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Guest editorial

An update on planning support systems

This essay and the theme issue it introduces provide an update to a similar theme issue on planning support systems (PSS) that appeared in this journal six years ago (Klosterman, 1999). The three papers here were selected from the ones presented at the Eighth International Conference on Computers in Urban Planning and Urban Management (CUPUM) conference held in Sendai, Japan in 2003, and are being published to coincide with the Ninth CUPUM Conference being held in London in 2005.

Much has happened in the area of PSS in the last six years. Two edited volumes devoted to the topic are now available: Brail and Klosterman's *Planning Support Systems* (2001) and Geertman and Stillwell's *Planning Support Systems in Practice* (2002). A large number of articles devoted to PSS have been published, including a recent paper in this journal (Geertman, 2002), and the topic is now part of many academic and user conferences. PSS are being developed around the world and three reviews of 'land-use change' models which embody such PSS have been published (Agarwal et al 2002; Niemann and Limp, 2004; US EPA, 2000).

More importantly, PSS are being applied—slowly and often painfully—to real planning problems worldwide. A large (if unknowable) number of 'one off' models have been developed and applied by planning academics and professionals the world over. A smaller number of systems have been matured enough that they are available either free or as 'commercial-off-the-shelf" (COTS) packages. Notable examples in the United States include CommunityViz suite (http://www.communityviz.com), SLEUTH (http://www.ncgia.ucsb.edu/projects/gig), INDEX® (http://www.crit.com), UrbanSim (http://www.urbansim.org) and What if?™ (http://www.what-if-pss.com).

PSS techniques and tasks

Much work still needs to be done, of course. The first task, from an intellectual standpoint at least, is that we need a clearer idea of just what PSS are. Several definitions have been proposed in the literature including, in chronological order: (1) the unremembered person who first used the term in 1987 to describe the "constellation of digital techniques (such as GIS) which were emerging to support the planning process" (Batty, 2003, page v; Harris, 1989); (2) Klosterman (1997, page 51), who views PSS as "an *information framework* that integrates the full range of current (and future) information technologies useful for planning" (italics in original); (3) Geertman and Stillwell (2003, page 5) who propose that PSS "involve a wide diversity of geo-technology tools ... that have been developed to support public or private planning processes (or parts thereof) at any defined spatial scale and within any specific planning context"; and (4) most recently, Brail (2005) who defines them as "planning decision support systems [that] have as their purpose either projection to some point in the future or estimation of impacts from some form of development."

It is of course somewhat unproductive to devote too much time to debating *the* definition of PSS. However, it may be useful to begin identifying different types of PSS. This helps not only to structure the development of this diverse set of technologies but also to lay the foundations for assessing the advantages and disadvantages of applying different kinds of tools to different tasks in different contexts.

We can begin by identifying two main groups of PSS: (1) systems dedicated to planners' analytic, forecasting, or design tasks, and (2) systems designed to improve their presentation and/or communication (Geertman and Stillwell, 2003, page 9). The categorization to be developed below will consider thirteen PSS analysis and forecasting tools that are described in the collections prepared by Brail and Klosterman (2001) and Geertman and Stillwell (2003), or have attracted a substantial amount of academic interest.(1) The typology will not consider systems that were designed to facilitate planning communication or were custom developed for a single application.

The models will be categorized by two dimensions: (1) *technique*, the modeling approach that was used to develop the PSS, and (2) *task*, the analytic task which the PSS helps address. The four modeling techniques listed in table 1 by the order in which they were first applied to planning are: (1) large-scale urban models, (2) rule-based models, (3) state-change models, and (4) cellular automata models.

Table 1. Categorization of selected planning support systems.

Technique	Task			
	land-use/land-cover change	comprehensive projection	3D visualization	impact assessment
Large-scale urban	METROPILUS SPARTACUS TRANUS UrbanSim	METROPILUS SPARTACUS TRANUS UrbanSim		
Rule-based	CUF What if? 1.1	What if 2.0	CommunityViz	CommunityViz INDEX® Place^{3}S
State-change	CUF II CURBA			
Cellular automata	SLEUTH DUEM			

Large-scale urban models

Large-scale urban models for assessing the regional impacts of transportation policies on urban growth first attracted planners' attention to computer-based models in the 1960s (Harris 1965).(2) The first three models, METROPILUS, the SPARTACUS system, and TRANUS, are the current versions of mature and widely used large-scale urban models; UrbanSim has been developed in the last ten years. The fact that these models are the most heavily represented tools in our sample reflects the importance of spatial interaction in urban development and the continued appeal of theoretically rich and rigorously tested models for simulating urban development processes.

Rule-based models

Rule-based models first became popular in planning with the publication of Landis's landmark California Urban Futures (CUF) model, the first GIS-based urban development model (Landis, 1994). CUF and other rule-based models do not attempt to duplicate the spatial interaction and market-clearing processes that underlie the large-scale urban models. Instead, they incorporate explicit decision rules which allow model users to specify how the model will behave. Thus, for example, rule-based urban

(1) Information sources for these models, including chapters in these two books and websites is provided in table 2 below.

(2) There are of course many different kinds of large-scale urban models and approaches to urban modeling. Useful reviews are provided by Miller et al (1998), Southworth (1995), and Wegener (1994).

growth models such as CUF and What if? incorporate rules for determining the relative suitability of different locations, projecting future land-use demands, and allocating projected land-use demands to suitable sites. Similarly, rule-based impact assessment models such as CommunityViz, INDEX, and Place^{3}S specify rules determining the impacts that future development patterns will have on transportation facilities, public infrastructure, and the like.

State-change models
State-change models were first used to model urban development patterns in Landis's equally innovative CUF II model (Landis and Zhang, 1998a; 1998b). Like the rule-based models, state-change models project future land-use/land-cover growth without attempting to simulate the demographic and economic processes which cause that growth. Instead, they use information on land uses at two points of time to calibrate a statistical model which relates a set of independent variables to the observed land use changes at each location. Current and projected values for the independent variables are then used to project future land-use changes.

Cellular automata models
Cellular automata (CA) models of urban growth have received a tremendous amount of academic attention in recent years (Batty and Xie, 2005). CA models represent an urban area with a lattice of cells, each of which exists in one of a finite set of states: for example, 'developed' and 'undeveloped'. The progression of time is modeled as a series of discrete steps with future patterns determined by transition rules which specify the behavior of cells over time (for example, whether a cell switches from undeveloped to developed), as a function of conditions at each cell and its neighboring cells at each time step. SLEUTH, which stands for the input requirements of the models—slope, land cover, exclusion, urbanization, transportation, and hillshade—(Clarke et al, 1997), and DUEM, the Dynamic Urban Evolutionary Model (Batty and Xie, 2005; Xie, 1996), represent well-developed examples of this approach.

The second dimension of the table includes four planning tasks: land-use/land-cover change; (2) comprehensive projection, (3) three-dimensional (3D) visualization, and (4) impact assessment.

Land-use/land-cover change
As their name suggests, these models project changes only in an area's land uses or land cover. All of the large-scale urban models, state change, and CA models identified in table 1 can be used to project future land-use patterns, as can the CUF and What if? rule-based models. However, the number of land-use categories which can be projected and the scale at which they can be projected vary substantially for the different types of models.

Comprehensive projection
Comprehensive projection models project not only land-use changes but also other variables of interest such as transportation flows, population, employment, floor space, and environmental impacts. The four large-scale urban models—METROPILUS, SPARTACUS, TRANUS, and UrbanSim—project a large number of impacts; What if? 2.0 projects small area population and employment patterns.

Three-dimensional visualization
A great deal of very innovative work has been done in the area of visualization over the last few years (Batty et al, 2001; Langendorf, 2001; Pettit et al, 2004). Ideally, all PSS would use 3D visualization to convey information on the implications of alternative policy choices to users in a more comprehensible way. Unfortunately, CommunityViz

is the only tool in our sample that incorporates 3D visualization directly. The other PSS require the use of other 3D visualization tools, such as those that are being increasingly incorporated into commercially available GIS packages such as ERDAS's Imagine VirtualGIS and ESRI's 3D Analyst, ArcScene, and ArcGlobe.

Impact assessment

All PSS can be used to assess the impacts of alternative public choices in some way; if they could not do this, it is not clear that they would be PSS. However, the three rule-based models in this category—CommunityViz, INDEX, and Place^{3}S—are unique in dealing primarily with assessing the impacts of public policies, largely at a neighborhood or community scale. That is, they do not include procedures for projecting future conditions; instead, they require the user to specify what the future will be and use clearly defined rules—often incorporated into spreadsheets—to measure and evaluate the impacts that an assumed future state will have on variables of interest.

Table 2 provides a list of resources for the thirteen PSS which have been noted here.

Table 2. Information sources for selected planning support systems.

Model	References	Web-site
CommunityViz	Kwartler and Bernard (2001)	http://www.communityviz.com
CUF, CUF II, and CURBA	Landis (2001)	
DUEM	Xie (1996)	http://igre.emich.edu/
INDEX®	Allen (2001)	http://www.crit.com
METROPILUS	Putman and Shih-Liang (2001)	
Place^{3}S	Snyder (2001)	http://www.energy.ca.gov/places
SLEUTH	Clark et al (1997), Silva and Clarke (2002)	http://www.ncgia.ucsb.edu/projects/gig
SPARTACUS	Lautso (2003)	http://www.fhwa.dot.gov/planning/toolbox/spartacus_overview.htm
TRANUS	de la Barra (2001)	http://www.modelistica.com/
UrbanSim	Waddell (2001)	http://www.urbansim.org
What if?™	Klosterman (2001), Klosterman et al (2003)	http://www.what-if-pss.com

The theme papers

This theme issue provides an introduction to current developments in PSS by describing three systems that were developed or applied in four parts of the world—Europe, North America, Japan, and Australia. The first two papers by Kii and Doi (2005) and by Saarloos and his colleagues (2005) represent the theoretical cutting edge of PSS development—multiagent systems (MAS). The third paper by Pettit (2005) describes the application of a rule-based model in a real policy setting.

As their name suggests, MAS or, agent-based systems, attempt to model the behavior of complex systems by representing the behavior of the various agents that make up the system. Thus, for example, the 'agents' in the CityDev model (Sembolini et al, 2004) represent families, industrial firms, and developers who produce and consume goods and interact via a simulated market. The behavior of each of these agents is modeled, along with their interactions with other agents and with the environment, which together determine future urban development patterns.

A great deal of work has been done in the area of multiagent modeling over the last few years (Parker et al, 2003) and thus the models described in this theme issue are of particular interest. The model developed by Kii and Doi (2005) is interesting because it combines three types of models—an MAS model, a CA model, and a large-scale spatial equilibrium (SE) model. The model is similar to one developed by Webster and Wu (1999) that also combined CA and SE modeling approaches. However, the Webster and Wu model incorporated the profit-maximization behavior of households into the CA transition rules. The model considered here takes the opposite approach in formulating an urban system based on Alonso's bid-rent model and uses a CA/MAS framework to represent the neighborhood effects of interactions among agents within the spatial equilibrium imposed by market equilibrium. The paper describes the model in detail, applies it to a hypothetical city with 50×50 cells, and uses it to evaluate policies for encouraging compact city development for a portion of a real community.

The second paper by Saarloos and his colleagues (2005) is an equally innovative MAS application, of an entirely different type. The majority of multiagent models simulate the behavior of agents within a virtual urban environment in an attempt to model the long-term development of an area and evaluate the effects of enacting different policy alternatives. The MASQUE model described in this paper deals with the plan-development stage of the planning process in which a group of actors collectively develop a land-use plan which specifies legally binding regulations for permissible uses in designated zones of a community. The model simulates a group-decision process by incorporating agents that represent land-use experts who initiate plan proposals and negotiate with other experts to draw up the final plan incrementally. It is particularly interesting in incorporating uncertainty and strategic action as agents negotiate with each other to find mutually acceptable solutions. The model is applied to a hypothetical study area of 100 cells with four agents (a housing agent, a business agent, a green agent, and a services agent) and evaluated by determining the impacts that changes in the agents' behavioral parameters have on the final plan.

The third paper by Pettit (2005), provides a detailed description of the application of What if? 1.1 to Hervey Bay, Australia. The Hervey Bay application is particularly interesting because it introduces social, economic, and environmental concerns into the planning process in a rapidly growing coastal community that includes a World Heritage site. The rule-based model uses GIS and census data for Hervey Bay to conduct three types of analyses: (1) a land-suitability analysis that rank orders different locations with respect to their suitability for different land uses; (2) a demand component that projects the future demand for each use; and (3) an allocation component that allocates the projected demand to different locations on the basis of their suitability for each use and user-defined land-use controls and growth patterns. Pettit provides a thorough description of the model and its application in Hervey Bay, evaluates the model, and makes suggestions for improving it.

The future of PSS

These papers suggest that the future of PSS as research tools is bright indeed. Computers continue to become larger, faster, and cheaper, and high-quality spatially related data are becoming increasingly available. Software development tools are becoming steadily more sophisticated and easier to use. The Internet allows planners around the world easily to obtain up-to-date information about different PSS (and in some cases the tools themselves). Perhaps more importantly, a new generation of academic planners has entered the stage who are comfortable with computers, undaunted by the difficulties of the past, and eager to take on the challenge of developing new computer-based tools to support planning.

The future role of PSS in professional planning practice is less clear. As Brail (2005) suggests, the largely successful history of urban transportation modeling systems in the United States suggests that three factors are required for computer-based tools to be widely used in practice: a shared commitment to a well-defined methodology, extensive government support, and the ability of available tools to provide needed outputs for a substantial user community. None of these conditions exists for PSS anywhere in the world today.

Furthermore, a recent survey of PSS experts (Vonk et al, 2005) identifies other obstacles to the widespread use of PSS in professional practice. Planning practitioners have a low awareness of PSS and their potential, limited experience with these systems, and little interest in using them. The limited use of PSS deprives the field of the practical experience needed to improve the current generation of PSS tools and limits the ability of PSS developers to market and improve their systems. Their limited marketing and development efforts lead in turn to a continued limited awareness and use of PSS by practitioners. Until this vicious cycle is broken, PSS will never reach their potential for improving planning practice. Fortunately, government agencies such as the Queensland State Government in Australia are making significant financial commitments in developing and applying PSS technologies, and interest in PSS among planners, community groups, and public officials continues to grow.

On the fortieth anniversary of Britton Harris's landmark special issue on urban models (Harris, 1965), the dream of using computer-based tools to support planning has proven to be much more difficult to achieve than he—or we—imagined. However, many valuable lessons have been learned and the use of computers to support planning has clearly come a long way since the 1960s. We continue to be optimistic that the further development of truly *collaborative* PSS tools that can be adapted to a wide range of planning problems will lead to their widespread adoption by planners, community groups, and decisionmakers.

Richard E Klosterman, University of Akron
Christopher J Pettit, Royal Melbourne Institute of Technology, Australia

References

Agarwal C, Green G M, Grove J M, Evans T P, Schweik C M, 2002, "A review and assessment of land-use change models: dynamics of space, time, and human choice", TR NE-297, US Department of Agriculture, Forest Service, Northeast Research Station, Newton Square, PA

Allen E, 2001, "INDEX: software for community indicators", in *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools,* Eds R K Brail, R E Klosterman (ESRI Press, Redlands, CA) pp 229 – 262

Batty M, 2003, "Planning support systems: techniques that are driving planning", in *Planning Support Systems in Practice* Eds S Geertman, J Stillwell (Springer, Heidelberg), pp v – viii

Batty M, Xie Y, 2005, "Urban growth using cellular automata", in *GIS, Spatial Analysis and Modeling* Eds D Macguire, M Batty, M Goodchild (ESRI Press, Redlands ,CA) in press

Batty M, Chapman D, Evans S, Haklay M, Kueppers S, Shiode N, Smith A, Torrens P M, 2001, "Visualizing the city: communicating urban design to planners and decision makers", in *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools* Eds R K Brail, R E Klosterman (ESRI Press, Redlands, CA) pp 405 – 443

Brail R K, 2005, "Planning support systems evolving: when the rubber hits the road", in *Complex Artificial Environments* Ed. J Portugali (Springer, New York) in press

Brail R K, Klosterman RE (Eds), 2001 *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools* (ESRI Press, Redlands, CA)

Clarke K C, Hoppen S, Gaydos L, 1997, "A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area" *Environment and Planning B: Planning and Design* **24** 247 – 261

de la Barra T, 2001, "Integrated land use and transport modeling: the TRANUS experience", in *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools* Eds R K Brail, R E Klosterman (ESRI Press, Redlands, CA) pp 129 – 156
Geertman S, 2002, "Participatory planning and GIS: a PSS to bridge the gap" *Environment and Planning B: Planning and Design* 29 21 – 35
Geertman S, Stillwell J (Eds), 2003 *Planning Support Systems in Practice* (Springer, Heidelberg)
Harris B (Ed.), 1965, "Urban development models: new tools for planning" *Journal of the American Institute of Planners* **31** 90 – 183
Harris B, 1989, "Beyond geographic information systems: computers and the planning professional" *Journal of the American Planning Association* **55** 85 – 92
Kii M, Doi K, 2005, "Multiagent land-use and transport model for the policy evaluation of a compact city" *Environment and Planning B: Planning and Design* **32** 485 – 504
Klosterman R E, 1997, "Planning support systems: a new perspective on computer-aided planning" *Journal of Planning Education and Research* **17** 45 – 54
Klosterman R E (Ed.), 1999, "Theme issue: New perspectives on planning support systems" *Environment and Planning B: Planning and Design* **26** 317 – 408
Klosterman R E, 2001, "The What if? planning support system", in *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools,* Eds R K Brail, R E Klosterman (ESRI Press, Redlands, CA) pp 263 – 284
Klosterman R E, Siebert L, Hoque M A, Kim J W, Parveen A, 2003, "Using an operational planning support system to evaluate farmland preservation policies", in *Planning Support Systems in Practice* Eds S Geertman, J Stillwell (Springer, Heidelberg) pp 391 – 407
Kwartler M, Bernard R N, 2001, "CommunityViz: an integrated planning support system", in *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools* Eds R K Brail, R E Klosterman (ESRI Press, Redlands, CA) pp 285 – 308
Landis J, 1994, "The California Urban Futures Model: a new generation of metropolitan simulation models" *Environment and Planning B: Planning and Design* **21** 399 – 420
Landis J, 2001, "CUF, CUF II, and CURBA: a family of spatially explicit urban growth and land-use policy simulation models", in *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools* Eds R K Brail, R E Klosterman, (ESRI Press, Redlands, CA) pp 157 – 200
Landis J, Zhang M, 1998a, "The second generation of the California urban futures model. Part 1: Model logic and theory" *Environment and Planning B: Planning and Design* **25** 657 – 666
Landis J, Zhang M, 1998b, "The second generation of the California urban futures model. Part 2: Specification and calibration results of the land-use change" *Environment and Planning B: Planning and Design* **25** 795 – 824
Langendorf R, 2001, "Computer-aided visualization: possibilities for urban design, planning, and management", in *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools* Eds R K Brail, R E Klosterman (ESRI Press, Redlands, CA) pp 309 – 359
Lautso K, 2003, "The SPARTACUS system for defining and analyzing sustainable land use and transport policies", in *Planning Support Systems in Practice* Eds S Geertman, J Stillwell, (Springer, Heidelberg) pp 453 – 463
Miller E J, Kriger D S, Hunt J D, 1998, "Integrated urban models for simulation of transit and land use policies", final project report to TCRP Project H-12, Joint Program on Transportation, University of Toronto, Toronto
Niemann B, Limp F, 2004, "Evaluation of community decision support software", National Consortium for Rural Geospatial Innovations in America, University of Wisconsin – Madison
Parker D C, Manson S M, Janssen M A, Hoffman M J, Deadman P, 2003, "Multi-agent systems for the simulation of land-use and land-cover change: a review" *Annals of the Association of American Geographers* **93** 314-337
Pettit C J, 2005, "Use of a collaborative GIS-based planning-support system to assist in formulating a sustainable-development scenario for Hervey Bay, Australia" *Environment and Planning B: Planning and Design* **32** 523 – 545
Pettit C, Nelson A, Cartwright W, 2004, "Using on-line geographical visualisation tools to improve land use decision-making with a bottom-up community participatory approach", in *Recent Advances in Design and Decision Support Systems in Architecture and Urban Planning* Eds J Leeuwen, H Timmermans (Kluwer, Dordrecht) pp 53 – 68

Putman S H, Shih-Liang C, 2001, "The METROPILUS planning support system: urban models and GIS", in *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools* Eds R K Brail, R E Klosterman (ESRI Press, Redlands, CA) pp 99 – 128

Saarloos D, Arentze T, Borgers A, Timmermans H, 2005, "A multiagent model for alternative plan generation" *Environment and Planning B: Planning and Design* **32** 505 – 522

Sembolini, F, Assfalg A, Armeni S, Gianassi R, Marsoni F, 2004, "CityDev, an interactive multi-agents urban model on the web" *Computers, Environment and Urban Systems* **28** 45 – 64

Silva E A, Clarke K C, 2002, "Calibration of the SLEUTH urban growth model for Lisbon and Porto, Portugal" *Computers, Environment and Urban Systems* **26** 525 – 552

Snyder K, 2001, "Tools for community design and decision-making", in *Planning Support Systems in Practice* Eds S Geertman, J Stillwell (Springer, Heidelberg) pp 99 – 120

Southworth F, 1995, "A technical review of urban land use-transport models as tools for evaluating vehicle travel reduction strategies", ONLL-6881, Oak Ridge National Laboratory, Oak Ridge TN

US EPA, 2000, "Projecting land-use change: a summary of models for assessing the effects of community growth and change on land-use patterns", EPA/600/R-00/098, US Environmental Protection Agency, Office of Research and Development, Cincinnati, OH

Vonk G, Geertman S, Schot P, 2005, "Bottlenecks blocking widespread usage of planning support systems" *Environment and Planning A* **37** 909 – 924

Waddell P, 2005, "Between politics and planning: UrbanSim as a decision-support system for metropolitan planning", in *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools* Eds R K Brail, R E Klosterman (ESRI Press, Redlands, CA) pp 201 – 228

Webster C J, Wu F, 1999, "Regulation, land-use mix, and urban performance, Part 1: theory" *Environment and Planning A* **31** 1433 – 1442

Wegener M, 1994, "Operational urban models: state of the art" *Journal of the American Planning Association* **60** 17 – 30

Xie, Y, 1996, "A generalized model for cellular urban dynamics" *Geographical Analysis* **284** 350 – 373