulator. The simulation engine does the actual forecasting of the demographic, economic, and land-use data. To do so, the simulation engine either uses the data the user has prepared manually or has generated with SimPrep. The engine then runs. In a run, agents in the community can do a variety of activities—working, shopping, moving, buying and selling land and buildings, visiting the community, and so on. Businesses can open and close, raise and lower prices in their stores, hire and fire employees, and so forth.

Agent activities are guided by individual characteristics. An agent with minimal education is unlikely to work at a white-collar job making a large salary. Businesses hire agents who have skills that match the jobs that they need done. When a business closes, agents are fired and must seek employment elsewhere. When agents shop, they use a function that balances distance, price sensitivity, and need for particular goods (as determined by typical expenditures). They spend their available income to satisfy the needs they have.

Agents also have the ability to move into, out of, and within the community. Agents typically only move within the community if their household gets too large for their current dwelling. Agents move into or out of the community based on several factors, the most salient being whether they get a job or lose a job. In addition, agents constantly assess the quality of life in the community, and if they believe it has gone down, they have a greater chance of moving out. Conversely, if an agent living outside of the simulated community assesses the quality of life to be improving, that agent might consider moving into the town.

A simulation consists of specifying the number of months in the run, the data sets to be used, the current best set of calibrated parameters, a set of policies, and a random number seed. The simulation engine runs iteratively, with each iteration simulating one month. The user can view the output in ArcView GIS at the conclusion of the simulation.

DISPLAYING THE OUTPUT

Policy Simulator exports its output to ArcView GIS. Much of the information consists of tables of information (new buildings, population changes, etc.). In addition, several types of spatial information are also available (maps of new buildings, land value, etc.). Policy Simulator can also create "splat" themes, thematic probability distribution maps where the variable mapped (new development, for instance) is represented by different color intensities. These splat maps convey the uncertainty behind the Policy Simulator's forecasts, while still presenting useful information. Figure 6 shows an example of splat themes.

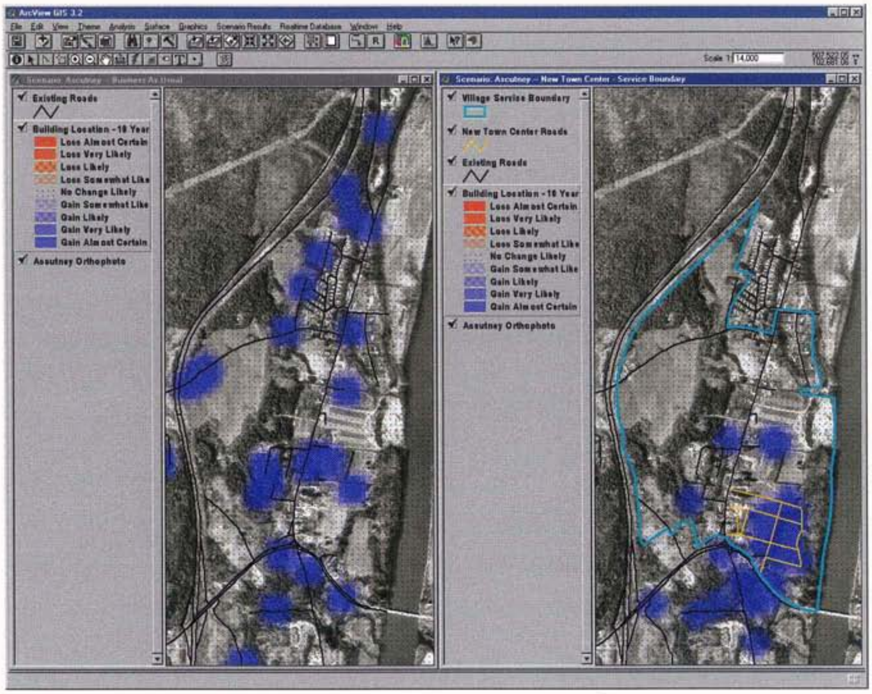

Figure 6. Policy Simulator Splat Themes: Policy Simulator produces themes that display spatial probabilities of change through its splat themes.

Early users of Policy Simulator indicated that they wanted greater access to the decisions and motivations of agents in the simulation, spurring development of the Agent Viewer and Polling Module. In this module, users have the ability to look at the timelines of major decisions and events in each agent's life. Users can also group agents by a variety of characteristics to better understand the simulation process and results.

DEVELOPING POLICIES

The Policy Construction Template (PCT) submodule is used for creating the policy sets used in the simulation runs. Policy sets are groups of various local policies that the user may want to "try out" as alternatives to the "no change" policy set (i.e., business as usual). A user can explore a range of public policy options designed to capture, as closely as possible, the type of planning alternatives available to local decision makers. The PCT Module provides templates for approximately sixteen policy options through which users can create customized local alternatives. These sixteen types of policies were organized into three major categories:

- Tax incentive ordinances
- Site alteration and land-use ordinances
- Municipal budgeting options for construction, leasing, and demolition

The policy templates assist users in readily identifying relevant information requirements and in understanding the data interactions driving the simulation. In addition, the structure of the templates gives decision makers flexibility in designing and implementing the various policy options. Figure 7 shows the specific policy options for tax-related policies.

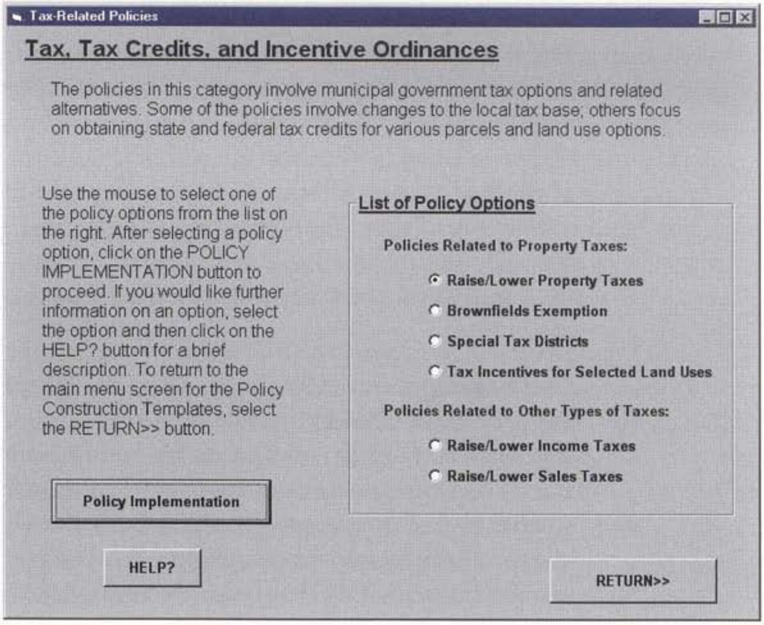

Figure 7. Policy Simulator Tax Policies: Users can try out various land-use and economic policies in Policy Simulator and see how those changes might affect the results of simulation runs.

Many of the policy options represented in the PCT Module include a distinct spatial component. For example, several of the tax-related policy options require the user to specify certain buildings or parcels of land within the municipal landscape to which to apply the tax credit or rate change. Other policy options, such as constructing new roads or determining a service boundary area, require the user to modify the local landscape by drawing or choosing new feature elements for the relevant data layers. Once the spatial extent of the policy option has been decided, the PCT Module allows the user to customize the details of how the policy should be applied. For instance, if the policy option involves a tax credit or rate reduction, the user would be asked to enter the dollar amount or percentage calculation of the credit. The PCT Module takes all the information generated by the user and integrates it with the larger simulation process of the Policy Simulator simulation engine.

POTENTIAL CONCERNS IN USING THE POLICY SIMULATOR

There are several concerns that might be raised regarding the Policy Simulator. Of foremost concern is the "hypercomprehensiveness" argument (Lee 1973). With all the data sets required, the Policy Simulator is a comprehensive model. Yet, it does not succumb to some of the issues that surrounded other comprehensive models, such as the one developed by Forrester (1969). First, Policy Simulator is spatially disaggregated. Furthermore, users can calibrate it so that aggregate data from their community matches Policy Simulator's predictions.

Another concern is the openness of the system that we are modeling. Forrester (1969) modeled a completely closed system. The city was self-contained and had no interactions with the outside world. The Policy Simulator, on the other hand, does model the outside world. In one community using the model there were 700 residents and workers inside the simulated area and 1,900 outside. Policy Simulator modeled the lifecycles of all 2,600 agents in the model. When agents live outside the town, however, we do not explore many individual behavioral patterns. Instead, we assume that agents outside of the simulated area will not change too much (except for their life cycle changes—aging, marriage, childbirth, death, educational changes, and some shopping inside the simulated area). We are trying to maintain a balance between a completely closed system, which is unrealistic but easier to model, and a completely open system where we would have to model everything.

The third major concern is the plethora of free parameters in the Policy Simulator. This is a general problem with many agent-based models. Our calibration routines better match the results of the simulations with broader aggregate measures, but we do realize that you can get from A to B on many different paths.

The fourth major concern is the wealth of data required for the Policy Simulator to function. We have partially addressed this problem by providing intelligently generated data using SimPrep, but we heed the old adage—garbage in, garbage out. Nevertheless, we are confident that with the increase of enterprise GIS systems, better remote sensing data for building identification, and other advances, these data problems will eventually be overcome.

APPLYING COMMUNITYVIZ PLANNING SUPPORT SOFTWARE

THE PROCESS OF USING COMMUNITYVIZ

The process of using CommunityViz is neither linear nor hierarchical. The system does not require either a specific entry point or a pre-determined order in which its component modules are used. For example, the user is not required to enter at the macro-scale of public policy choices and work toward the micro-scale of the design of a neighborhood block. Instead, the system has been designed to encourage the user to simultaneously test and evaluate the implications of a proposal at different scales.

CommunityViz allows users to analyze a proposed development from its policy effects on land use to its impact on neighborhood infrastructure or potential obstruction of view corridors. For example, CommunityViz could be used at a series of community planning and design workshops that would be programmed to address the development pressures that may irrevocably change the character of that community. The objectives of such workshops would be described, and the participants asked questions such as the following: What are the social, economic, cultural, man-made, and natural characteristics that make their community special? What are the issues confronting them? What are their choices? How might they begin to implement those that they agree upon? CommunityViz is designed to help define these considerations and inform the planning and design decision-making process. Like any tool, it depends upon the craftsmen who use it. CommunityViz does not present answers. It helps the users frame the important questions, then provides a comprehensive environment in which users can propose responses, policies, plans, and designs, and see possible future results of decisions made today.

In a community meeting the 3-D digital model and ArcView GIS map are projected side by side on the screen, introducing the participants to the tools and information (see figure 4). A moving view cone, outlined in red, locates the viewer on the map while a meeting facilitator navigates through the 3-D model. The 3-D model and GIS contain specific information on the town, its people, and its environment. Census data, infrastructure use and location, zoning, soils, parcels, roads, land use, among others, are all organized and available for use. By visualizing policy alternatives in both two and three dimensions, the workshop participants can better understand how various policies would affect the land and the town and what the impacts of alternative development patterns might be on schools and local infrastructure. The workshop process is open-ended and permits widespread participation.

The implications of a community's existing zoning, land-use, and environmental regulations can be evaluated in CommunityViz. The program translates the words, numbers, maps, and diagrams in these regulations into a 3-D model. Prebuilt buildings from the CommunityViz Model Library can be used to illustrate the type of places that would typically result from the application of a community's existing regulations. Participants can then locate themselves interactively in the 3-D model to better understand both the overall patterns of development and the specific impacts on places.

CommunityViz can also be used to demonstrate the effects of a build-out if current policies, practices, and regulations remained in place for ten to fifteen years, the life span of most regulations. Using the policy construction templates in the Policy Simulator, current tax, land-related, and capital budgeting policies can be combined into a "business as usual" policy set and then simulated. Some communities may find that this may irrevocably change their community in ways that are unacceptable. Simulations of the same policy set can be run repeatedly. Because of the stochastic nature of agent-based forecasting, each simulation will yield different results, showing a range of possible futures (see figure 6 as an example).

Alternative land development policies can also be explored in CommunityViz through different scenarios. The first scenario might be the extension of existing built-up areas. The second might be the creation of a series of discrete interconnected hamlets set among the community's forested areas, working farms, and ranches. The common goal for both growth area scenarios would be to accommodate the anticipated population growth. The boundaries of each growth area scenario would be delineated and checked against the rule-based constraints checking feature of Scenario Constructor. For example, growth areas that reduced habitat areas to unworkable sizes would be highlighted simultaneously in the model and on the map.

The next step would be to evaluate the capacity of the newly developed areas outlined in the two scenarios to accommodate the anticipated growth. Working simultaneously in the 3-D model and map, the workshop participants select parcelization grids (e.g., acre, 1 acre, etc.) that roughly estimate the land areas developed in the two scenarios. In 2-D the participants see a map that delineates the proposed growth areas with the parcelization grid and building footprints. More impressively, participants see the parcels and buildings in 3-D on the landscape. Almost instantaneously, virgin land is populated with buildings, vacant lots in town are infilled, underdeveloped areas filled with new development, and impacts assessed. See figure 8.

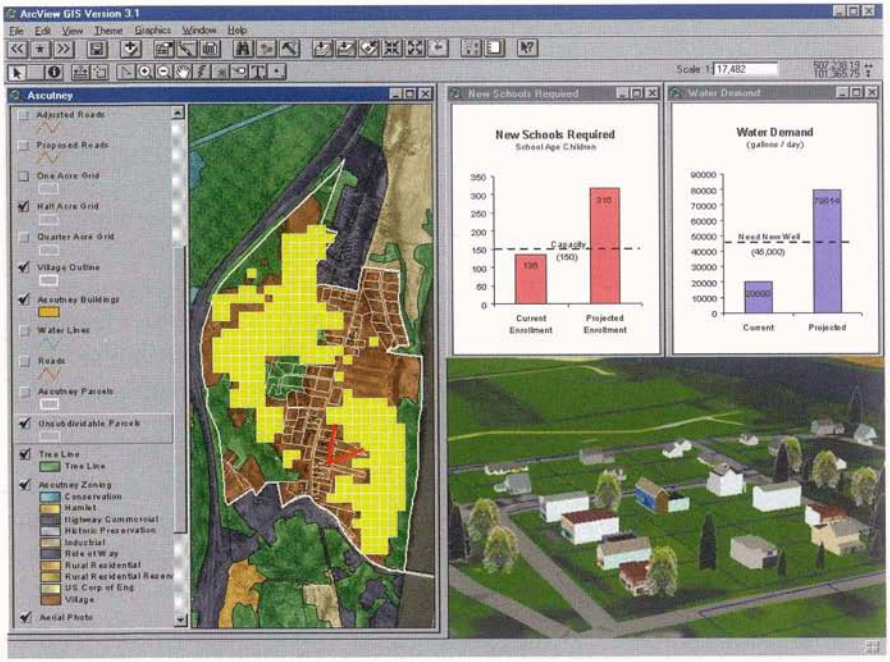

Figure 8. Half-Acre Scenario. Users have created a half-acre scenario and new town center that is displayed in both the 2-D and 3-D environments, as well as having its impacts assessed.

This example demonstrates that CommunityViz can be used to both visualize and quantify abstract policy and planning issues. Citizen planners can see that the form development takes is as important as the aggregate numbers. These digital tools open new possibilities for the fostering of community consensus and decision making, and the design of innovative-use regulations and other regulatory structures. The CommunityViz planning support system represents an opportunity to move from static regulation to management, creating a participatory structure that learns and adjusts regulations over time in response to events and experience (Kwartler 1993; Kwartler 1998).

FUTURE DEVELOPMENTS OF COMMUNITYVIZ

In the first release of TownBuilder 3D, the Model Library consists only of completed buildings. It is envisioned that subsequent versions of TownBuilder 3D will come with a "Kit-of-Parts" that communities could use to create a hypothetical set of buildings that are place-based (Moed 1994; Carlton, Kwartler, and Morgan 1996). The Kit-of-Parts would be like smart LEGO® bricks, architectonic geometric solids and planes that could be fashioned into buildings that reflect the patterns and conventions unique to the community. As a 3-D model of a building is assembled from component parts, the Model Library would update the physical attributes of the model on the fly. For instance, if an addition were added to a house, the Model Library would calculate the total square footage of the house and the result would be instantaneously passed to the corresponding record in the appropriate Scenario Theme. Cultural attributes could also be assigned to the component parts of a model, allowing sophisticated planning and design analyses in support of techniques such as mixed-use and "vertical" zoning.

In later versions of CommunityViz we expect that the Policy Simulator will be better able to deal with issues more typically found in urban communities. For instance, in the current version, the handling of zoning is rather basic. We anticipate that more comprehensive and complicated land-use regulations (density, complex mixed uses, etc.) will be available to the user. In addition, we anticipate that we will have many more policies from which the user can choose, policies that deal with crime, homelessness, storm water, and so on. Finally, the Policy Simulator will incorporate a more complete transportation model, perhaps including integration with other agent-based models such as TRANSIMS (Nagel, Beckman, and Barrett 1998).

We anticipate that CommunityViz will be updated to ArcView 8, to take full advantage of its object-oriented architecture. To make it easier for citizen planners to use CommunityViz, future releases will likely incorporate wizards that will walk the use through setup and integrated application of CommunityViz's three modules.

ACKNOWLEDGEMENTS

This paper was completed with the generous help of Paul H. Patnode of the Environmental Simulation Center. CommunityViz represents the work of many people and many organizations, including the Orton Family Foundation (Bill Shouldice, Noel Fritzinger, Lyman Orton, Andy Bush, Helen Whyte, Towny Anderson), the Environmental

Simulation Center (Paul Patnode, Roy Chan, Elke Solomon), Green Mountain GeoGraphics (Gary Smith), PricewaterhouseCoopers and its subcontractors (George Janes (PwC), Win Farrell (PwC), John Rannenberg (PwC), Holly Morehouse, Joe Oh, Nick Taylor, Paul Carmouche, Peter Duval), Fore Site Consulting (Brenda Faber, Jim Faber), MultiGen-Paradigm, (Jon Zucker, Steve Hanning, Dan Brockway, Gordon Tomlinson, Jay Kidd), Nina Seaman, as well as many other developers, beta testers, coordinators, trainers, and support staff, without whom this project would not be complete.

CURRENT STATUS

At the time this article was written, CommunityViz had been tested with eight communities, and it will be by at least another 20 in the first six months of 2001. For more information, please see the following Web sites:

- CommunityViz (www.CommunityViz.com)
- Orton Family Foundation (www.orton.org)
- Environmental Simulation Center (www.simcenter.org)
- PricewaterhouseCoopers (www.policysimulator.com and www.pwcglobal.com)
- MultiGen-Paradigm (www.multigen.com)

Note: Articles may refer to the working names for CommunityViz, Community Works, and Community Planning Simulation Project.

REFERENCES

Bernard, Robert N. 1999. Using Adaptive Agent-based Simulation Models to Assist Planners in Policy Development: The Case of Rent Control. Working paper 99-07-052E. Santa Fe, NM: Santa Fe Institute.

Bressi, Todd. 1995. The Real Thing: We're Getting There. *Planning* (July):16–20.

Byrne, John A. 1998. Virtual Management. *Business Week*, September 21:80–82.

Carlton, John, M. Kwartler, and L. Morgan. 1996. New York, New Jersey Highlands Demonstration Planning Project: Balancing Economic Development and Environmental Conservation Priorities in Rural and Exurban Communities. New York, NY: Regional Plan Association.

Chan, Roy, and J. Zucker. 1999. Urban Planning Simulation. *The Military Engineer*, 92:603.

Cowan, George A., D. Pines, and D. Meltzer, eds. 1994. *Complexity: Metaphors, Models, and Reality*. Reading, MA: Addison–Wesley.

de la Barra, Tomas. 2001. Integrated Land Use and Transport Modeling: The Tranus Experience. *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools,* ed. Richard Brail and Richard Klosterman. Redlands, CA: ESRI Press.

Division of Consumer Expenditure Surveys. 1994. Consumer Expenditure Survey. Washington, D.C.: Bureau of Labor Statistics.

Delaney, Ben. 2000. Visualization in Urban Planning: They Didn't Build LA in a Day. *IEEE Computer Graphics and Applications* (May/June).

Dunlap, David. 1995. Bringing Downtown Back Up. *New York Times* (October 15):1.

Dunlap, David. 1992. Impact of Zoning is Pretested on Computers. *New York Times* (June 14):1, 11.

Faber, Brenda. 1997. Active Response GIS: An Architecture for Interactive Resource Modeling. *Proceedings of the GIS '97 Annual Symposium on Geographic Information Systems.* Vancouver.

Farrell, Winslow. 1998. *How Hits Happen.* New York: Harper Collins.

Forrester, Jay. 1969. *Urban Dynamics.* Cambridge, MA: MIT Press.

Holland, John H. 1995. *Hidden Order.* Reading, MA: Addison–Wesley.

Kirkpatric, S., C. D. Gelatt Jr., and M. P. Vecchi. 1983. Optimization by Simulated Annealing. *Science,* 20:671–80.

Koselka, Rita. 1997. Playing the Game of Life. *Forbes* 159 (7):100–7.

Kwartler, Michael. 1993. Planning and Zoning for a Mature City. *Planning and Zoning New York City: Yesterday, Today and Tomorrow,* ed. Todd Bressi. New Brunswick, NJ: Center for Urban Policy Research.

Kwartler, Michael. 1998. Regulating the Good You Can't Think of. *Urban Design International 3* (vol. 1 and 2).

Lee, Douglass B., Jr. 1973. Requiem for Large-scale Models. *Journal of the American Institute of Planners,* 39:163–78.

Moed, Andrea. 1994. Mapping the Neighborhood. *Metropolis* (Jan/Feb):60–65.

Mitchell, Melanie. 1996. *An Introduction to Genetic Algorithms.* Cambridge, MA: MIT Press.

Nagel, K., R. J. Beckman, and C. L. Barrett. 1998. TRANSIMS for Transportation Planning. Unclassified Report LA-UR 98–4389. Los Alamos, NM: Los Alamos National Laboratory.

Orton Family Foundation. 2000. www.orton.org

Peterson, Merril, D., ed. 1975. *The Portable Thomas Jefferson,* New York: Viking.

Putman, Stephen H., and S. Chan. 2001. The METROPILUS Planning Support System: Urban Models and GIS. *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools,* ed. Richard Brail and Richard Klosterman. Redlands, CA: ESRI Press.

Teicholz, Nina. 1999. Shaping Cities: Pixels to Bricks. *New York Times* (December 16):G1.