SILO: A Land-Use Model For Integrated Modeling

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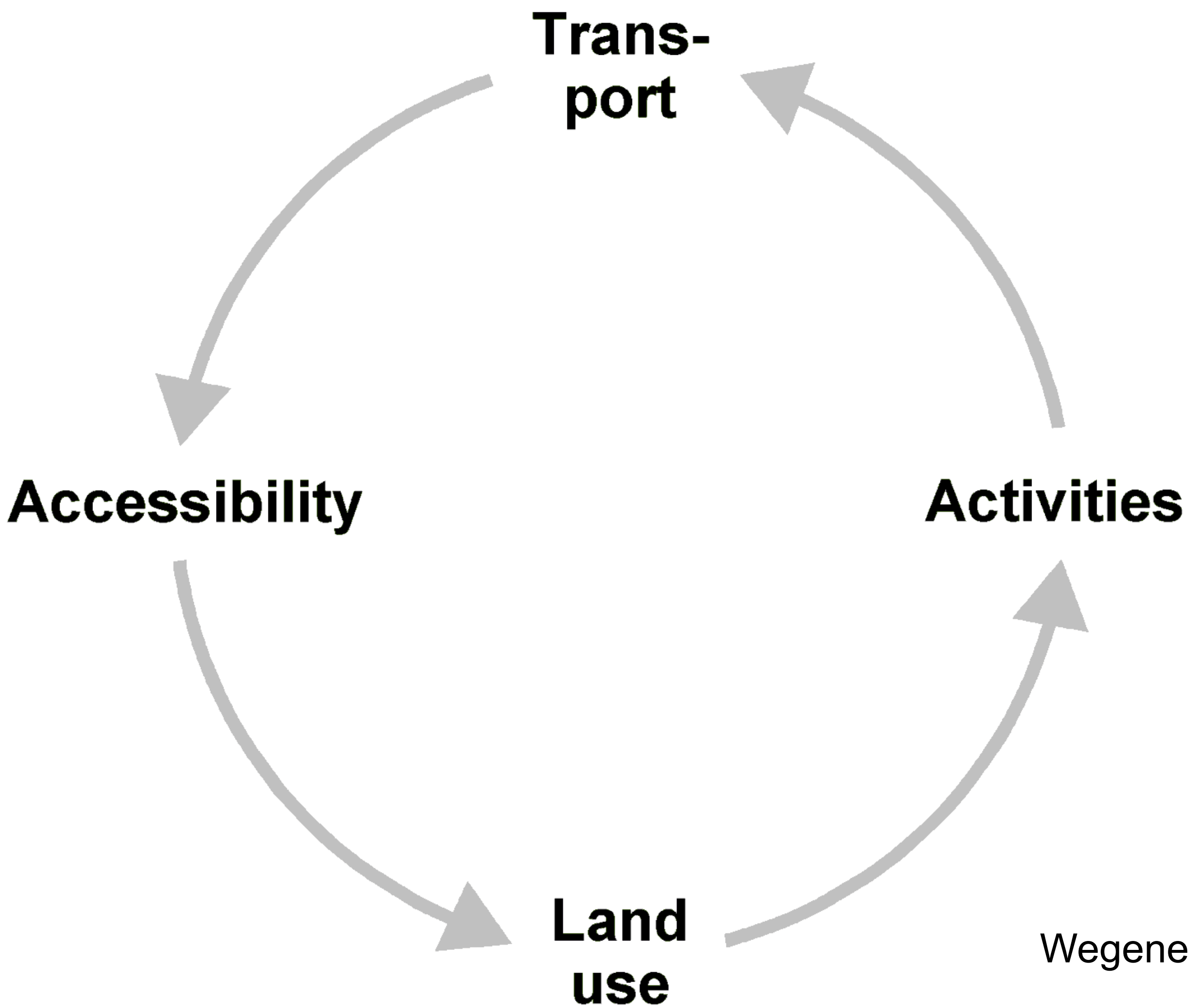
CUPUM Conference · Lake Louise AB Canada · 6 July 2011

Interaction of Land Use and Transport



Wegener (1994)

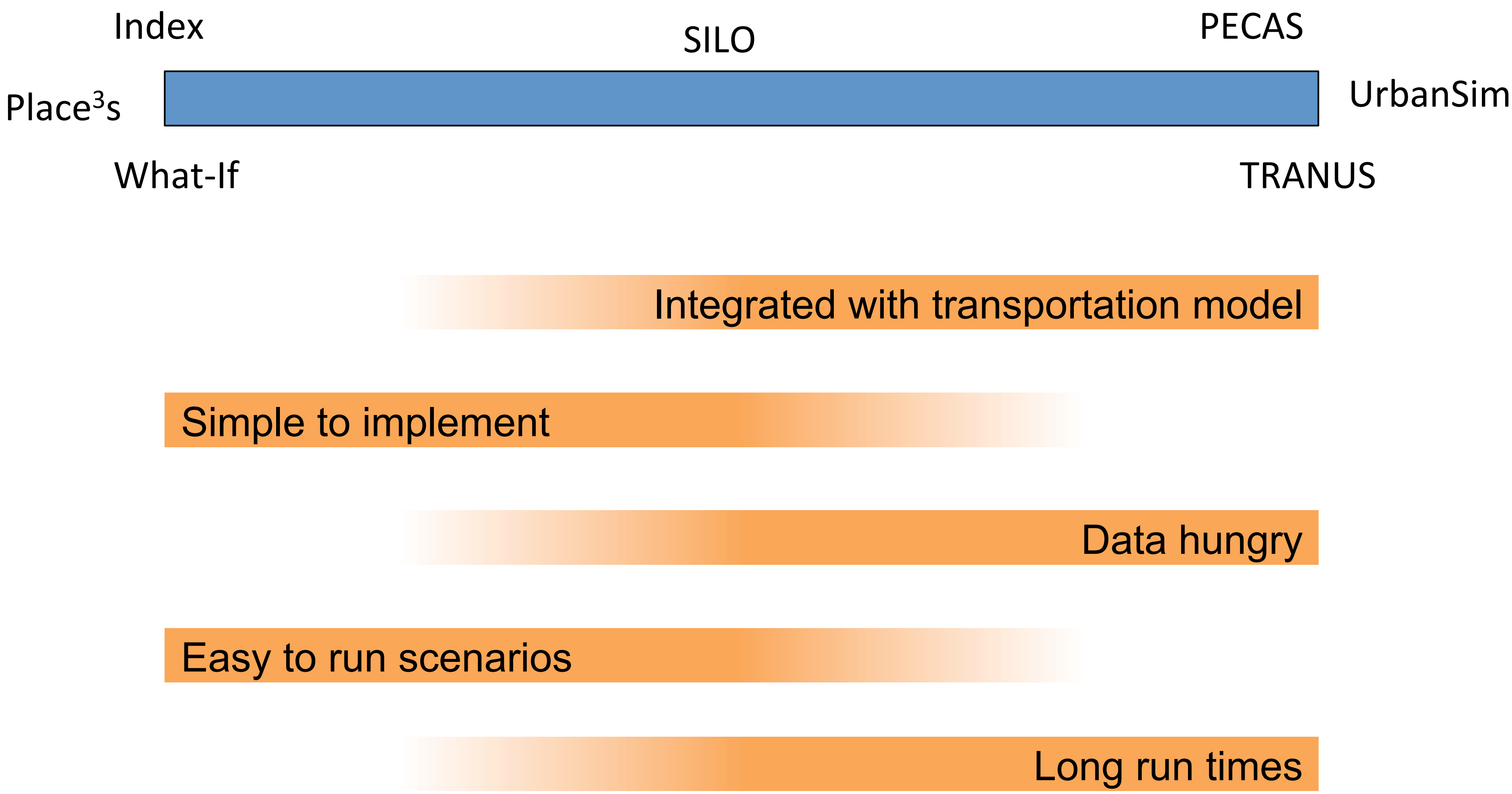
Need for land-use modeling

- It is known that transportation and land use influence each other. The extent and direction of this influence usually is guessed only.
- Integrated modeling helps
  - decision makers,
  - transparency,
  - public participation,
  - and the tradeoffs between these three.

Simple Land Use Orchestrator

SILO IDEA

Land use modeling in the U.S.



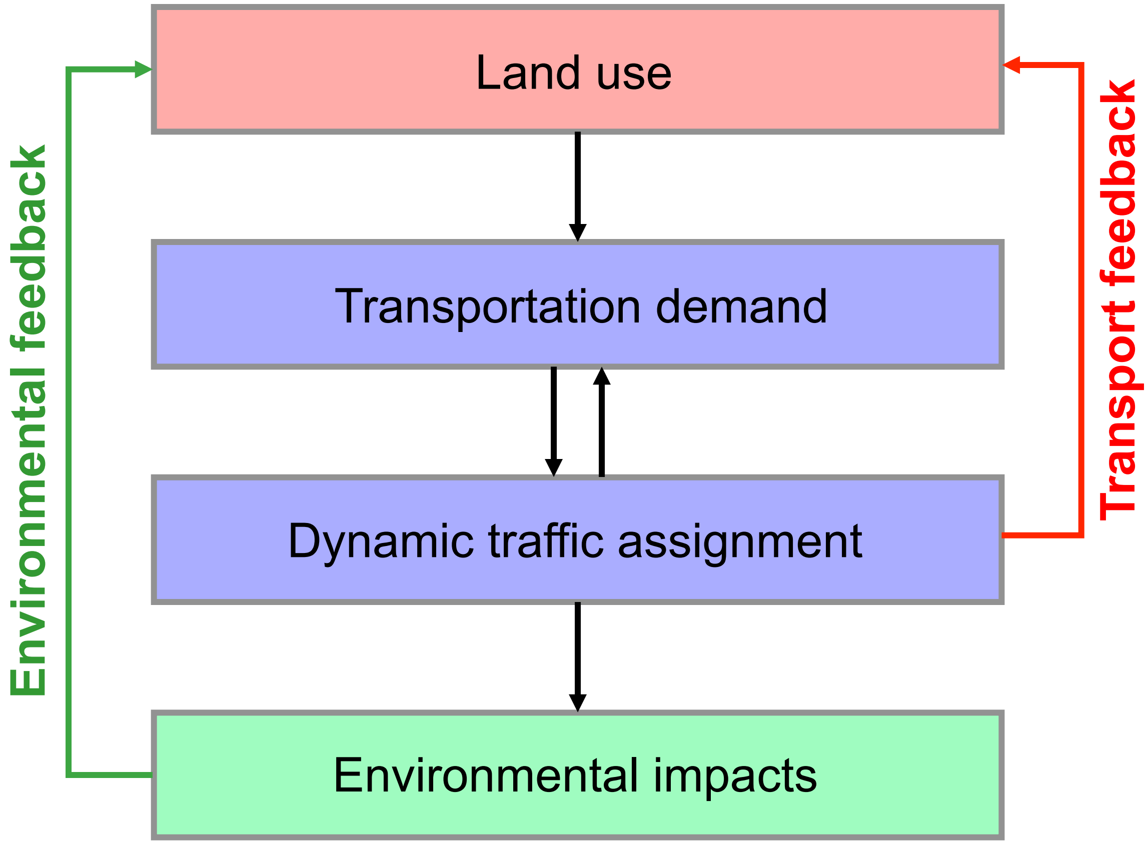
Motivation

- Fully represent the land-use transport feedback cycle
- Develop a tool that can be implemented with tight schedules and/or a smaller budget
- Ability to analyze smart growth strategies
- Simulate greenhouse gas emissions
- Ability to run many scenarios in a short time frame

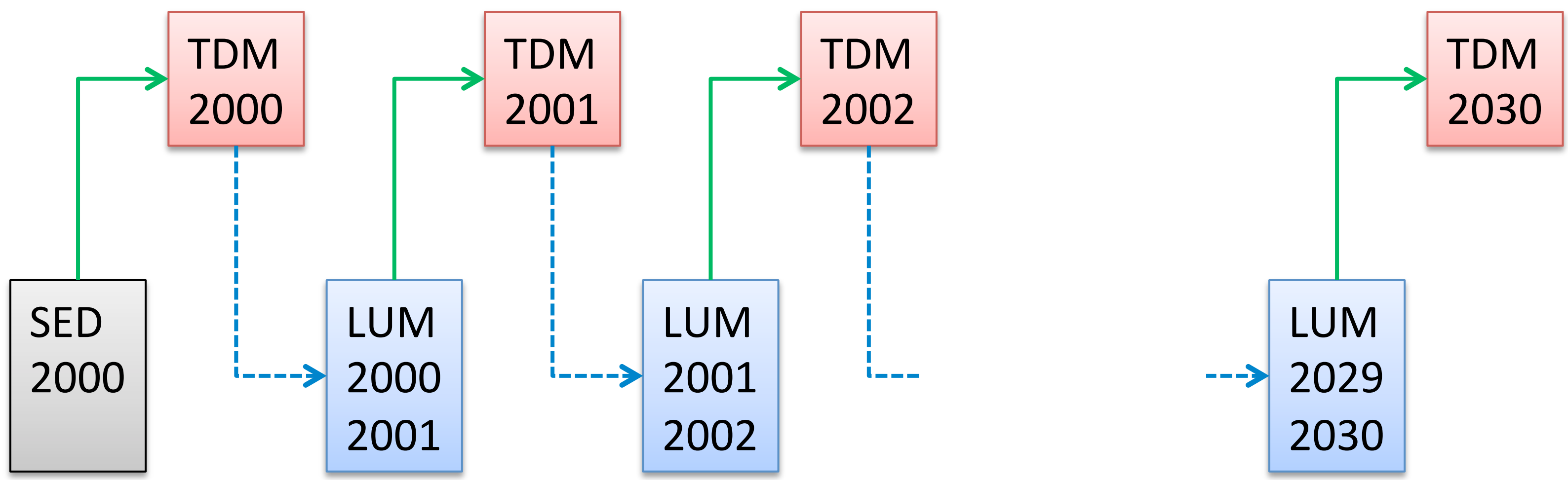
Design Principles

- Integrated with travel demand model
- Microscopic
- Logit-based discrete choice
- Evolutionary instead of equilibrium
- Location decisions constraint by budgets
- GUI controlled
- Develop a tool that can be implemented with tight schedules and/or a smaller budget
- Short runtimes

Concept of integrated simulation models



Integration in an Ideal World



Zonal data: Population and employment

Travel time and travel costs matrices

Key assumptions

- Regional population and employment numbers are exogenous to model
- Base year is in the past (such as 2000), and validation year close to today (such as 2010)
- Sensitivity tests to demonstrate reasonableness more important than exhaustive calibration

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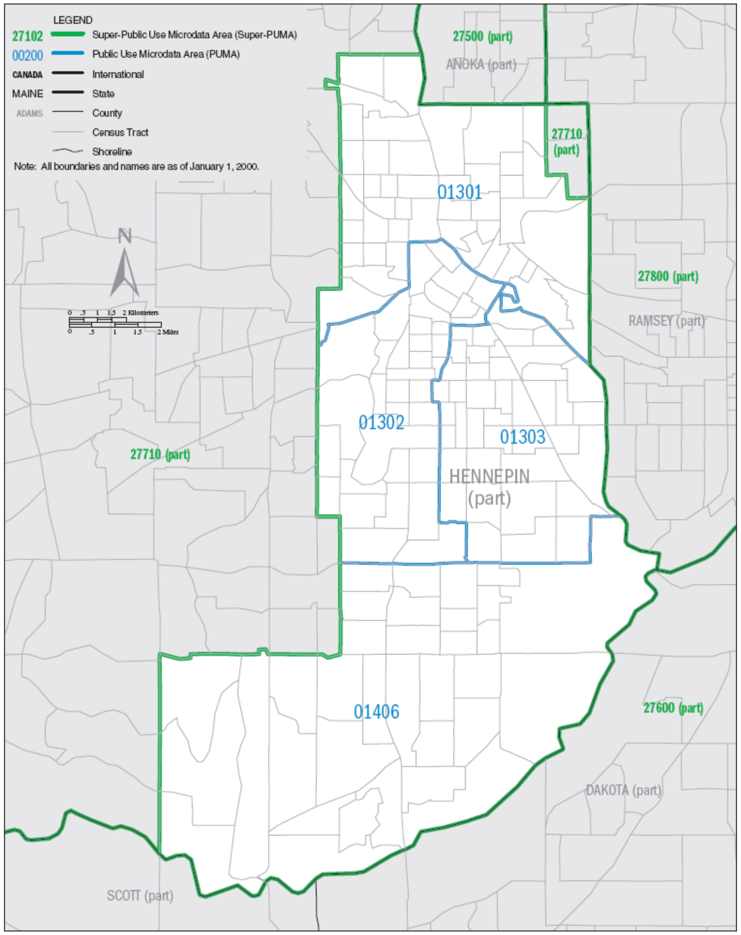
SYNTHETIC POPULATION

Synthetic Population

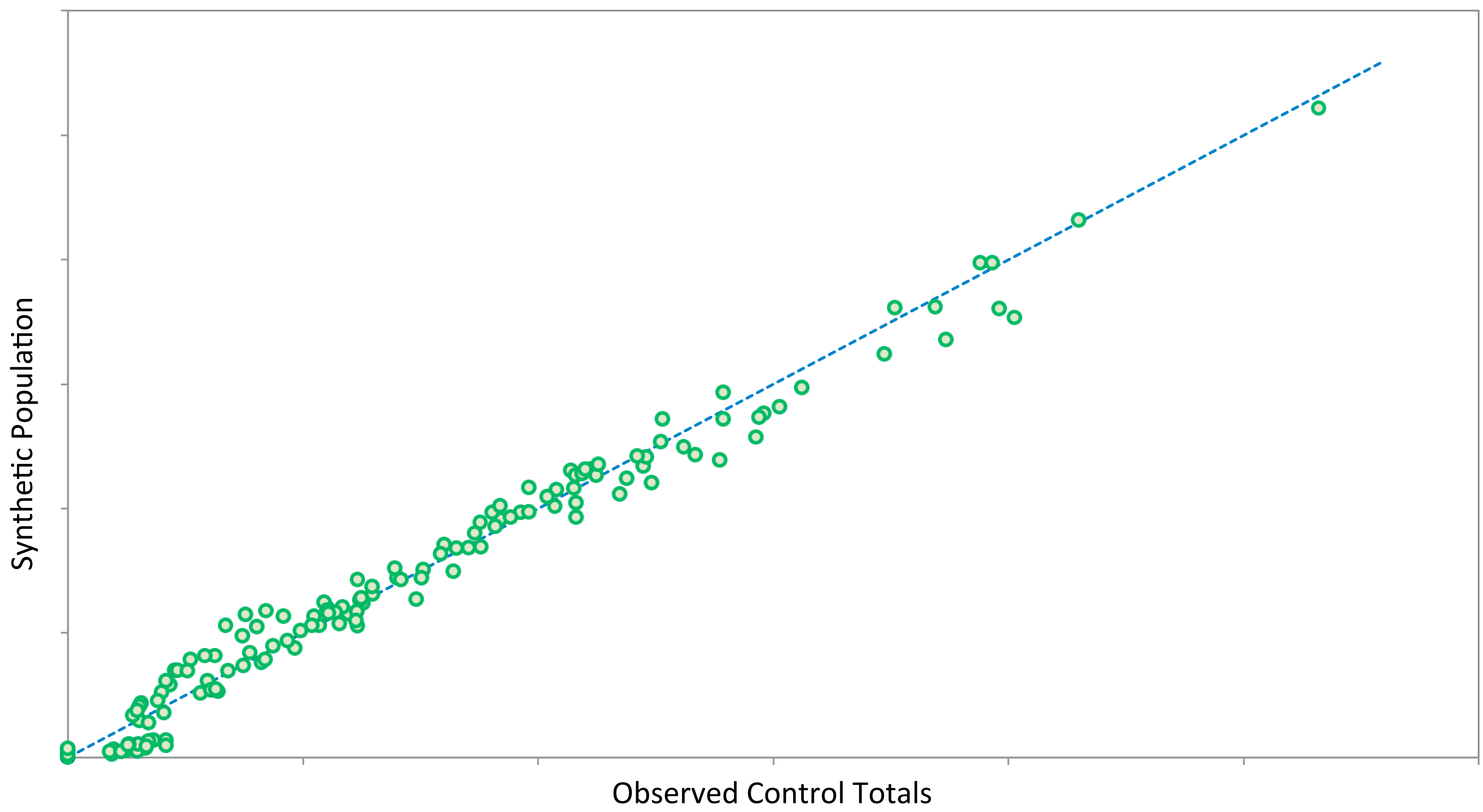
- Looked at ARC population generator
- Looked at ASU population generator
- Decided to develop SILO population generator

Public Use Micro Sample (PUMS)

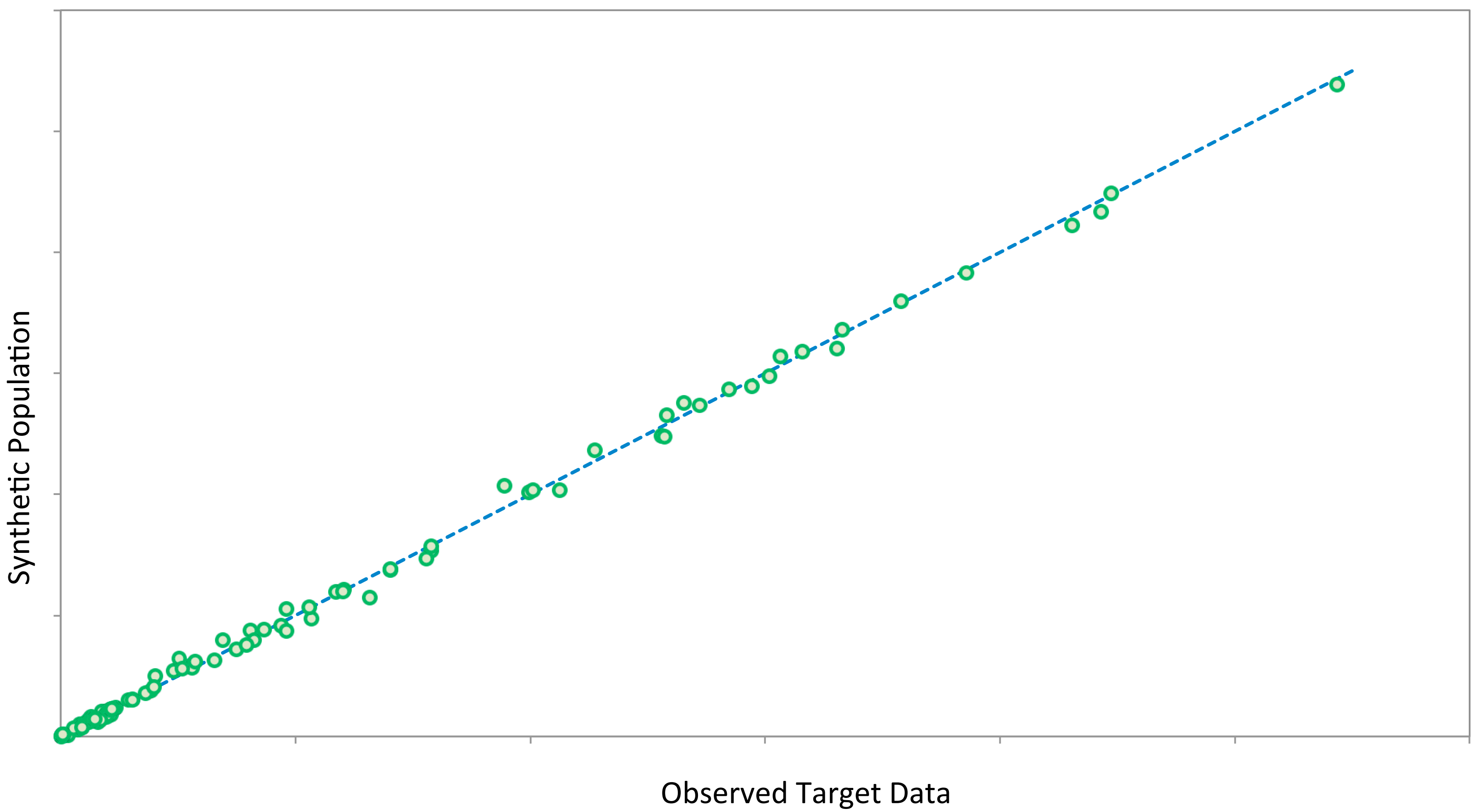
- PUMS data expanded to create micro data
- Use 5% sample to increase spatial resolution



Households by Size, Age and PUMA



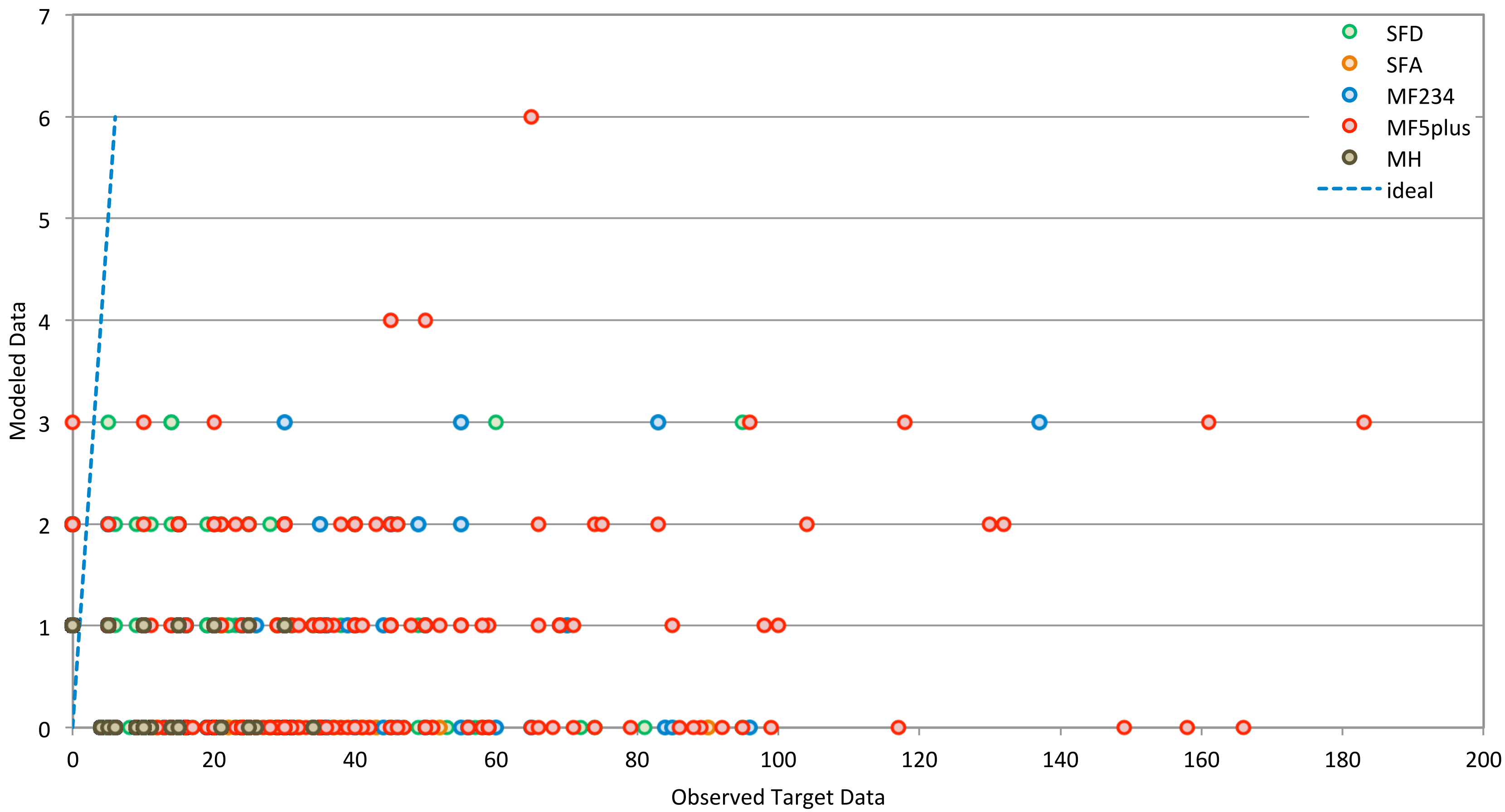
Dwellings by type and PUMA



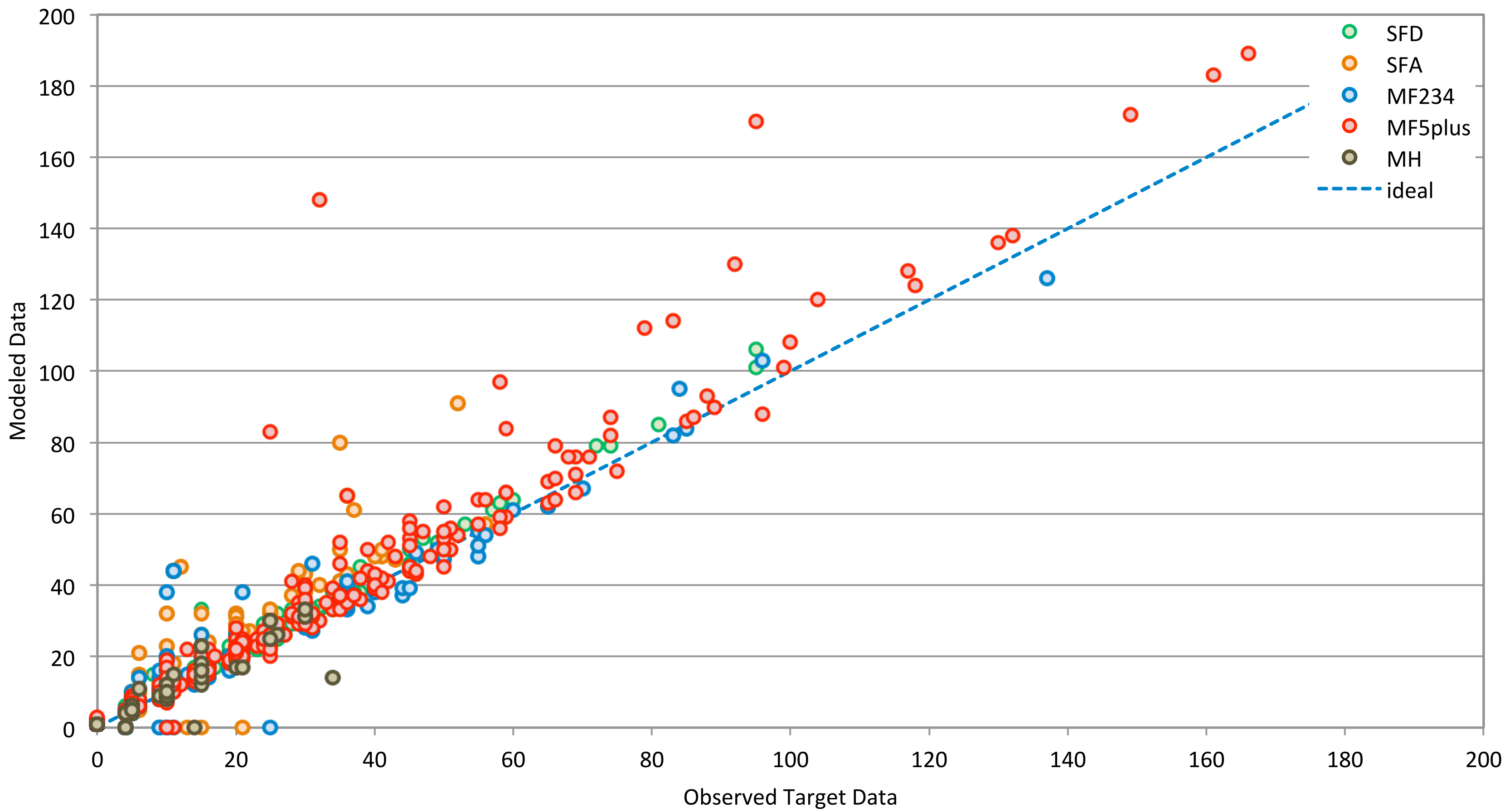
Validation of Synthetic Population

Population	Observed	Modeled	Deviation
Households	1,024,263	1,017,153	-0.69%
Persons	2,415,649	2,405,601	-0.42%

Vacant dwellings by zone (raw)



Vacant dwellings by zone (adjusted)



Validation of Synthetic Population

Dwellings	Observed	Modeled	Deviation
SFD	633,811	630,599	-0.51%
SFA	87,348	89,072	1.97%
MF234	62,790	60,670	-3.38%
MF5plus	246,555	250,482	1.59%
MH	16,718	16,178	-3.23%
Total	1,047,222	1,047,001	-0.02%

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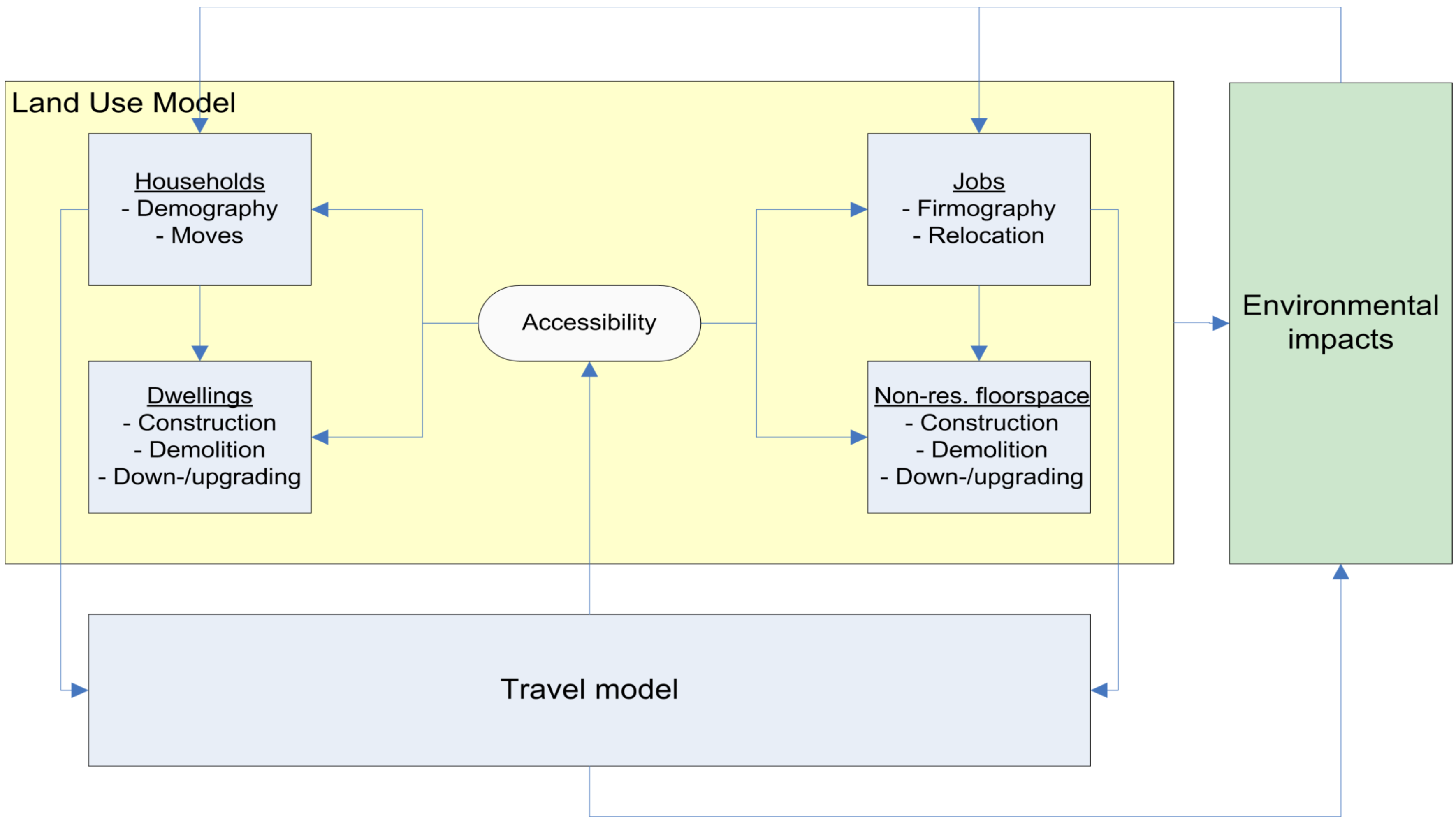
CONCEPT

Concept


Land Use Model
Households
- Demography
- Moves
Dwellings
- Construction
- Demolition
- Down-/upgrading
Accessibility
Jobs
- Firmography
- Relocation
Non-res. floorspace
- Construction
- Demolition
- Down-/upgrading
Environmental impacts
Travel model

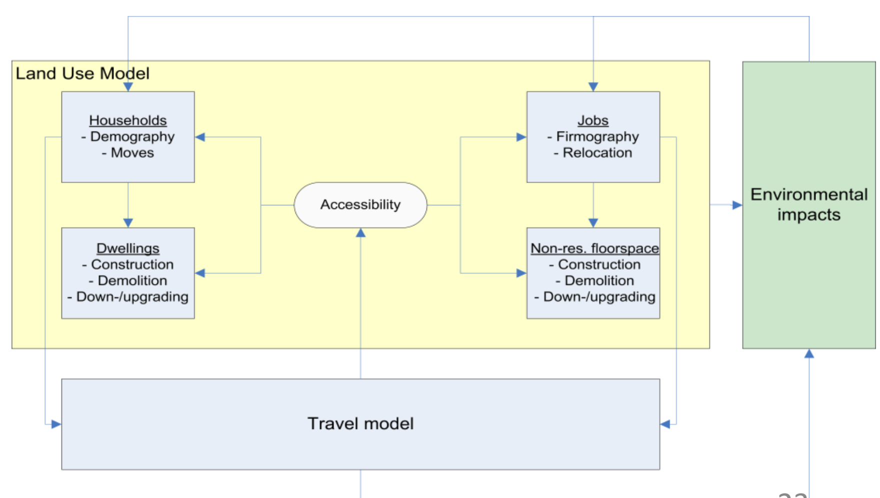
Data Input

- Essential data
  - PUMS data
  - HH by size, income and auto-ownership
  - Persons by age and gender
  - Dwellings by type
  - Non-res floorspace by type
  - Forecasts of pop./emp. growth for study area
- Desirable (can use national averages instead)
  - Preferences for location choice
  - Demographic transition probabilities

SILO Modules

- Housholds
  - Demography (birth, aging, marriage, divorce, death etc.)
  - Moves

- Dwellings
  - Type, size, price, quality
  - Allows policy overrides (new dwellings, demolitions etc.)



Events currently simulated in SILO

Population

- aging
- give birth to child
- leave parental household
- get married/cohabitate
- get divorced/separate
- death
- move
- immigrate/outmigrate

Dwellings

- build new dwellings
- renovate dwelling
- dwelling deterioration
- demolish dwelling

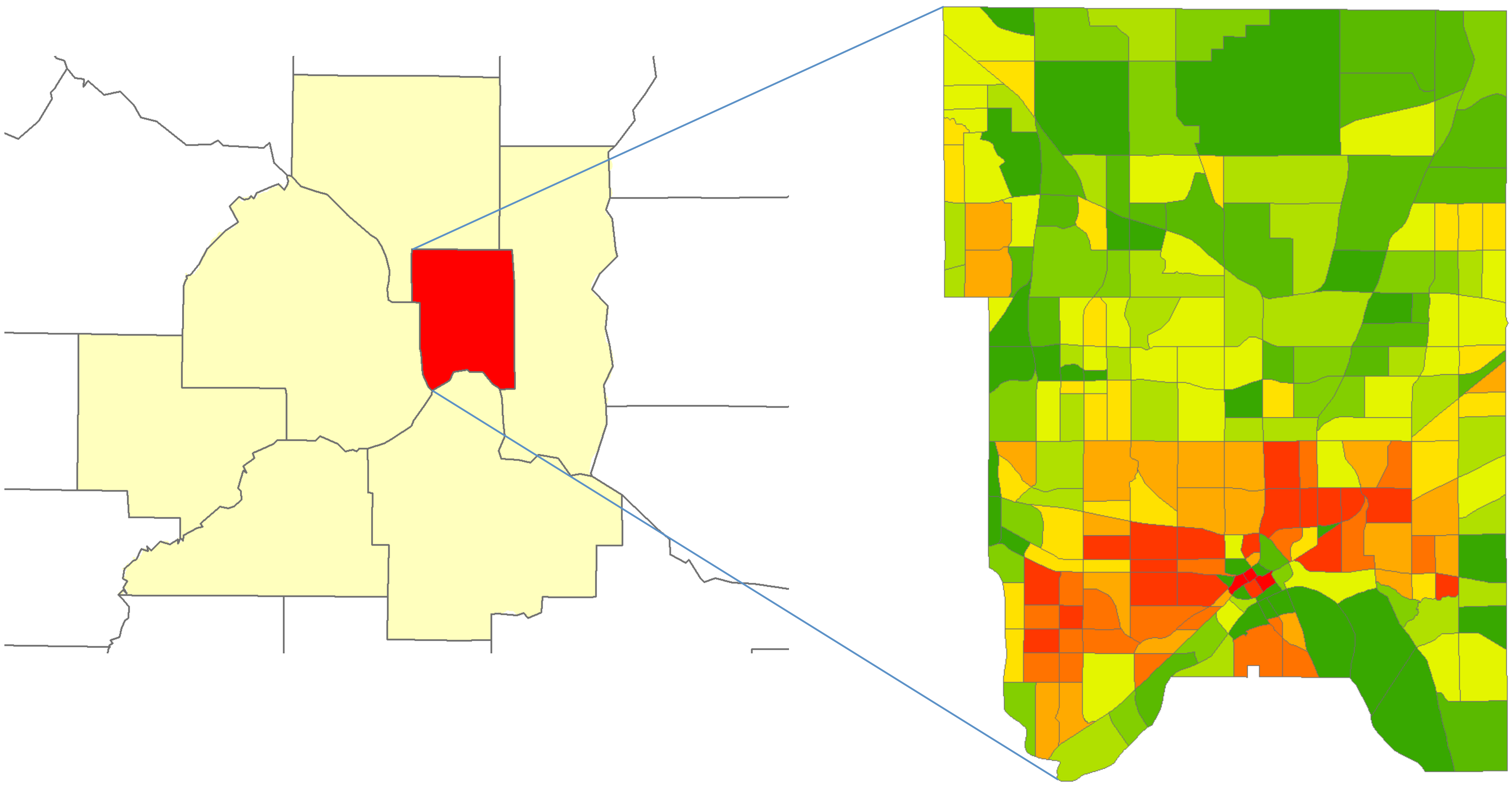
Household relocation

- Household relocation is simulated using logit models.
- First, the decision is modeled whether the household wants to move or not
- If the household decides to move
  - (1) a neighborhood is selected
  - (2) a new dwelling is selected

Household relocation

- Logit models are not built to compare hundreds of alternatives at the same time
- SILO first selects a region, and then a dwelling within that region is chosen.

Household move: 2-step selection



Decision: To Move or Not to Move

$$p_{move} = c - \frac{c}{1 + exp\left(\beta \cdot (1 - \Delta\bar{u})\right)}$$

where p_{move} = Probability to move
c = constant
β = parameter
$\Delta\bar{u}$ = expected average improvement in housing utility

$$\Delta\bar{u} = \frac{\sum_j \exp\left(\mu \cdot (u_j - u_i)\right)}{\sum_j \exp(\mu \cdot 0)}$$

Stands for u_i - u_i

where j = Available vacant dwelling
μ = parameter
u_i = Utility of dwelling i

Utility a Region

$$u_n = \alpha_1 \cdot \widehat{p_n} + \alpha_2 \cdot acc_n + \alpha_3 \cdot env_n$$

where u_n = Utility of neighborhood n
α_1, α_2, α_3 = Parameters, adding up to unity
$\widehat{p_n}$ = Median price of dwellings in neighborhood n
acc_n = Accessibility of neighborhood n
env_n = Environmental quality of neighborhood n

Select a Region

Probability to move from current region *i* to region *j*:

$$p_{i,j} = \frac{A_j \cdot u_j \cdot \exp\left(\gamma \cdot (u_j - u_i)\right)}{\sum_J A_j \cdot u_j \cdot \exp\left(\gamma \cdot (u_j - u_i)\right)}$$

where $p_{i,j}$ = Probability to move from *i* to *j*
A_j = Number of available dwellings in *j*
u_j = Utility of neighborhood *j*
γ = parameter

Selection of dwelling

$$p_i = \frac{\exp(\gamma \cdot u_i)}{\sum_J \exp(\gamma \cdot u_i)}$$

where p_i = Probability to choose dwelling *i*
u_i = Utility of dwelling *i*
γ = parameter

Utility of Dwelling

$$u_i = p_i^{\beta_1} \cdot s_i^{\beta_2} \cdot q_i^{\beta_3} \cdot a_i^{\beta_4} \cdot d_{iw}^{\beta_5}$$

where u_i = Utility of dwelling *i*

p_i = Price of dwelling *i*

s_i = Size of dwelling *i*

q_i = Quality of dwelling *i*

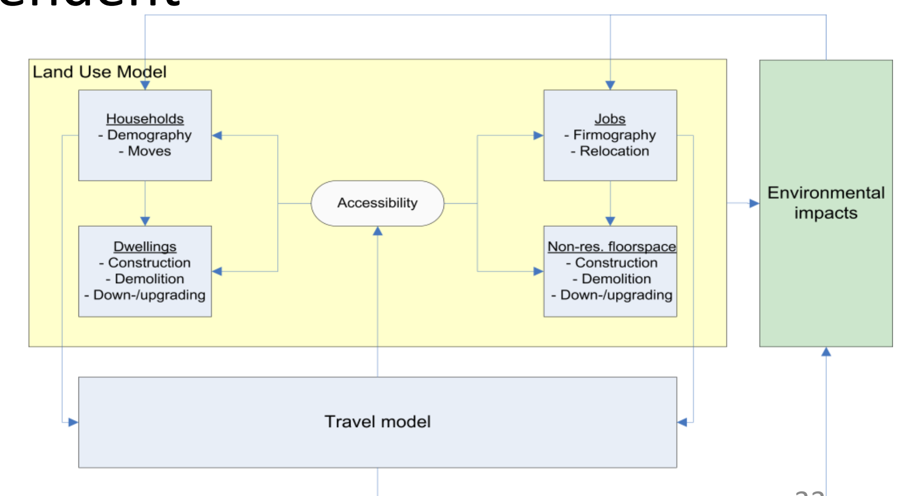
a_i = Accessibility of dwelling *i*

d_{iw} = Distance to work place

$\beta_1, \ldots \beta_5$ = Parameters, add up to unity

SILO Modules (planned)

- Jobs/Businesses
  - By industries (4 to 10 types)
  - Firm openings/closings
  - Job relocation
- Non-res. floorspace
  - Type, quality and price dependent
  - Locations
  - Renovation, deterioration and demolition



Logit and Markov Models

	Logit Models	Markov Models
Rationale	Simulate decisions made under uncertainty, such as limited information, habits and prejudices	Simulate transitions from one state to another
Application	Used where we care for the reasoning behind the decision process	Used where we do not plan to analyze the impact of policies
Classic example	Mode Choice	Death probability
In SILO	- Household relocation - Business relocation - Investors decision where to build new dwellings	- Demographic changes - Firmographic changes - Dwelling change of quality

Output Indicators

- Population by age, hh size, auto ownership
- Employment by type
- Dwelling vacancy
- Non-residential floorspace vacancy
- Change in housing costs
- Land-use consumption

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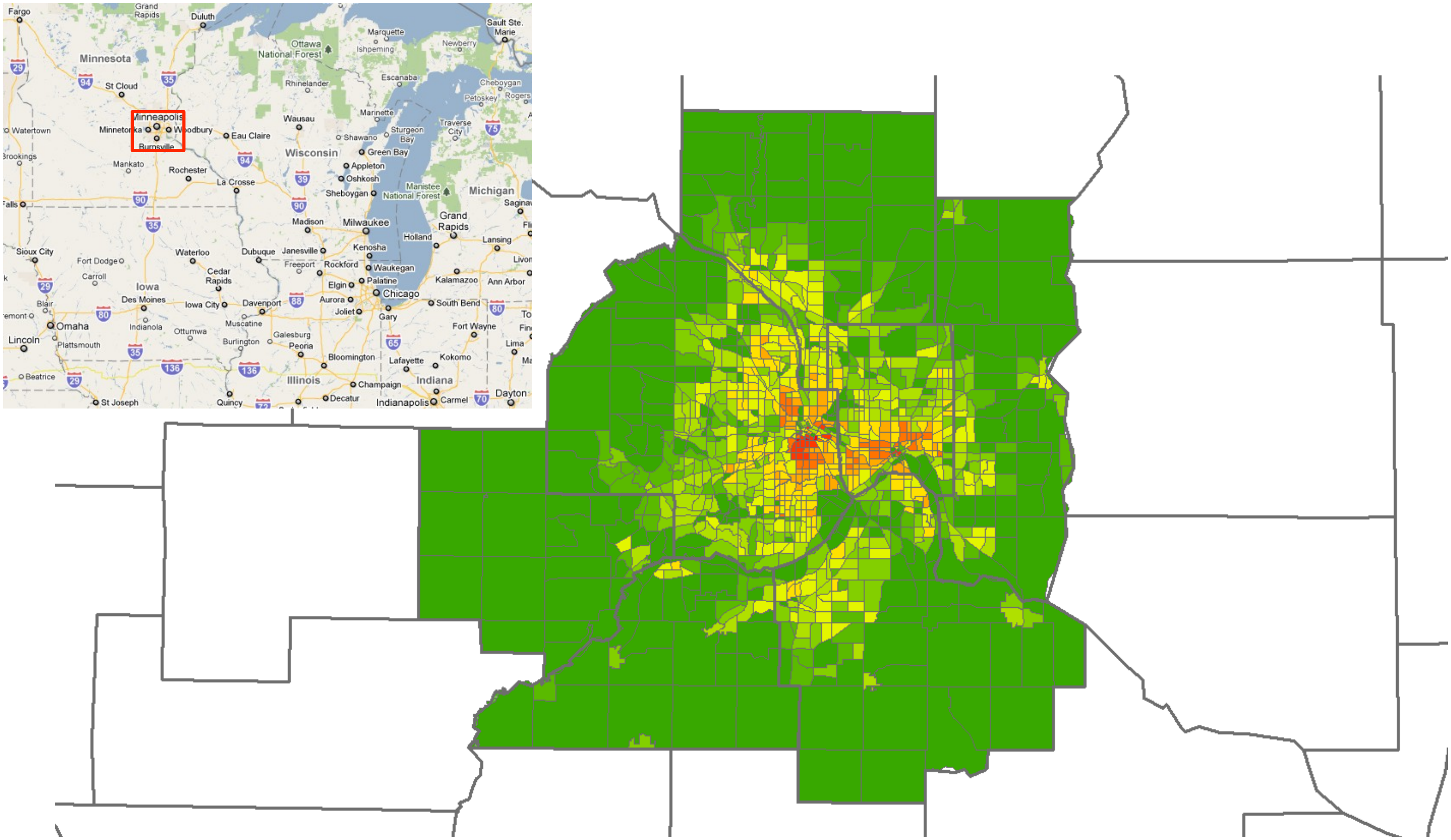
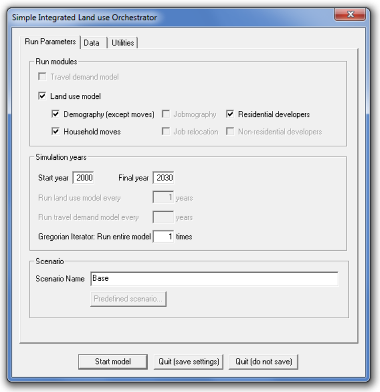
PROTO TYPE IMPLEMENTATION

Application for Minneapolis/St. Paul

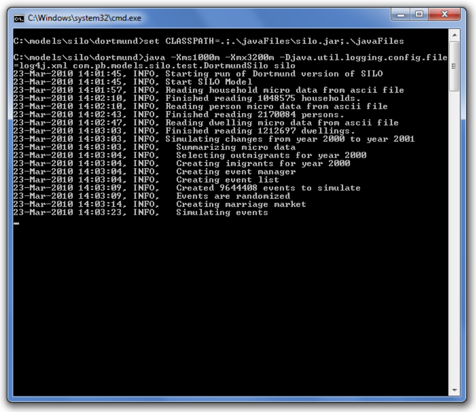


Implementation

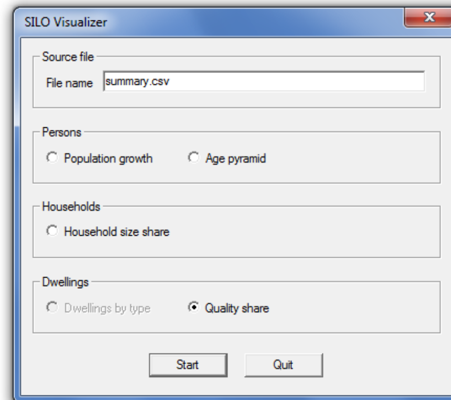
Setup
Fortran



Model
Java



Visualizer
Fortran



Proper-
ties file

Result
file

Simple Land Use Orchestrator

CONCLUSIONS

Status of SILO

- Synthetic Population
- Demographic changes
- Household moves (50% done)
- Update of existing dwellings
- Development of new dwellings (next on list)
- GUI interface to run model
- Result analysis tool
- Website on integrated modeling
- Model calibration & sensitivity test (this summer)

Innovations of SILO

- Explicit treatment of housing budget, which is sensitive to transportation costs.
- Less focus on exhaustive calibration and more focus on reasonable responsiveness, and therefore, behavior of past is not locked into the model for forecasts.
- Continuously monitoring runtime during model development (currently 1 h for 30 years).