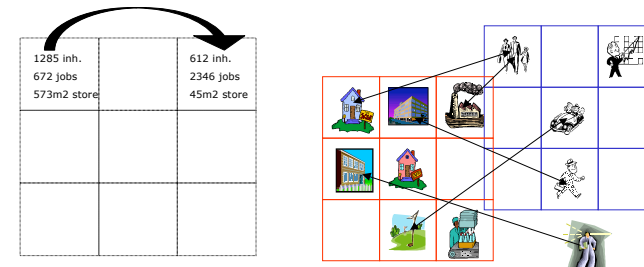


## PUMA (Predicting Urbanisation with Multi-Agents): multi-agent modelling of urban systems

Dick Ettema (Utrecht University)

## Agent-based models: principles

- zone based
- agent based




## Agent-based models: principles (2)

- individual representation of agents (individuals, households, firms, jobs, dwellings)
- object oriented
- micro-simulation (increased computing power)
- emergence
- Examples:
  - UrbanSim (Waddell)
  - Ilumass (Wegener)
  - Ilute (Miller)
  - PUMA (Ettema, Timmermans)

## Why agent-based models?


- need for better theoretical underpinning of LUTI models:
  - emphasis on processes, not only on end state
  - wider range of interests (segregation, equity, environment, economic markets)
  - better behavioural models (travel/activities, relocation, social interactions)
  - incorporation of activity-based models
  - micro-macro interactions

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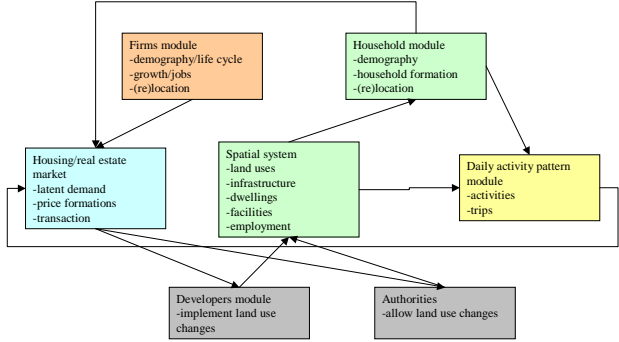
## PUMA (Predicting Urbanisation with Multi-Agents)

- joint effort UU, TU/e, MNP
- agent-based model of short and long term spatial behaviour
- use of advanced behavioural models
  - housing market
  - activity based travel model
  - interaction short term/long term decisions
  - social interaction

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## PUMA : components



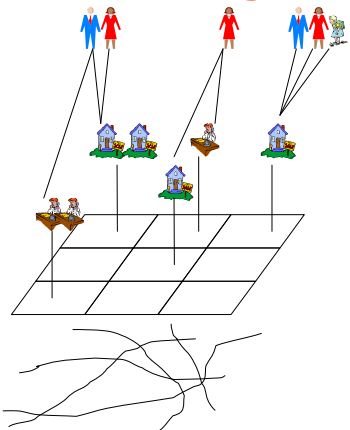
```

    graph TD
      Firms[Firms module  
-demography/life cycle  
-growth/jobs  
-(re)location] --> Housing[Housing/real estate market  
-latent demand  
-price formations  
-transaction]
      Firms --> Spatial[Spatial system  
-land uses  
-infrastructure  
-dwellings  
-facilities  
-employment]
      Household[Household module  
-demography  
-household formation  
-(re)location] --> Spatial
      Household --> Daily[Daily activity pattern module  
-activities  
-trips]
      Housing --> Spatial
      Spatial --> Daily
      Developers[Developers module  
-implement land use changes] --> Spatial
      Authorities[Authorities -allow land use changes] --> Spatial
      Daily --> Spatial
  
```


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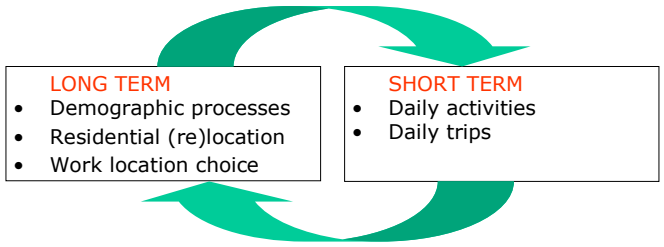
## PUMA : Data organisation



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## PUMA : Households' behaviour




**LONG TERM**

- Demographic processes
- Residential (re)location
- Work location choice

**SHORT TERM**

- Daily activities
- Daily trips

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## PUMA : demographic processes (1)

- Birth, death, marriage, divorce, leaving home (alone or to form a couple): probabilities derived from CBS statistics

**Necessary conditions for events**

Event	Necessary condition of $S_t$
giving birth	female, age 18+
dying	no requirements
leaving parental home	living with parents, age 18+
marriage	single or living with parents, age 18+
divorce	being married
moving	no requirements

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## PUMA : demographic processes (2)

**Consistency between events**

Event	Rules out (for the same year)
dying	giving birth, leaving home, marriage, divorce, moving
leaving home to live single	Marriage
leaving home to marry	Divorce
marriage	Divorce
divorce	Marriage

- 'Marriage broker' to match individuals looking for a partner

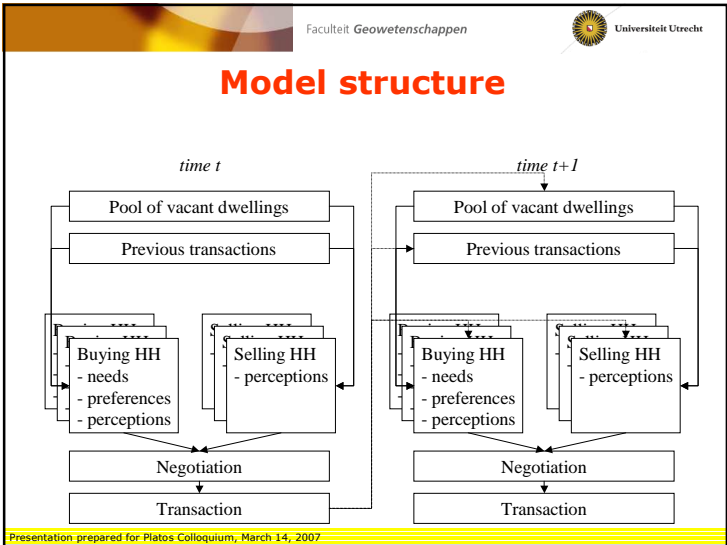
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## Residential (re)location/housing market

- Prices and availability affect residential patterns
- Price setting under uncertainty
- Perception of prices and probabilities
- Negotiation
- Market volatility vs. Equilibrium

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## Buying household

Relocate?  
 $U^o > U^c + T^s$

Evaluate dwellings 1...n

Negotiate?  
 $U^i > U^c + T^n$

Accept?  
 $U^i > U^c + T^b$   
 $U^i > E(U^o)$


$$U^c = f(X_1^D, \dots, X_n^D, X_1^H, \dots, X_n^H)$$

$$U^o = \max(U_1, U_2, \dots, U_n)$$

$$EU(X, L) = P^o(X, L)U(X, L) + (1 - P^o(X, L))d_2EU(X, \alpha_2L)$$

$$P^o(X, L) = 1 / (1 + \exp(\gamma_1 + \gamma_2(L - \bar{S}(X)))$$


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## Comparing scenarios

	Vacancy rate <b>20%</b>	Vacancy rate <b>10%</b>	Vacancy rate <b>5%</b>	Vacancy rate <b>2.5%</b>
UTIL	13.48	3.11	-3.97	-11.04
UOPT	17.83	5.18	-0.75	-6.21
Price	0.97	1.54	1.80	2.05
%wait	0.92	0.55	0.14	0.00
$P^o$	0.22	0.50	0.54	0.55
$P^{oo}$	0.40	0.27	0.15	0.05
%sold	0.19	0.42	0.47	0.50
#search	417	232	255	288
#sold	23	25	14	7

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## PUMA : worklocation and -status

**work status and work location choice models**


	Logistic regression model of work status (1= working)		Multinomial Logit model of work location choice
Constant	0.867	Commute distance	-0.092
Age < 25	0.462	HighEduc*commute dist.	0.055
Age 40-54	-0.336	Kids*commute dist.	-0.029
Age 55-65	-1.980	Female*commute dist.	-0.050
Mother	-0.401	# jobs within 30 minutes by car	$0.425 \cdot 10^{-5}$
Male	0.845	# inhabitants within 30 min. by	$-0.156 \cdot 10^{-5}$
Male*Age < 25	-0.785	HighEduc*% office jobs	1.539
HighEduc*Age < 25	0.443	HighEduc*# of jobs	$0.938 \cdot 10^{-6}$
HighEduc*Age 25-39	1.128		
HighEduc*Age 40-54	1.081		
HighEduc*Age 55-65	0.786		
Nagelkerke $\rho^2$	0.272	adjusted $\rho^2$	0.327

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## PUMA : simulation process

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## PUMA : implementation

- Northwing Dutch Randstad
- 1.5 million households, 3.16 million ind.
- 1.6 million dwellings
- synthetic population base year 2000
- population of ind. dwellings and jobs
- PC6-zones (62,000 zones)

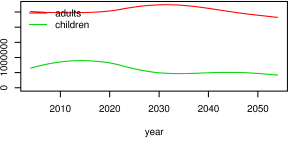


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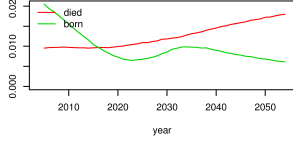
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## PUMA : results (1)

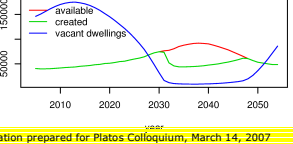
**a: Adults and children**



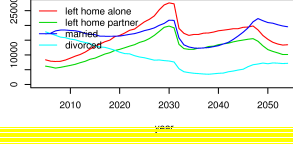
**b: Percentage died and born**




**c: Households**



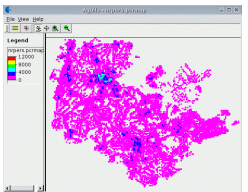
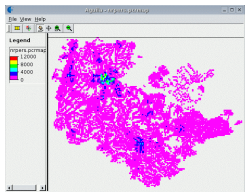
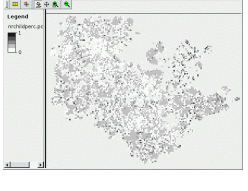
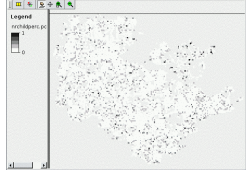
**d: Marital status**




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## PUMA : results (2)


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## New developments

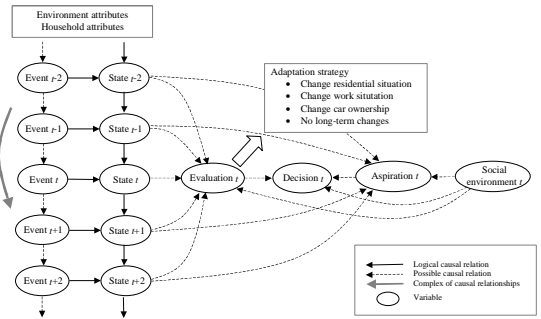
- Modelling firms development
  - Offices (locational preference data combined with detailed office data, fuzzy decision tables)
  - Model of firms demographics (PhD grant-applied for)
- Integration long term model with activity based model (Albatross/Aurora)

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## New developments

- Integrated modelling of long-term mobility decisions (1 PhD project)

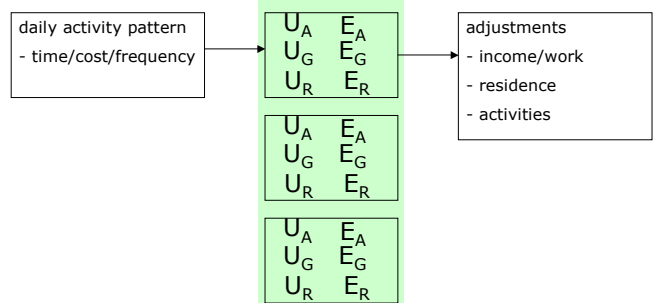


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## New developments

- Integrated modelling of short-term and long-term behaviors



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## PUMA : conclusions

- Advantages of agent-based LU model
  - more detail in effects
  - more realistic behavioural models
  - micro-macro interactions
- Metropolitan level (1,5 million households) is feasible

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