The Revival of Urban Modeling

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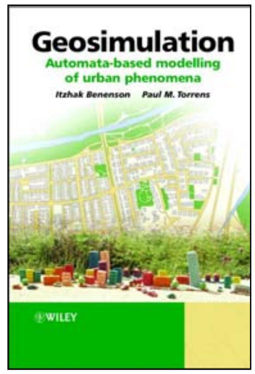


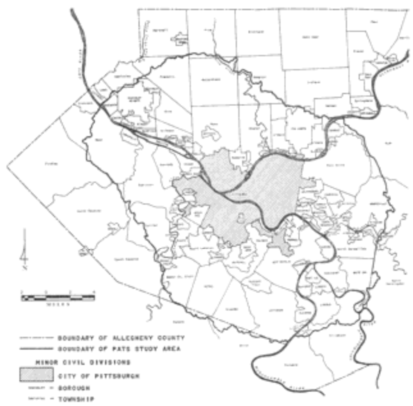
The Golden Age

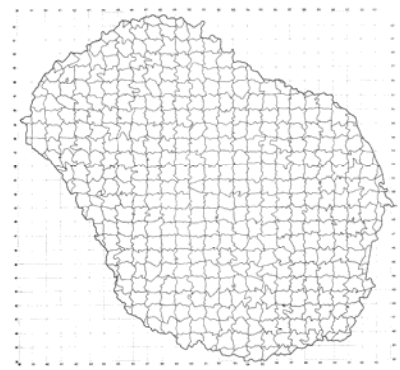
1960s-1970s

Ira Lowry, 1964 – Pittsburg, gravitation model

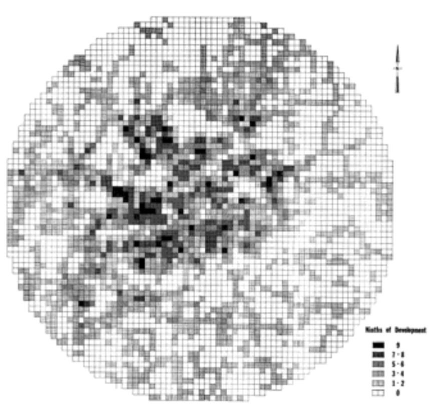
$$T_{ij} \sim 1/(a + bd + cd^2)$$

• a basic sector, including industrial, business, and administrative activities, whose clients are mostly non-local;
• a retail sector, dealing with the local population;
• a householder sector.

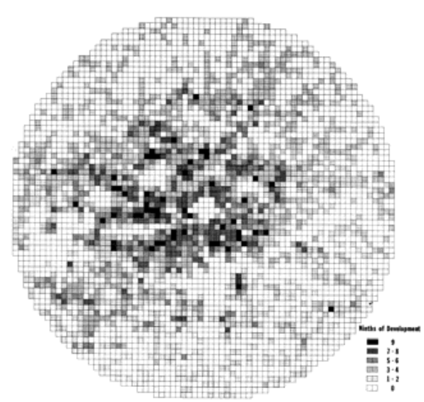




F. Chapin, Weiss, Donnelly, 1962 - 1968, Greensboro, 300x300 m units, probabilistic model, based of *potential* for development as a linear function of few easily estimated variables, initial conditions – 1948, median run is compared to 1960.

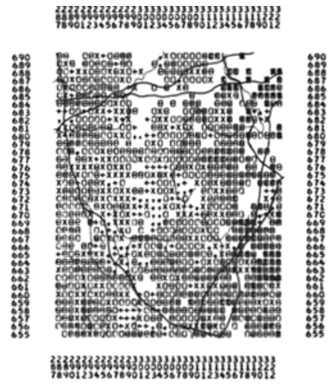


LAND IN RESIDENTIAL USE, GREENSBORO, NORTH CAROLINA, 1960



EXPECTED RESIDENTIAL LAND USE, GREENSBORO, NORTH CAROLINA, 1960
BASED ON USE OF PROBABILISTIC MODEL – MEDIAN OUTCOME OF 50 RUNS

Steinitz and Rogers, 1974, Boston, many factors, intentionally simple linear expression of potential for development on the base of existing maps of land-uses, topography, transport network, etc.



Attractiveness for high-cost housing.

$y = 3.62 - .82x_1 - 1.77x_2 + 1.88x_3 + .14x_4 + 2.58x_5$

where

y = attractiveness for high-income housing

3.62 = intercept

x_1 = access to limited access highway

x_2 = access to Route 128

x_3 = distance to elementary school

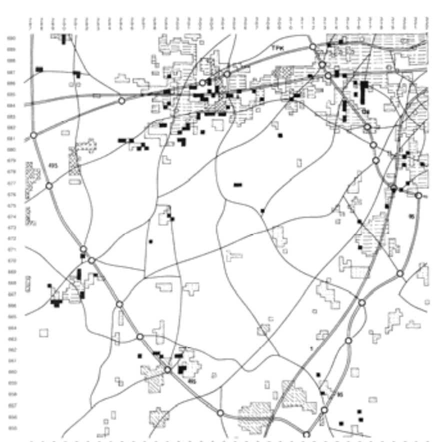
x_4 = visual quality

x_5 = percentage of area well drained

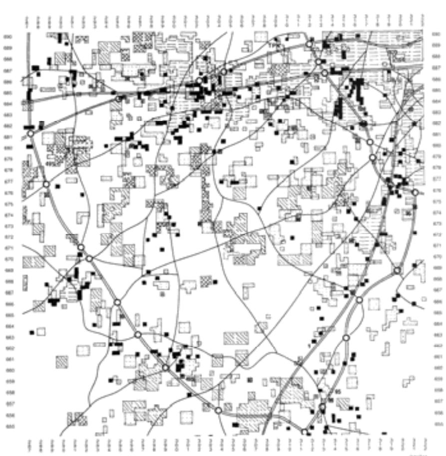
. 0 = lowest attractiveness

■ 9 = highest attractiveness

Steinitz and Rogers, 1974, Boston, many factors, intentionally simple linear expression of potential for development on the base of existing maps of land-uses, topography, transport network, etc.



Initial conditions of 1974



2000, Current development tendencies

Urban models of 1960s

•**Focus on the allocation of externally defined development quote**.

• Separation between cells' potential and locations where change does occur.

• Two-level hierarchy of urban space.

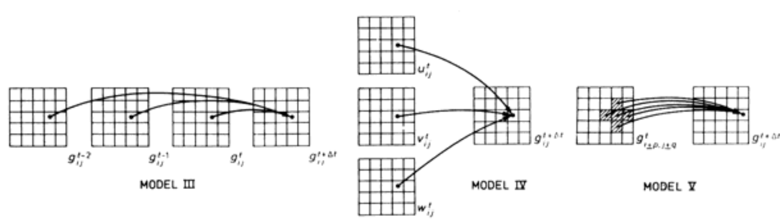
• Separation of the factors of land-use change into endogenous, determined by land unit properties and location, and exogenous, controlled by public authorities.

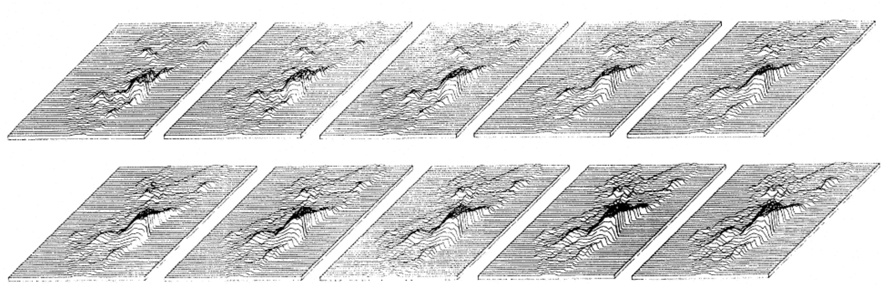
• Investigation of the variance of model results.

• Comparison of the actual pattern with a median, and not the best fit, outcome.

W. Tobler, 1970 (1979) Urban Cellular Automata

$$\sum p \in[-2, 2], q \in [-2, 2], p + q \leq 2w_{pq}P_{i+p,j+q}(t) \qquad w_{pq} = a_{pq} + b_{pq}\Delta t,$$



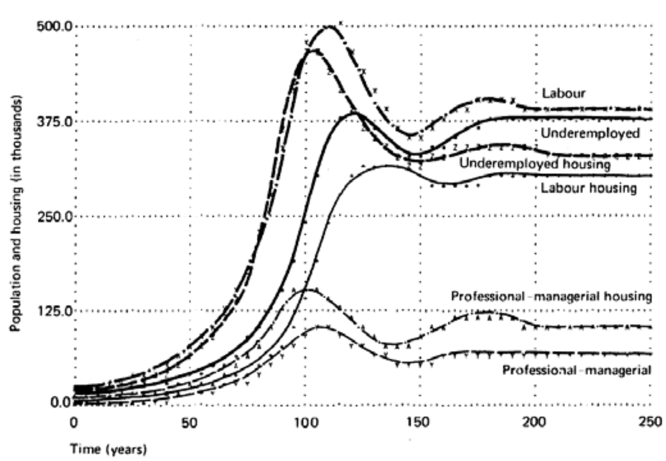


Dark Age

1970s – 1980s

Forrester (1969), Wilson (1970+), many others:

(Commonsensical) System Dynamics, The Hope of Robustness and The Hope of Order Parameters



Lee, 1973, *Requiem for Large-Scale Models*

Seven Sins of Large-Scale Models:

• Hypercomprehensiveness (attempt to explain too much with too many constraints and relationships)

• Grossness (reliance on aggregate input)

• Mechanicalness (narrow language of computation)

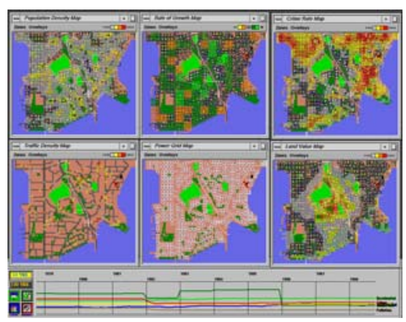
• Expensiveness (high price of data and parameter estimates)

• Hungriness (tremendous data requirements)

• Tuningness (tautological tuning the model until outputs conform to 'reasonable' expectations)

• Complicatedness (inability of the modelers to adequately understand their own creatures)

Nowadays Forrester considers comprehensive models as learning and not a predictive tool. SimCity and Sims seem the best implementations



Are urban systems just the same as chemical ones?

The general agreement is that the answer is NO

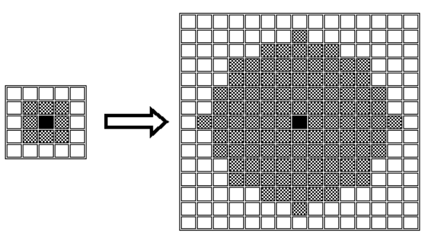
- Distant action and immediate spread of the disturbance
- Fast components (humans) can influence slow ones (infrastructure)
- Laws of unit's changes and interactions are approximations of empirical data, not the laws of nature

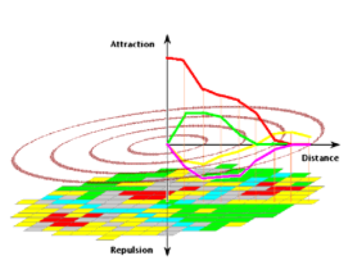
Renaissance

1990s - 2000s

Cellular Automata

Constrained Cellular Automata (Turner, 1988; White & Engelen, 1994, 1997).
White & Engelen, 1997, Cincinnati, 1966 on the base of 1840





Larger neighborhood

Non-monotonous weight(d)

White & Engelen, 1997, Constrained Cellular Automata – Allocation of development quote again! Cincinnati, forecast of 1966 on the base of **1840**

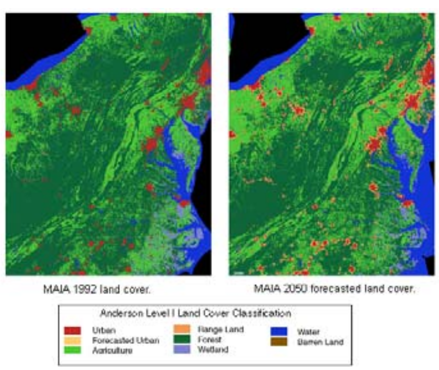
Stage 1: The potentials $p_{c,i}$ of transition from the current state into S_i, i = 1; . . . ; N, are estimated for each cell.

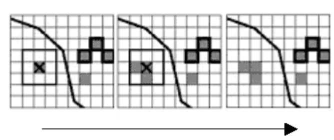
Stage 2: For each cell, obtained potentials are sorted in decreasing order.

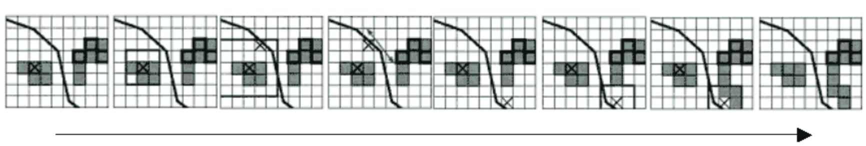
Stage 3: An externally defined amount ni of land that must be in Si use is distributed over the cells c, for which the potential $p_{c;i}$ is the highest.

Cincinnati, 1966, Model 1966 Model 1996, networks

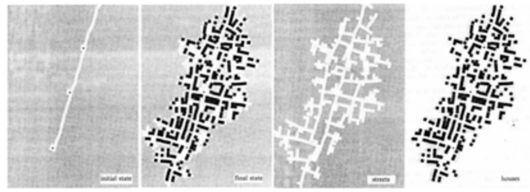
Spread of urban patters (Deltatrons) Clarke, 1997

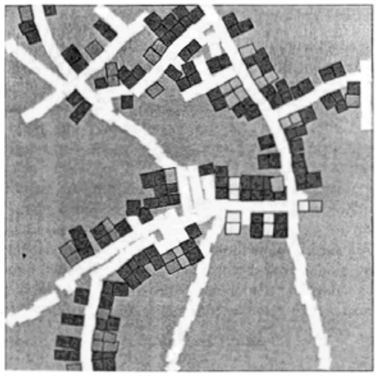


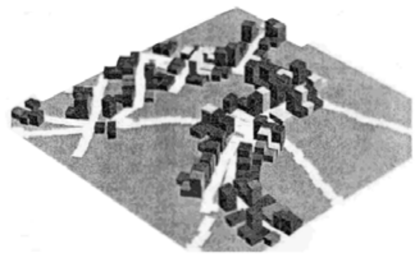




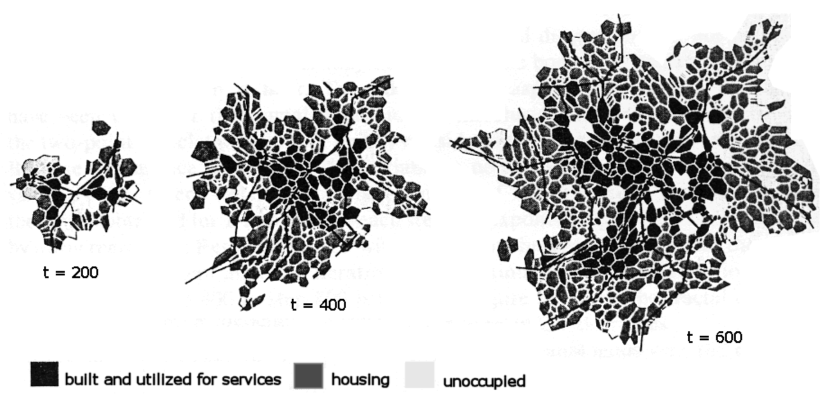
Why cells, actually? (Erickson and Lloyd-Jones, 1997).



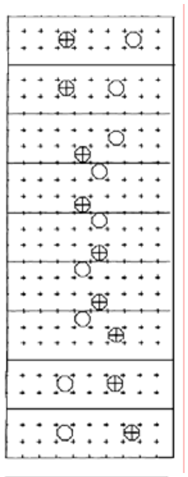


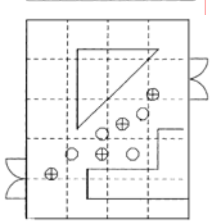


Cells can also change! (Simboloni, 2000)



Multi-Agent Systems



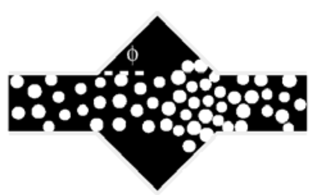


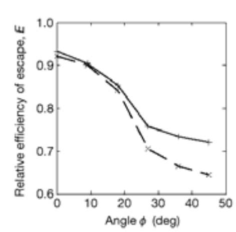
Pedestrian traffic and evacuation models Gipps and Marksjo, 1985

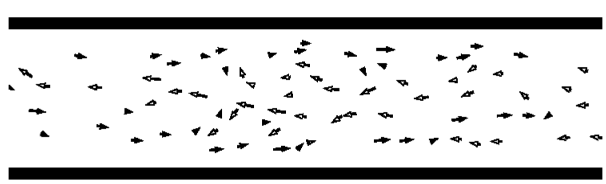
$$\text{Repulsion force} = 1/((D - 0.4)^2 + 0.015)$$

When it works, physicists catch the ride –

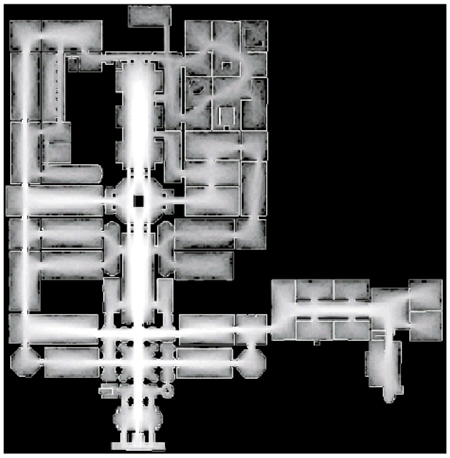
Helbing at al, 1998+, and many others, Physica *A*



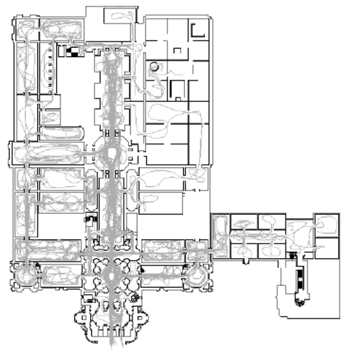




Geographers still take over in 'data rich' situations of complex space structure – Pedestrian movements in Tate gallery, Turner and Penn, 2002



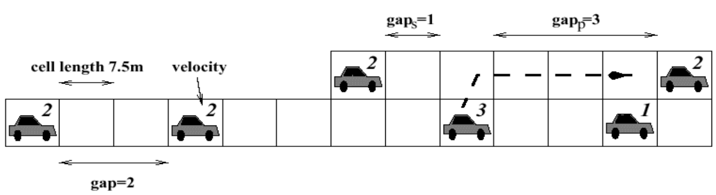
Simulation outcome

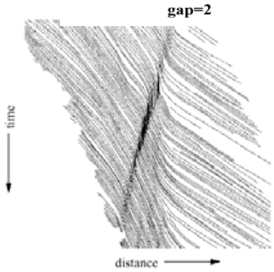


Actual trace in Tate

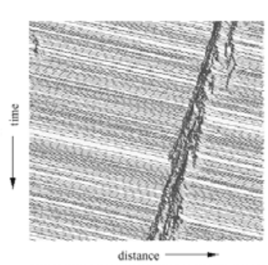
Car traffic in the city Nigel, Schreckenberg, 1999+, and many others

1. Acceleration: $v_A(t+1) = \min(v_A(t)+1, v^{\mathrm{MAX}})$;
2. Braking: $v_A(t+1) = \min(v_A(t), \mathrm{d}_A(t)-1)$;
3. Random deceleration with probability p: $v_A(t+1) = \max(v_A(t)-1, 0)$;
4. Driving: $x_A(t+1) = x_A(t) + v_A(t)$;

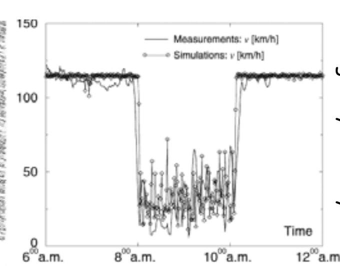




Real highway

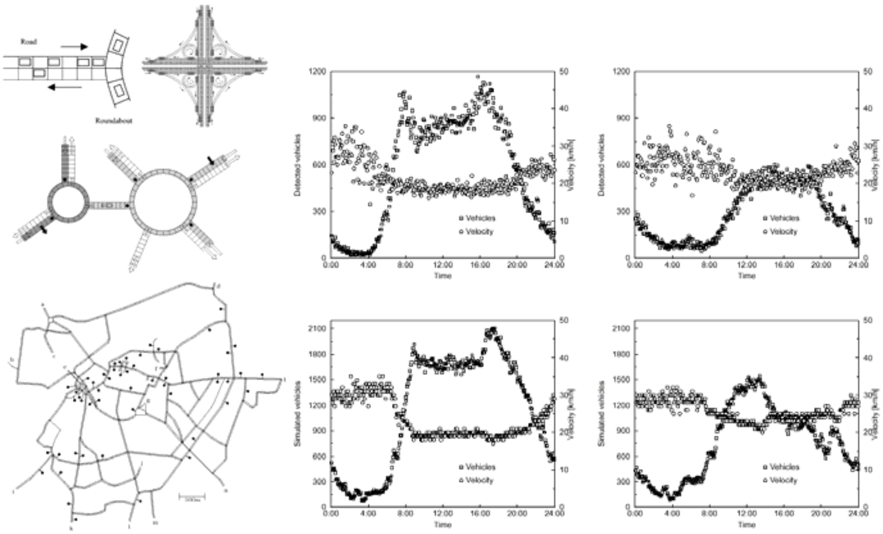


Model



Highway velocity

Car traffic in the city – real-time simulations

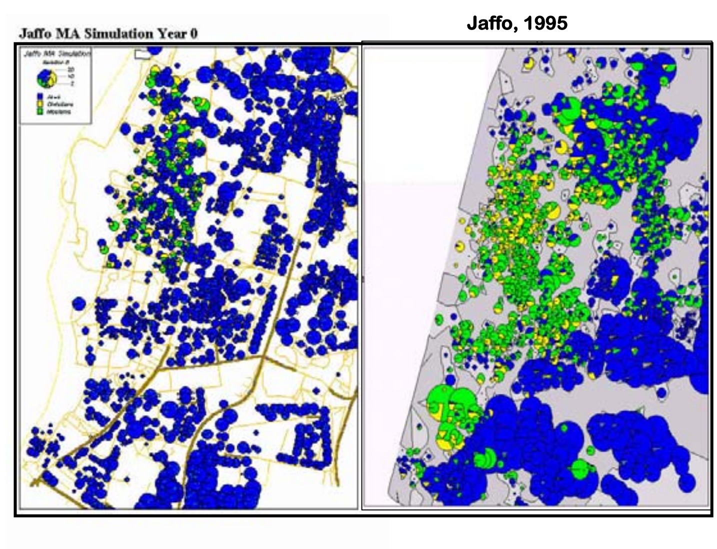


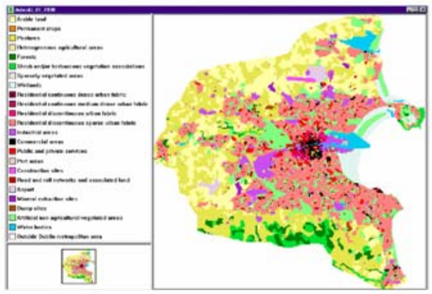
Check points

Real-world and Simulated traffic

Duisburg, Germany, (Wahle, et al, 2001)

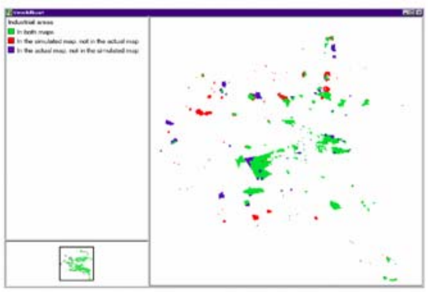
Residential dynamics in simple situations – Yaffo, Benenson et al, 2002

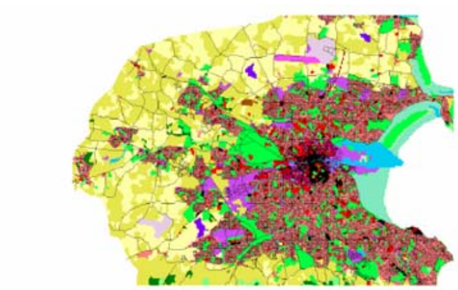




Comprehensive modeling White, Engelen and RIKS, 1998+, Landis, Zhang, 1998+ (California), Wadell, 2000+

Struggle with Hungriness, Tuningness, Complicatedness





The latest trend in land-use modeling for planning:

Make the rules as simple as possible, and investigate *robustness* of the model outcomes to varying planning policies.

If the model is not robust, then, most probably, you do not understand the system….

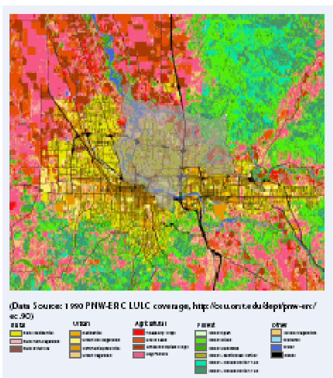
Evoland, EPA and Oregon State University

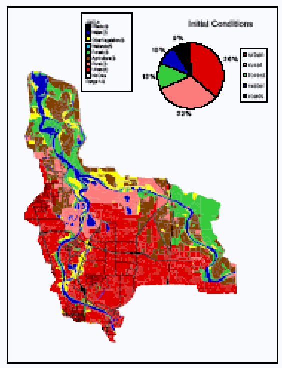
Discrete, reflecting planning constraints, rules of land-use changes

If (LU_t = 11 or LU_t = 4 or LU_t = 5) Then (LU_{t+1} = 10 or LU_{t+1} = 5);

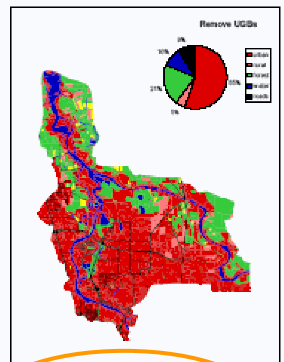
G1: What happens when the *process of application of rules* does not follow the "average" practice?

G2: Reveal planning constraints that cause negative consequences!





Initial conditions in McKenzie-Willamette River Confluence study area. This was the distribution of LULC in 2000.



A sample urban expansion scenario after 50 years. All runs end with basically the same pattern.

Claim of a day: Model must be robust!

How to achieve that?

1. Bidding or ordering opportunities according to their utilities **before** making choice – White and Engelen, Turner, Landis and Zhang, many others (but not "discrete choice" models)

		A (0.9)	B (0.8)	None
Unconditional probability to choose each one of options	Proportional choice	$\alpha(1 - \beta/2)$ [0.54]	$\beta(1 - \alpha/2)$ [0.44]	$(1 - \alpha)(1 - \beta)$ [0.02]
	Try the better	α [0.9]	$\beta(1 - \alpha)$ [0.08]	$(1 - \alpha)(1 - \beta)$ [0.02]

Probabilities of choice according to "bidding" heuristic

Opportunity	Utility at t1	Utility at t2	Utility at t3
A	0.8	0.8	0.8
B	0.4	0.7	0.85
A	0.8	0.8	0.12
B	0.08	0.14	0.85

My conclusion: models work well when

• Deal with physically existing objects - OK

• Data on objects' states are available – OK

• We understand the laws of objects' behavior and interactions ⇔ Simple systems

OR

• We are able to investigate the model dynamics ⇔ Robust complex systems