Micro-simulation Modelling of Land Use and Transport in North America: Space Development Micro-Simulation in Baltimore PECAS

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OUTLINE

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  - Previous Work
- PECAS
  - Framework
  - Baltimore Implementation
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  - Estimation
  - Calibration
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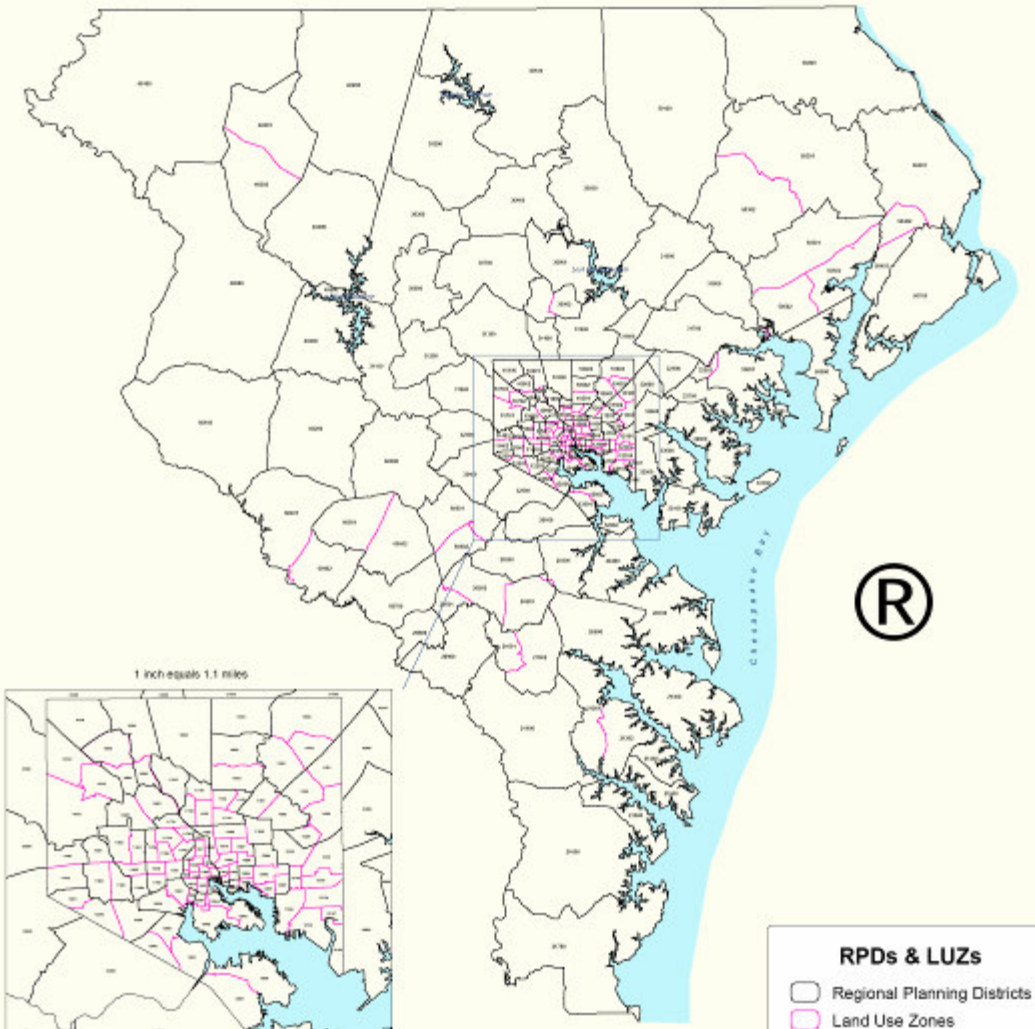
- Conclusions

Baltimore Region Land Use Zones
2005



1 inch equals 1.1 miles

RPDs & LUZs

- Regional Planning Districts
- Land Use Zones

Baltimore Metropolitan Council
2780 Lighthouse Point East, Ste 310
Baltimore, MD 21224-4774
www.baltometro.org

Prepared by
Transportation Planning Division - Data Development Section
Projected Coordinate System - NAD 1983 State Plane (ft)
Data Source - BMC Cooperative Forecast Round 6a
Printed - February 2005

1:145,917

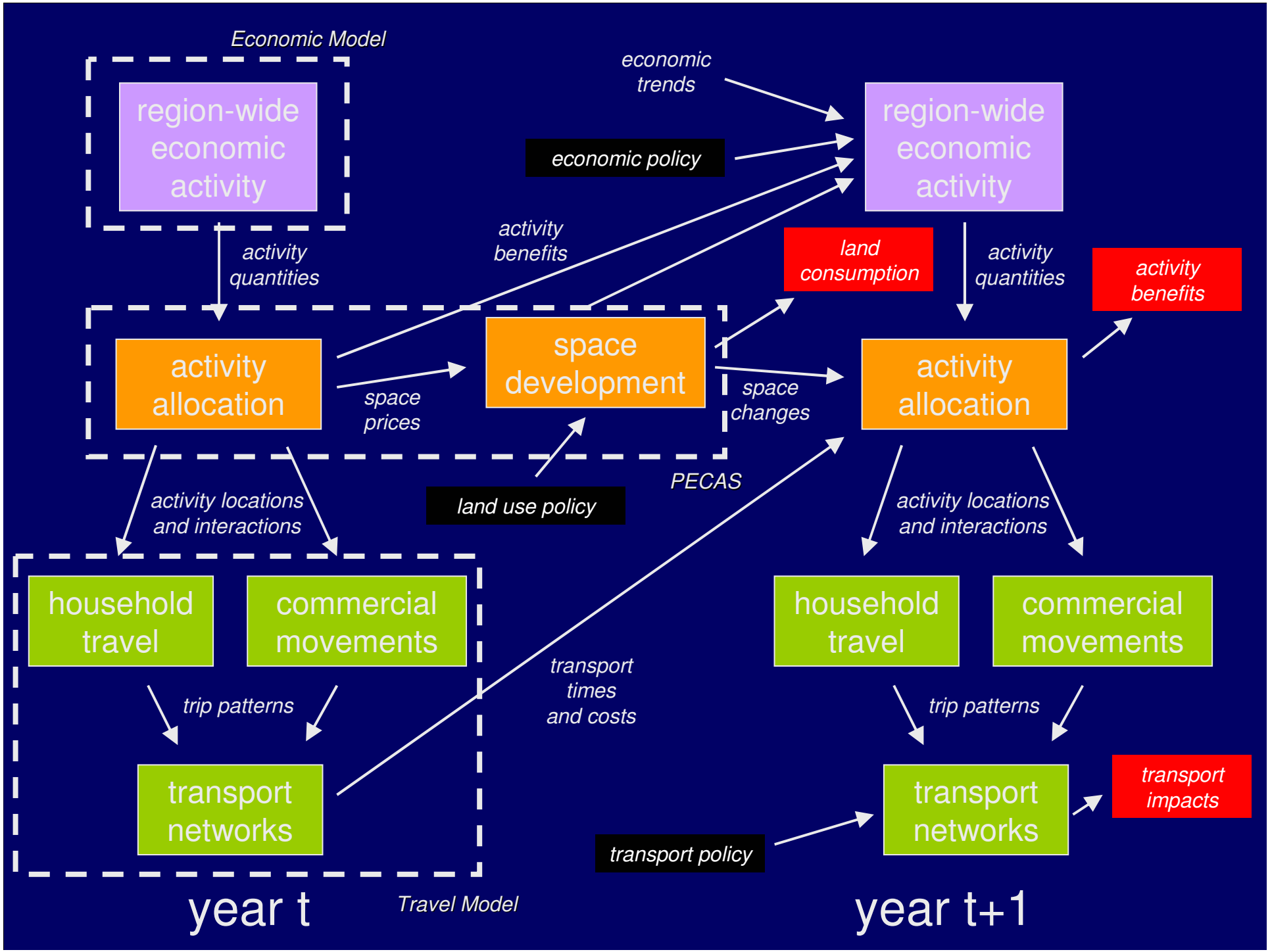
1 inch equals 2.3 miles

Introduction

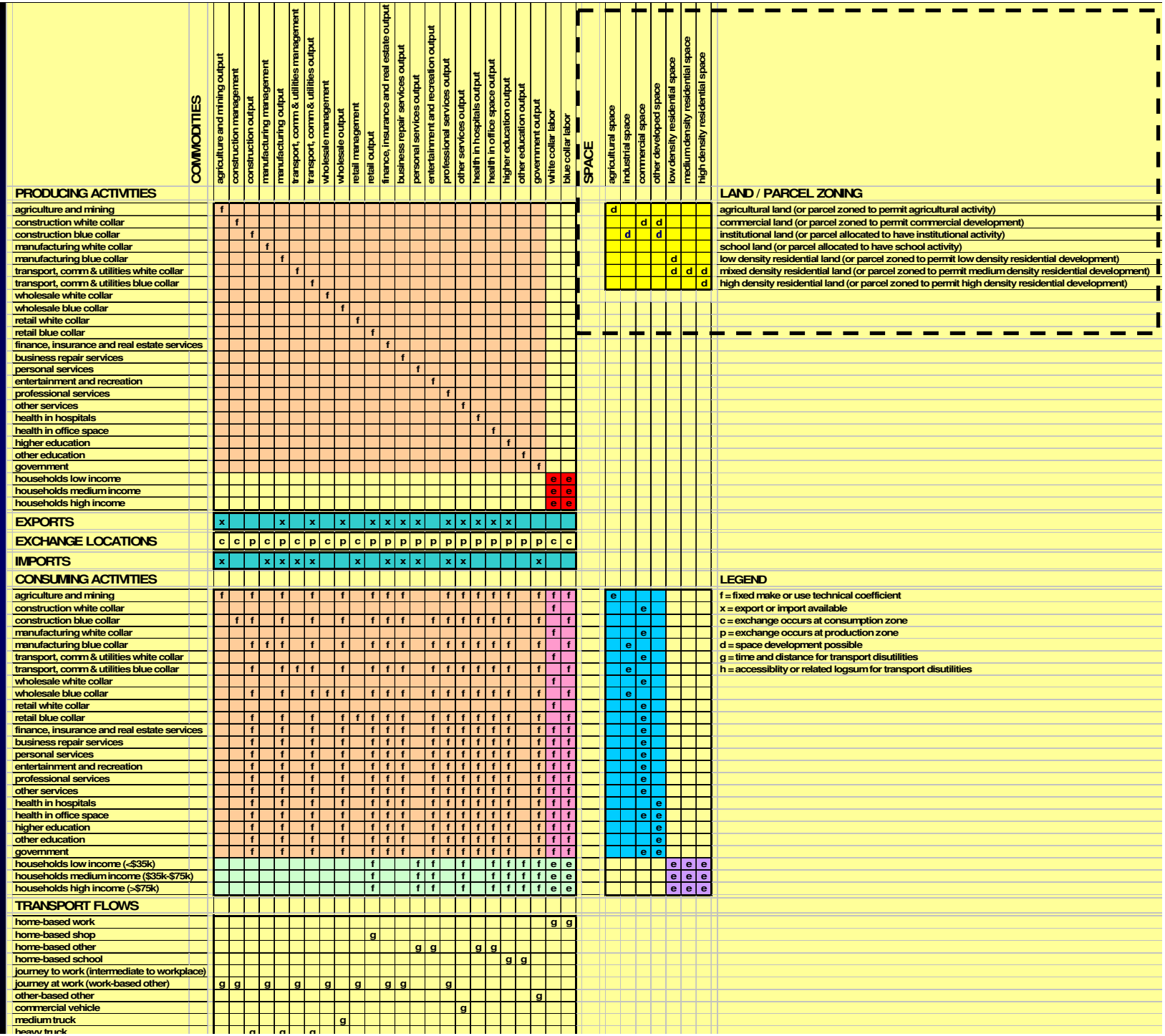
- Context
  - BMC Developing PECAS model
  - PECAS SD Module micro-simulation
    - Parcels GIS and development permits electronic = opportunity
- Previous and Other Related Work
  - Space Implicit or Mixed with Land
  - Aggregate Space Allocations
  - Explicit Treatment of Space Development at Disaggregate Level
    - Larger Micro-simulation System
    - Cellular Automata
      - spatial interactions, with top-down constraints
    - UrbanSim
    - Some previous PECAS work

PECAS

- Framework
- Baltimore Implementation


Economic Model
region-wide economic activity
economic trends
economic policy
region-wide economic activity
activity benefits
activity quantities
land consumption
activity quantities
activity benefits
activity allocation
space development
space prices
space changes
activity allocation
PECAS
land use policy
activity locations and interactions
activity locations and interactions
household travel
commercial movements
household travel
commercial movements
transport times and costs
trip patterns
trip patterns
transport networks
transport impacts
transport policy
transport networks
year t
Travel Model
year t+1

Baltimore Design Diagram



SPACE	agricultural space	industrial space	commercial space	other developed space	low density residential space	medium density residential space	high density residential space	LAND / PARCEL ZONING
	d							agricultural land (or parcel zoned to permit agricultural activity)
			d	d				commercial land (or parcel zoned to permit commercial development)
		d		d				institutional land (or parcel allocated to have institutional activity)
				d				school land (or parcel allocated to have school activity)
					d			low density residential land (or parcel zoned to permit low density residential development)
					d	d	d	mixed density residential land (or parcel zoned to permit medium density residential development)
							d	high density residential land (or parcel zoned to permit high density residential development)

SD Approach

- Micro-simulation of development events by parcel
  - Decision by land 'controller' of what, if any, development changes to make on land in the next 12 months.
  - Monte-Carlo: Parcels small enough so each random number draw 'not too important'
- Theory: controller (developer) is more likely to build on land as the rent exceeds amortized construction costs
- Most accessibility effects captured in zonal rent from AA
- Focus:
  - Rent
  - Construction costs, including site-specific effects
  - Zoning regulation
- Also sub-zonal impacts on attractiveness, rent modifiers for:
  - Frontage
  - Age
  - Local effects (density and proximities)

joint ... velop ... conti ... e

Rent less amortized construction cost <u>per unit space</u>

Additional Rent less development costs <u>per unit land</u>

$$RU_{hjp} = T_{hjp} j + lTr_{hjp} + l\varepsilon_s + l\varepsilon_q$$

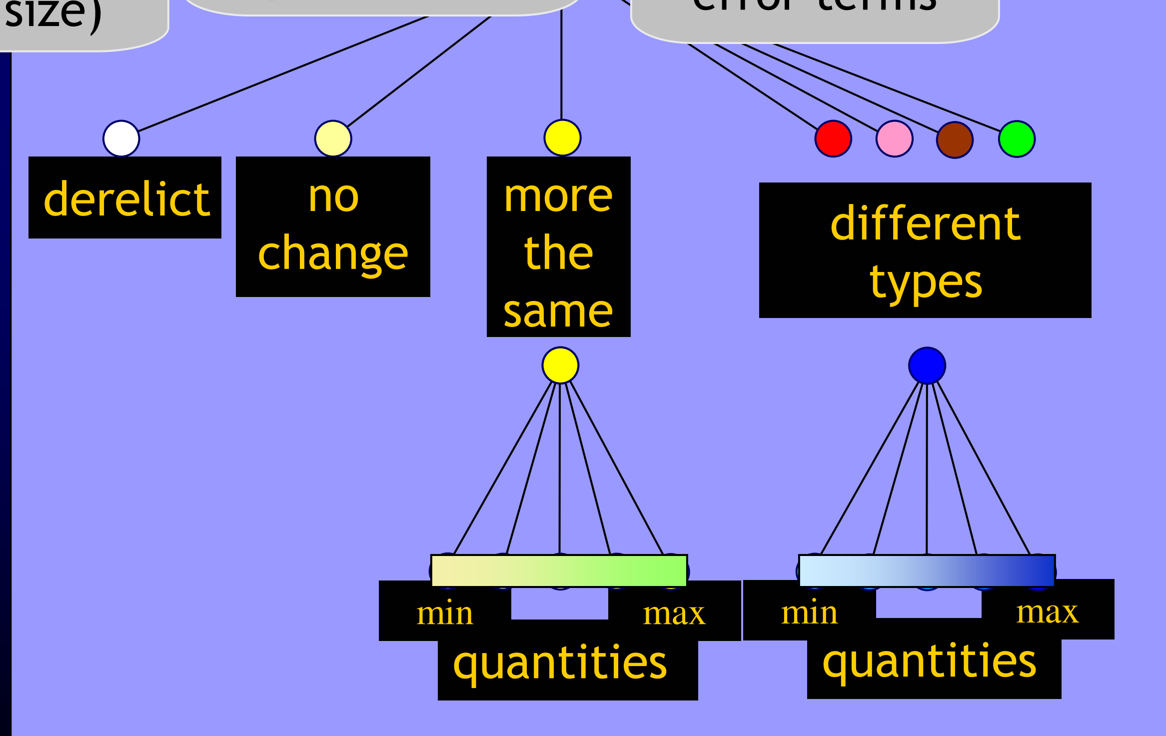
Space quantity (building size)

Land quantity (parcel size)

Stochastic error terms

- **Future space t** (development type)
- **Future space quantity j** (usually building size)
- On parcel *p* of size *l* currently containing quantity *b* of space type v
- Zoning restricts *j* to range

$$\left[Q_{hp}^{\min}, Q_{hp}^{\max}\right]$$



Simulating Space Type: Sampling Distribution

$$\Pr(h) = \frac{\exp\left(\frac{\tilde{V}_h}{l}\right)}{\sum_{h' \in S} \exp\left(\frac{\tilde{V}_{h'}}{l}\right)}$$

evaluating integral over range of permitted intensities

$$\tilde{V}_h = \frac{l}{\mu_q} \ln\left(\frac{l e^{\mu_q \left(T_{hjp} \frac{j}{l} + Tr_{hjp} \right)}}{\mu_q T_{hjp}} \Bigg|_{j=Q_{hp}^{\min}}^{Q_{hp}^{\max}} \right)$$

Simulating Space Quantity (Intensity): Sampling Distribution

From a random draw *x* in the interval [0,1] we can select *j**

$$j^* = \left(\frac{\ln \frac{\mu_q T_{hjp} \left(x D_{Q_{hjp}^{\max}} - D_{Q_b} \right)}{l}}{\mu_q} - Tr_{hjp} \right) \frac{l}{T_{hjp}}$$

$$D_x = \frac{le^{\mu_q \left(T_{hjp} \frac{j}{l} + Tr_{hjp} \right)}}{\mu_q T_{hjp}} \Bigg|_{j=Q_{hp}^{\min}}^{x}$$

And Q_b = the highest boundary point defined by the discontinuities in T_{hjp} and Tr_{hjp} for which

$$D_{Q_b} < x D_{Q_{hp}^{\max}}$$

Baltimore Estimation

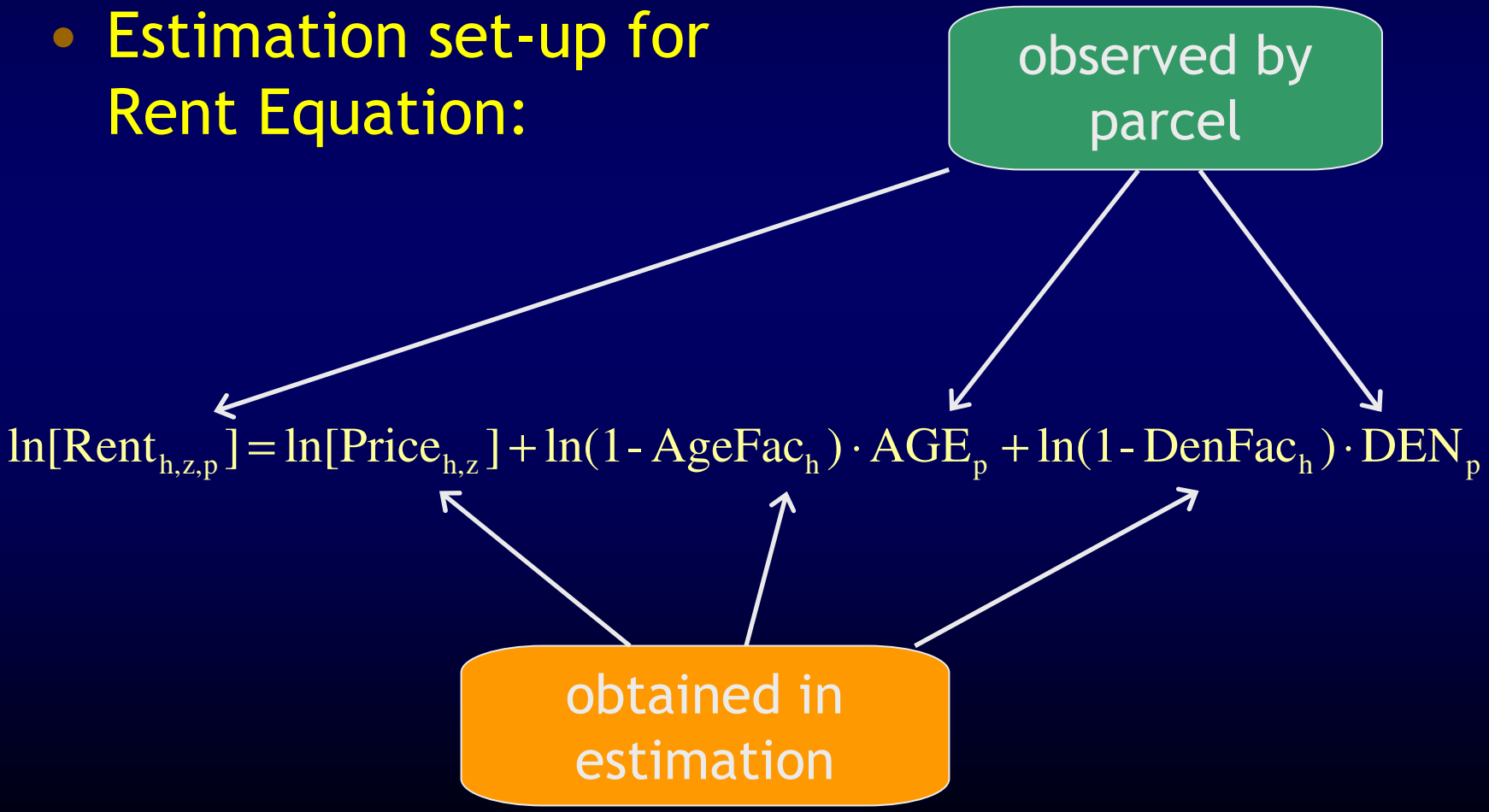
- Rent Equation:

$$\text{Rent}_{h,z,p} = \text{AA\_Rent}_{h,z} \cdot ((1 - \text{AgeFac}_h)^{\text{AGEp}}) \cdot ((1 - \text{DenFac}_h)^{\text{DENp}})$$

- Space Types:
  - Low Density Residential (11)
  - Medium Density Residential (12)
  - High Density Residential (13)
  - Agriculture (1)
  - Commercial (2)
  - Industrial (3)
  - Other Developed (4)

Baltimore Estimation

- Estimation set-up for Rent Equation:



Baltimore Estimation Values for Rent Equation

Space Type	Number of Records	Rent per year ($/sqft)^2 (reference)	$AgeFac_h$	$DenFac_h$	R^2(adj)
agricultural land	8,774	0.0502	0.0067925	N/A	0.24
industrial space	4,806	4.4167	0.0091909	0.000419	0.46
Commercial space	15,374	10.5949	0.0044341	0.000513	0.45
other developed space	8,214	9.6627	0.0039985	0.167661	0.65
low density residential space	175,203	7.9922	0.0006336	0.279508	0.39
Medium density residential space	3,015	8.6119	0.0014128	0.148666	0.64
high density residential space	20,033	4.9556	0.0000921	0.079338	0.34

Baltimore Estimation

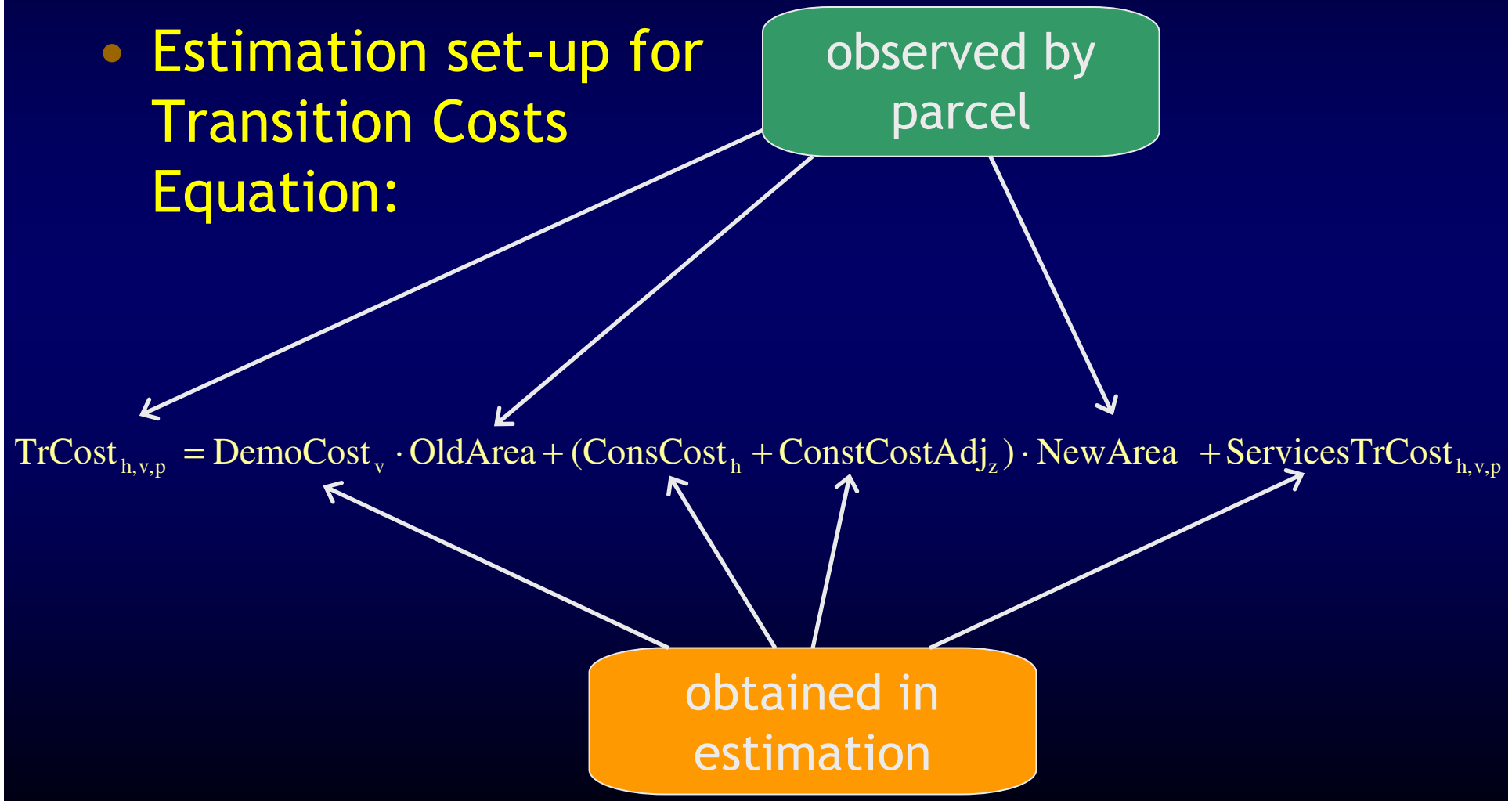
- Demolition and Construction (Transitions) Costs Equation:

$$\mathrm{TrCost}_{h,v,p} = \mathrm{DemoCost}_{v} \cdot \mathrm{OldArea} + (\mathrm{ConsCost}_{h} + \mathrm{ConsCostAdj}_{z}) \cdot \mathrm{NewArea} + \mathrm{ServicesTrCost}_{h,v,p}$$

- Space Types:
  - Low Density Residential (11)
  - Medium Density Residential (12)
  - High Density Residential (13)
  - Agriculture (1)
  - Commercial (2)
  - Industrial (3)
  - Other Developed (4)
  - Derelict Space (21)
  - Vacant Brown Field (31)
- Zoning Types:
  - High Density Residential (1)
  - Medium Density Residential (2)
  - Low Density Residential (3)
  - Very Low Density Residential (4)
  - Commercial (5)
  - Industrial (6)
  - Municipal (7)
  - Most Protective (8)
  - Moderate Protective (9)
  - Least Protective (10)
  - Mixed Used (11)
  - Other (12)
  - RoW (13)

Baltimore Estimation

- Estimation set-up for Transition Costs Equation:



Baltimore Estimation Values

Space Type	N	ServicesTrCost	DemoCost								R^2 (adj)
		Municipal Water Use	Industrial space	Commercial Space	Other Developed Space	Low Density Residential Space	Medium Density Residential Space	High Density Residential Space	Derelict Space	Vacant Brown Field Land	
Industrial Space	201	-	0.195	0.577	4.640	9.452	1.425	-	1.532	11.687	0.730
Commercial Space	572	63.966	1.063	2.888	4.096	41.721	23.104	50.588	-	20.623	0.657
Other Developed Space	161	-	-	-	1.461	-	-	-	-	-	0.900
low density residential space	18856	-	6.363	2.571	-	1.792	-	-	1.434	-	0.710
medium density residential space	1968	-	-	-	-	-	-	-	-	-	0.649
high density residential space	302	-	-	2.759	-	3.809	-	-	-	-	0.668
vacant brownfield land	171		3.432	3.432	3.432	1.322	3.432	14.708	1.723		0.663

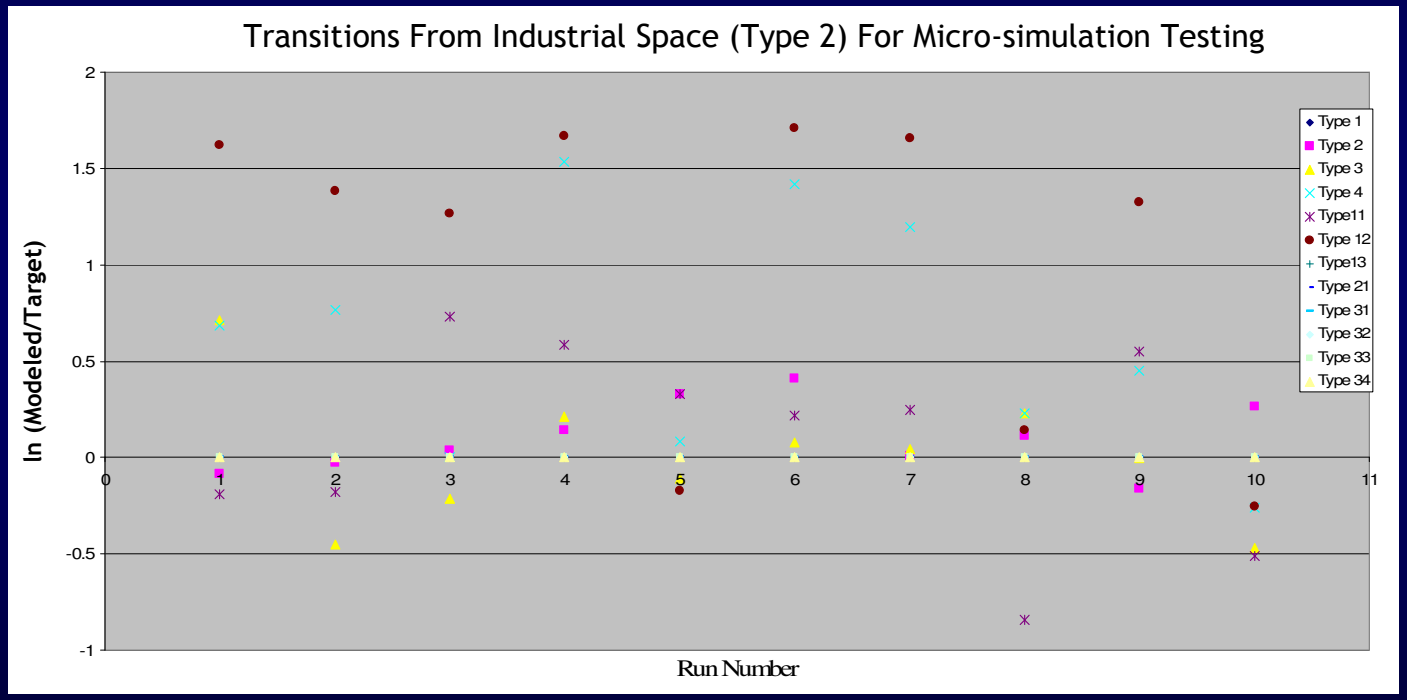
Space Type	ConsCost	ConsCostAdj											
		High Density Residential	Medium Density Residential	Low Density Residential	Very Low Density Residential	Commercial	Industrial	Municipal	Most Protective	Moderate Protective	Least Protective	Mixed Use	Other
Industrial Space	18.449	-6.450	-6.450	4.655	-	-	-	-	-	4.655	-6.450	-	-
Commercial Space	30.718	-17.309	-17.309	-20.110	-	-	-	-	-20.110	-20.110	-17.309	-	-12.711
Other Developed Space	36.340	56.822	20.995	15.313	65.285	33.407	-	-	21.599	15.918	37.550	-	-
low density residential space	33.548	-	-	-	-	-15.371	-15.371	-	3.321	-1.274	-	-	-
medium density residential space	46.181	-	-	10.705	-	-	-	-	-	-	-	-	-
high density residential space	31.872	-	-11.741	3.001	-	-6.041	-6.041	-	-	-	-	-	-
vacant brownfield land	-	-	-	-	-	-	-	-	-	-	-	-	-

Calibration

- Approach
  - Run model in Aggregate over 6 year period using the rent equation and transition cost equation estimations
  - Adjusting constants for transition probabilities to match aggregate targets for transitions
- Developing Aggregate Data for Targets
  - History of Transitions over 6 year period (2000-2005) from building permits – available in electronic form in BMC
  - Link them with parcel file (snap-shots from year 2000) to establish previous use and relevant zoning rules
  - Data for both parcels and sqft, but targets just sqft
  - Eliminated outliers from permit file (less than 1 $/sqft and more than 250 $/sqft)

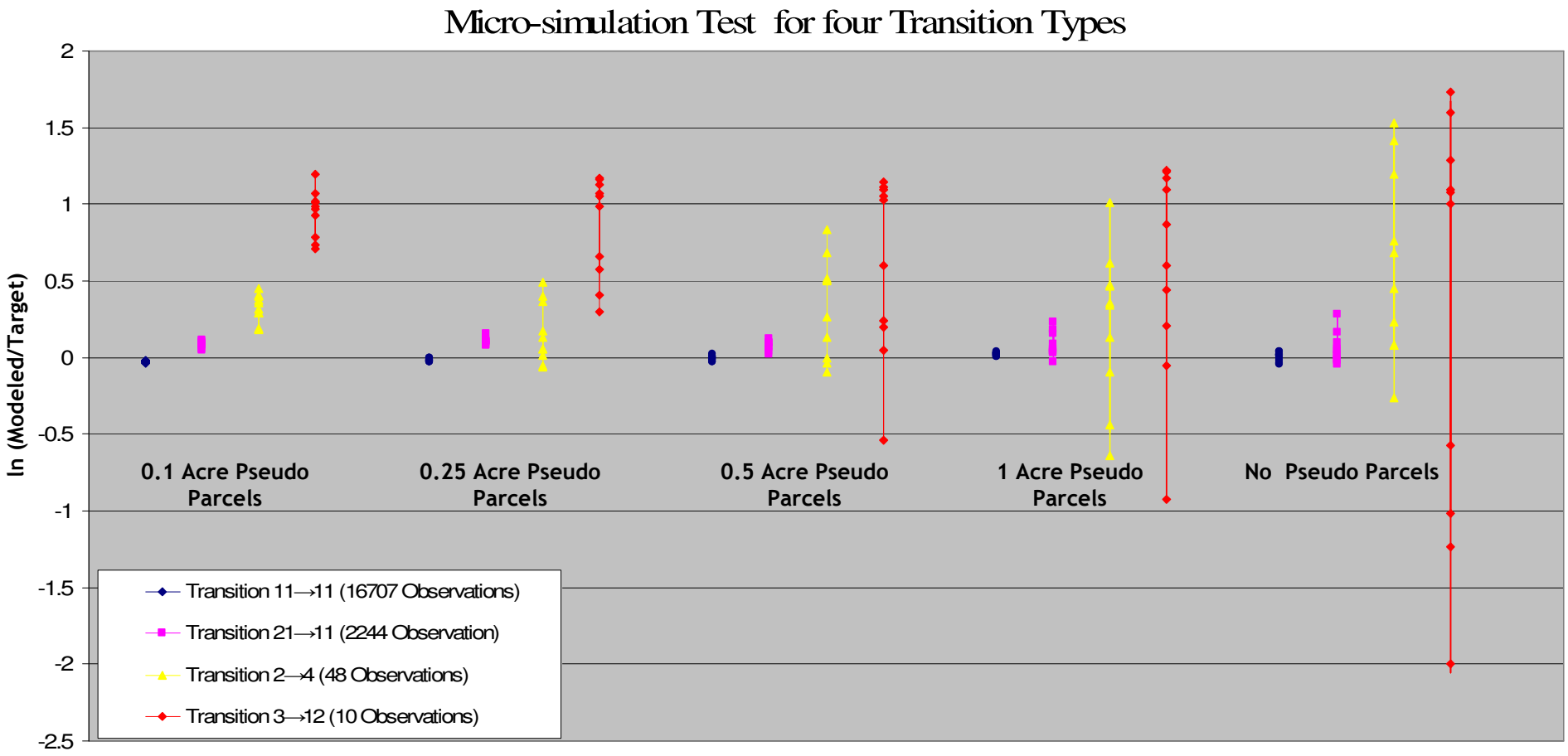
Calibration

- Issues encountered in Calibration
  - Micro-simulation error



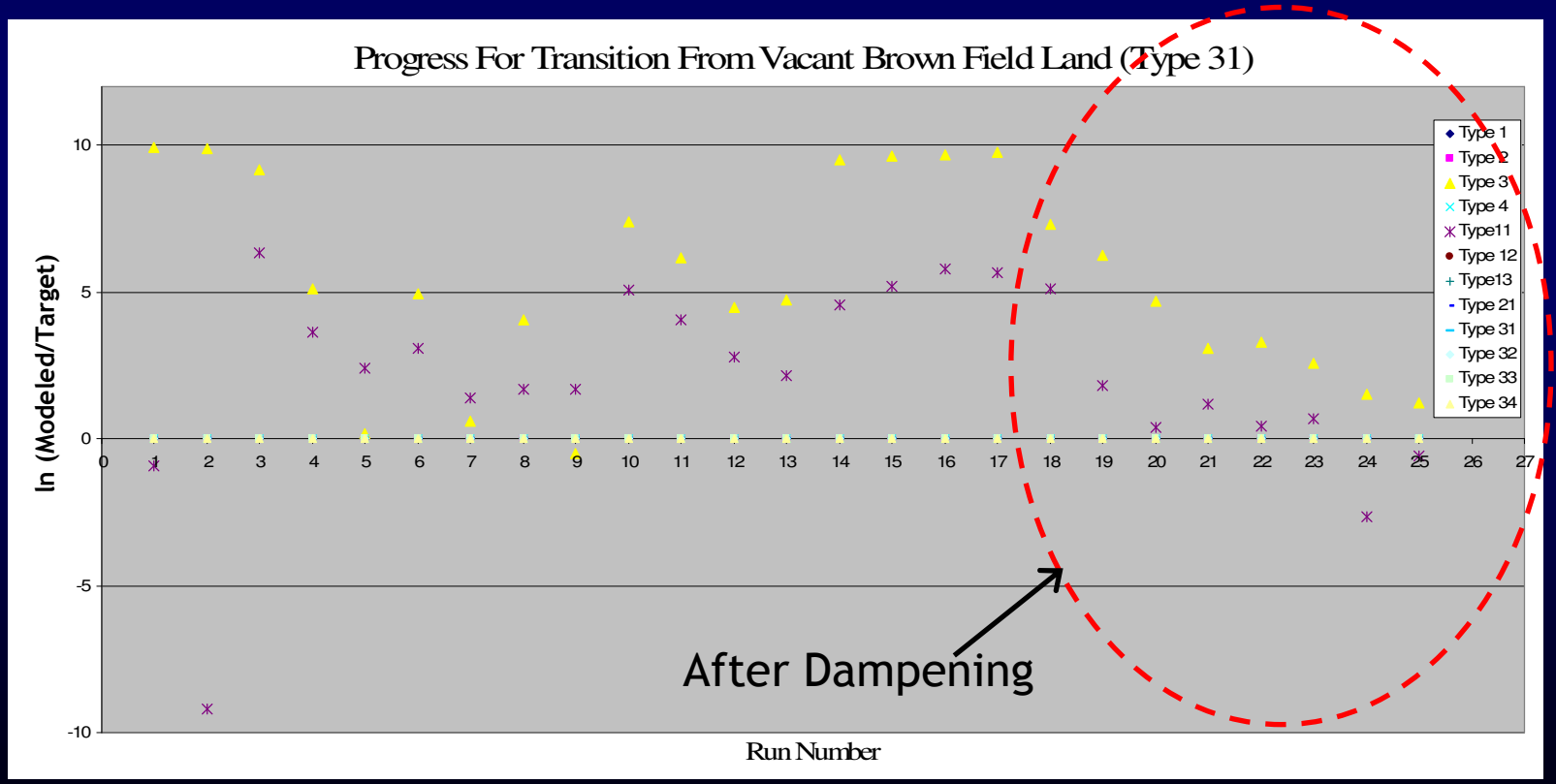
  - Eliminated extremely infrequent transitions and redistributed to maintain total sqft in category
  - Introduced pseudo-parceling

Calibration



Calibration

- Issues encountered in Calibration
  - Large Oscillations
    - Dampened update equation – Eventually to 25%



Results

- Transitions: Model Match to Targets

Modeled/ Target	agricultural land	industrial space	commercial space	other developed space	low density residential space	medium density residential space	high density residential space	derelict space	vacant brownfield land
From/To	1	2	3	4	11	12	13	21	31
1	-	0.84	1.26	-	1.00	-	-	-	-
2	-	0.98	1.00	0.87	1.03	0.99	-	-	-
3	-	1.00	0.99	1.01	1.01	1.16	1.99	-	1.26
4	-	1.00	1.06	0.99	0.99	-	-	-	-
11	-	0.97	1.06	0.88	0.99	0.98	1.29	-	0.89
12	-	-	1.05	0.79	1.01	1.03	-	-	-
13	-	-	0.48	1.37	1.02	0.96	1.57	-	-
21	-	-	1.42	1.10	1.01	1.00	1.28	-	0.99
31	-	-	1.54	-	0.84	-	-	-	-

Conclusions

- Micro-simulation approach reasonably viable in practical context
  - Good data
  - 6 minutes per year (GIS 'work-arounds')
  - Still a 'research element'
- Micro-simulation error problematic
  - Avoid small samples (infrequent transitions)
  - Implement pseudo-parcelling
  - Obtaining (sampling distribution) expectations – perhaps less 'lumpy' than real-world for infrequent transitions – an issue??