

Simulator of Network Growth (SONG 1.0) for Homework 4 A

Prepared for Homework 4A, CE 5214
April 13, 2004

What is Simulation?

- Definition
 - Dynamic representation of some part of the real world through building computer model and moving it through time (Drew 1968)
- Classifications of simulation
 - Microscopic, mesoscopic and macroscopic
 - Intersection, road section, and network simulation

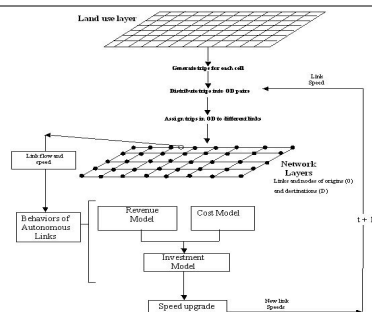
Why Simulation?

- Why simulation (vs. Field assessment)
 - Time
 - \$
 - Risk
- Application in transportation
 - Traffic safety
 - Effects of traffic control systems
 - Demand estimation
 - Assess policy alternatives

SONG 1.0 Overview

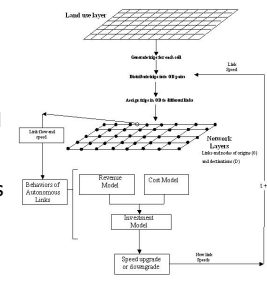
- Simulator of Network Growth
- Questions examined
 - How transportation network grow or decline?
 - Are network patterns (e.g., hierarchy) planned or emergent?
 - How policy alternatives affect location of network expansions and contractions?

Simulation Models



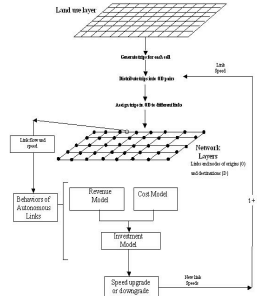
Layered Models

- System is split into two layers
 - Network layer
 - Land use layer
- Network is modeled as a directed graph
- Land use layer has small land blocks as agents that determine the populations and land use

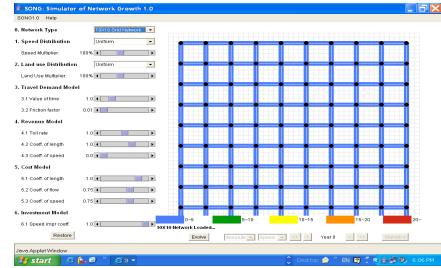


Models Required

- Network and Land use and population model
- Travel demand model
 - Trip generation
 - Trip Distribution
 - Trip Assignment
- Revenue model
- Cost model
- Network investment model



The Interface

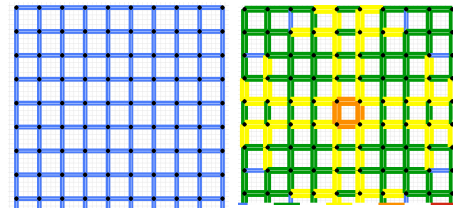


Access at: <http://www.ce.umn.edu/~levinson/Song/Dynamics.html>

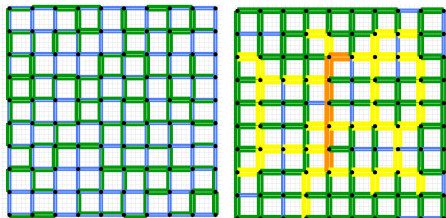
How to run SONG 1.0

- Set Network type, Land use and speed conditions
- Change values of parameters, representing different policies
- Run simulation
- Extract output (Graph and MOEs)

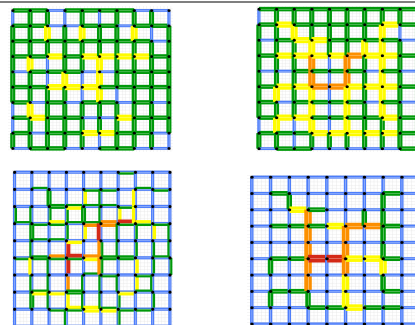
Example Base Case

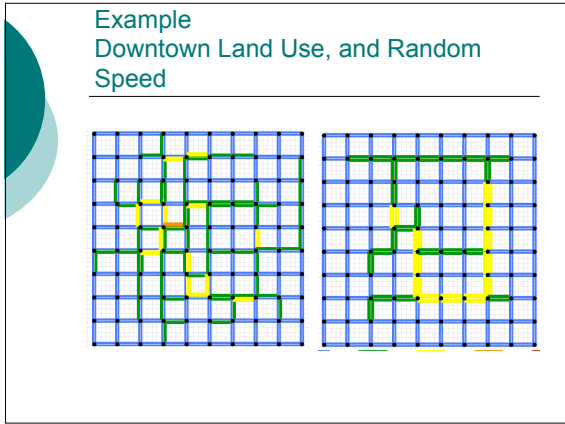
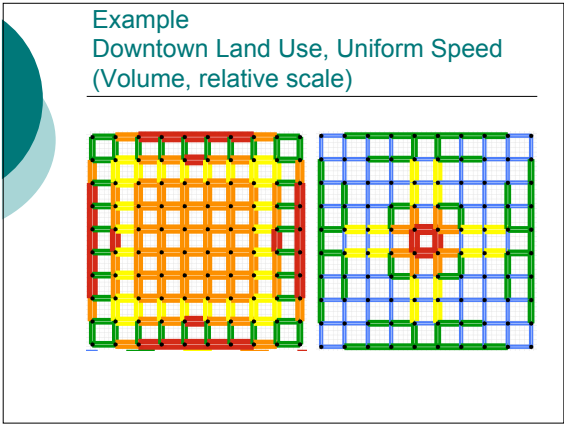


Example Uniform Land Use, and Random Speed



Example Random Land Use, and Random Speed





- ### Points of notice
- Iteration starts with initial speed
 - Effects of land use distribution on volume can be viewed from iteration 1, not iteration 0
 - Results can be viewed in absolute and relative scales
 - "Pre-specified random"
 - Allows you to select the same randomness cross different experiments
 - Speed and Land Use Multiplier
 - Number of iterations (Years)

- ### Homework 4A
- At network level, test effects of changes in:
 - Value of time
 - Willingness to travel
 - Toll
 - Revenue elasticity
 - Level of performance based investment
 - Perform system analysis with MOEs from simulation
 - Write up a report

SONG 1.0 Parameter table

| | Variables | Default value | Adjustable Range | Interpretation ^a |
|-----------------------------------|-----------|---------------|----------------------|--|
| Land use, network settings | | | | |
| Network types | 0 | 10x10 | 5x5-25x25 | network sizes |
| | | | network with river | |
| Speed distribution | 1 | uniform | uniform | no differentiation in link speeds cross the network |
| | | | random | randomly distribute speed |
| | | | pre-specified random | repeat the "same" random distribution |
| Speed multiplier | | 100% | 30% - 200% | network speed level |
| Land use distribution | 2 | uniform | uniform | |
| | | | random | |
| | | | urban | land use with downtown |
| | | | pre-specified random | repeat the "same" random distribution |
| Land use multiplier | | 100% | 30% - 200% | land use density |
| Travel Demand | | | | |
| Value of time | 5.1 | 1.0 | 0 - 5.0 | hourly time value |
| Friction Factor | 5.2 | α 0.01 | 0 - 1.0 | willingness to travel |
| Revenue | | | | |
| Toll rate | 5.1 | α 1.0 | 0.5 - 1.5 | toll |
| Length coefficient | 5.2 | α 1.0 | 0 - 1.5 | revenue responsiveness to distance traveled |
| Speed coefficient | 5.3 | α 0.0 | 0 - 1 | revenue responsiveness to road speeds |
| Link Maintenance Cost | | | | |
| Length coefficient | 7.1 | α 1.0 | 0 - 1.2 | elasticity of cost in response to road length |
| Flow coefficient | 7.2 | α 0.75 | 0 - 1.2 | elasticity of cost in response to link flow |
| Speed coefficient | 7.3 | α 0.75 | 0 - 1.2 | elasticity of cost in response to road speed level |
| Investment | | | | |
| Speed improvement factor | 8.1 | β 1.0 | 0 - 1 | responsiveness of link improvement (investment) to link performance (such as revenue/cost ratio) |

- ### Resources
- Help file
 - Variable tables
 - Descriptions of the parameters
 - Instructions
 - MnDOT webpage
 - Information about Simulation:
 - http://publish.uwo.ca/~jmalczew/gida_5/Pursula/Pursula.html

Questions?

Lab Time

Trip Generation

- Divide geographical area into zones
- Convert land use properties of the zones into trips produced and trips attracted by purposes
 - Population density (O)
 - Market density (D)

Trip Distribution

- Match generated trips by purpose between O and D

- Trips produced are differentiated according to Destination
- Trips attracted to a zone are differentiated according to Origin
- Gravity model

$$t_{rs} \propto \frac{p_r q_s}{f(d_{rs})}$$

Where:

- t_{rs} trips from origin node r to destination node s ,
- p_r is trips produced from node r ,
- q_s is trips attracted to node s ,
- d_{rs} : generalized cost of commuting between nodes r and s
- $f(d_{rs})$: friction factor

Route Assignment

Model the travelers' choices of routes by the relationship between flow and travel time

- Convert trips into flows on the links
- Path with least cost of traveling
- Generalized Cost of commuting between r and s

$$d_a = \eta \frac{l_a}{v_a} + \rho_o l_a^{\rho_1} v_a^{\rho_2}$$

- Dijkstras Algorithm
- Flow on a link is

$$f_a = \sum_{rs} t_{rs} \cdot \delta_{a,rs}$$

where

- l_a length of link a
- v_a speed of link a
- η value of time
- ρ_o tax/toll rate
- ρ_1, ρ_2 are coefficients
- K_{rs} is a set of links along the shortest path from node r to node s ,
- $\delta_{a,rs} = 1$ if $a \in K_{rs}$, 0 otherwise

Revenue Model

- Revenue is calculated by multiplying the toll and flow
 - Toll is assumed to be the only source of revenue
- $$R_a = \rho_o l_a^{\rho_1} v_a^{\rho_2} (365 \cdot f_a)$$
- coefficients are same as coefficients used in traveling cost function

Cost Model

- Cost of maintaining link speeds depending on traffic flow (diff. from cost of travel)
- Cost of a link is

$$C_a = c \cdot l_a^{\alpha_1} \cdot f_a^{\alpha_2} \cdot v_a^{\alpha_3}$$

Where, c is cost rate,
 $\alpha_1, \alpha_2, \alpha_3$ are coefficients.

Network Investment Model

- Revenue in excess of maintenance costs will be invested on the link to improve its condition
- Assumption: a link uses all the available revenue in a time step
- Speed of a link improves if $R > C$; speed drops if $R < C$
- With new speeds on the links, travel time, shortest path changes and the whole process will be iterated

$$v_a^{t+1} = v_a^t \left(\frac{R_a}{C_a} \right)^\beta$$

Where:

v_a^t is speed of link a at time step t ,
 β is speed reduction coefficient.

No revenue sharing between links:
 Revenue from a link is used in its own investment