MODELING TRANSPORT LAND USE INTERACTIONS SIMBAD MODEL

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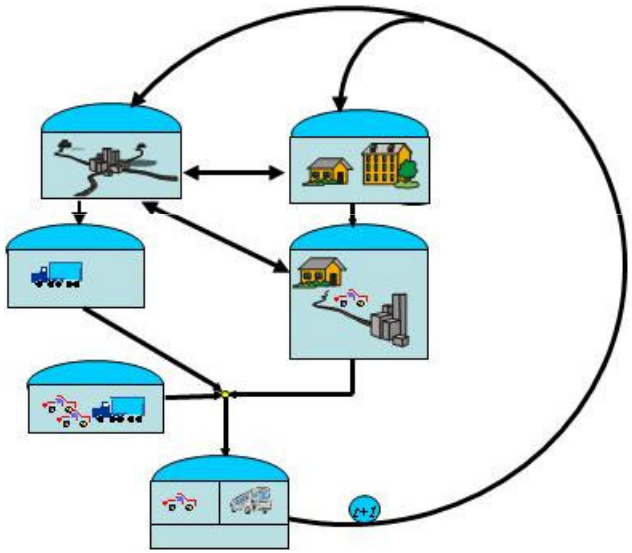
Simbad

SImuler les MoBilités pour une Agglomération Durable / Mobility simulation for a sustainable conurbation



- ❖Transport: development of a four steps model, urban freight modeling, through and exchange traffic
- ❖Land use: household and activity location choice models
- ❖Dynamics of land-use – transport interaction trough accessibility and a one year interval step

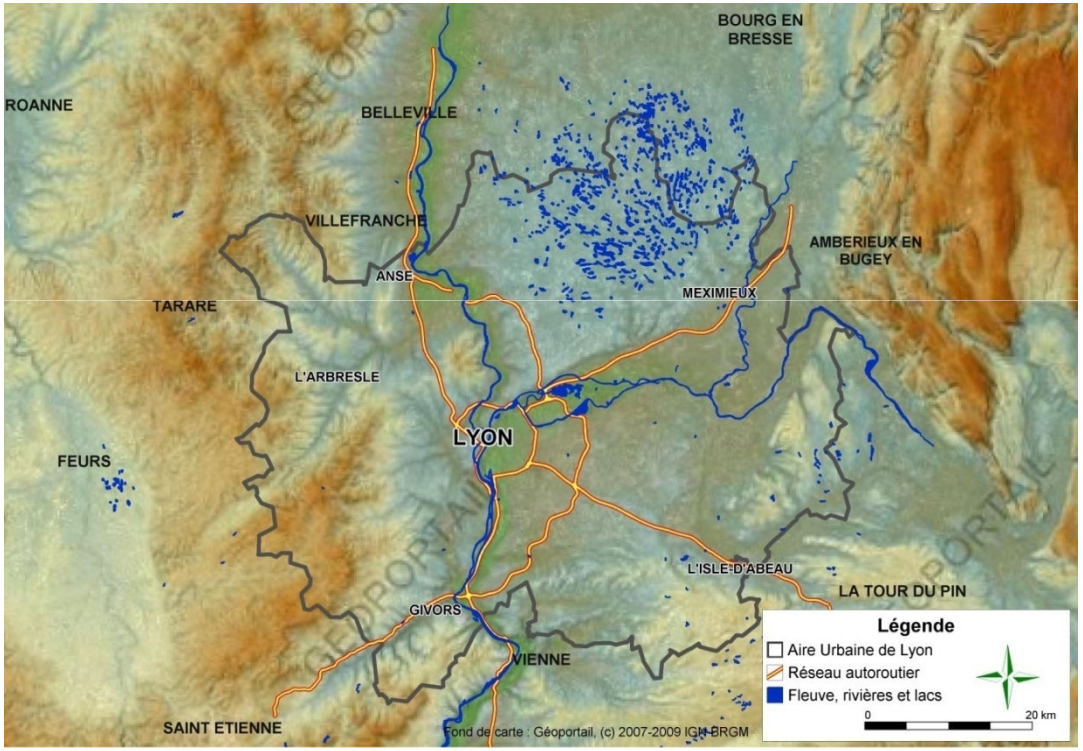
To assess transport and land use policy in the context of sustainable development

Simbad: objective

- **Objective**: assess transport and land use policy in the context of sustainable development
- **3 stakes:**
  - Assessment of public policy in transport and urbanism
  - Integrate sustainable development in assessment (economic + environmental and social dimensions)
  - Methodological in terms of modeling (land-use – transport interaction, simultaneous integration of person and freight traffics

Simbad: modeling dimension

- Time horizon:
  - Reference 1999 (census data)
  - Horizon: 2025
- Study perimeter:
  - Urban area (25-30 km around Lyon)
- Traffic:
  - Persons
  - Freight
  - Trough and exchange traffic



Lyon urban area
1,6 millions inhabitants in 1999

Simbad: sustainable mobility indicators

Services

Economic accessibility

- Employment accessibility
- Shopping & administrative matters accessibility
- Economic activity accessibility
  - Measurement: trip average duration and cost

Social accessibility

- Population segmentation based on income and localization
  - Daily time budget
  - Daily total travel expenditures
  - Daily distance budget per transport mode

Costs

Environnemental

- CO2, CO, NOx, particles and hydrocarbons emissions
- Energy consumption
- Transport space consumption
  - Global stock and unitary assessment by person*km and by surface

Economic

- Individual (real and perceived) and collective cost
  - by person/HH, trip, day, annual;
  - by person*km
  - By enterprise, administration…

Social

Household segmentation based on income and localization

- Annual expenditure, % of income

Simbad: implications for modeling

Model out-put indicators definition:

- Trip measurement by day (peak/off peak modeling), by year: duration, distance, O-D, transport mode, cost calculation, emission calculation
- Mobility per person and per household
- Segmentation per income, per home location (trip and mobility indicators), per zone
- Accessibility measurements
- Cost per stakeholder (household, enterprise, administration)

Simbad: strategic prospective

Business as usual scenario (2025/1999)

- Population increase: 18,5%
- GDP increase: 2%/year (for all economic/population segment),
- Constant car cost
- Decrease of road investments
- Still important public transport investments with a hierarchical network (train/metro/tramway/bus lane) for all urban area

-

Simbad: strategic prospective

Scenarii examples

- ***Mobile city*** strong economic increase which stimulates road investment
- ***Immobile city in an old Europe*** economic crisis which limits investment and increase social differentiation
- ***Car as vector of urban cohesion?*** still important urban sprawl (especially for low and medium income segment) with strong increase of car cost
- ***Looking for a territorial coherent policy*** consequence of coherent/divergent policy between center and outer suburbs area

Simbad: implications for modeling

Model in-put policy indicators:

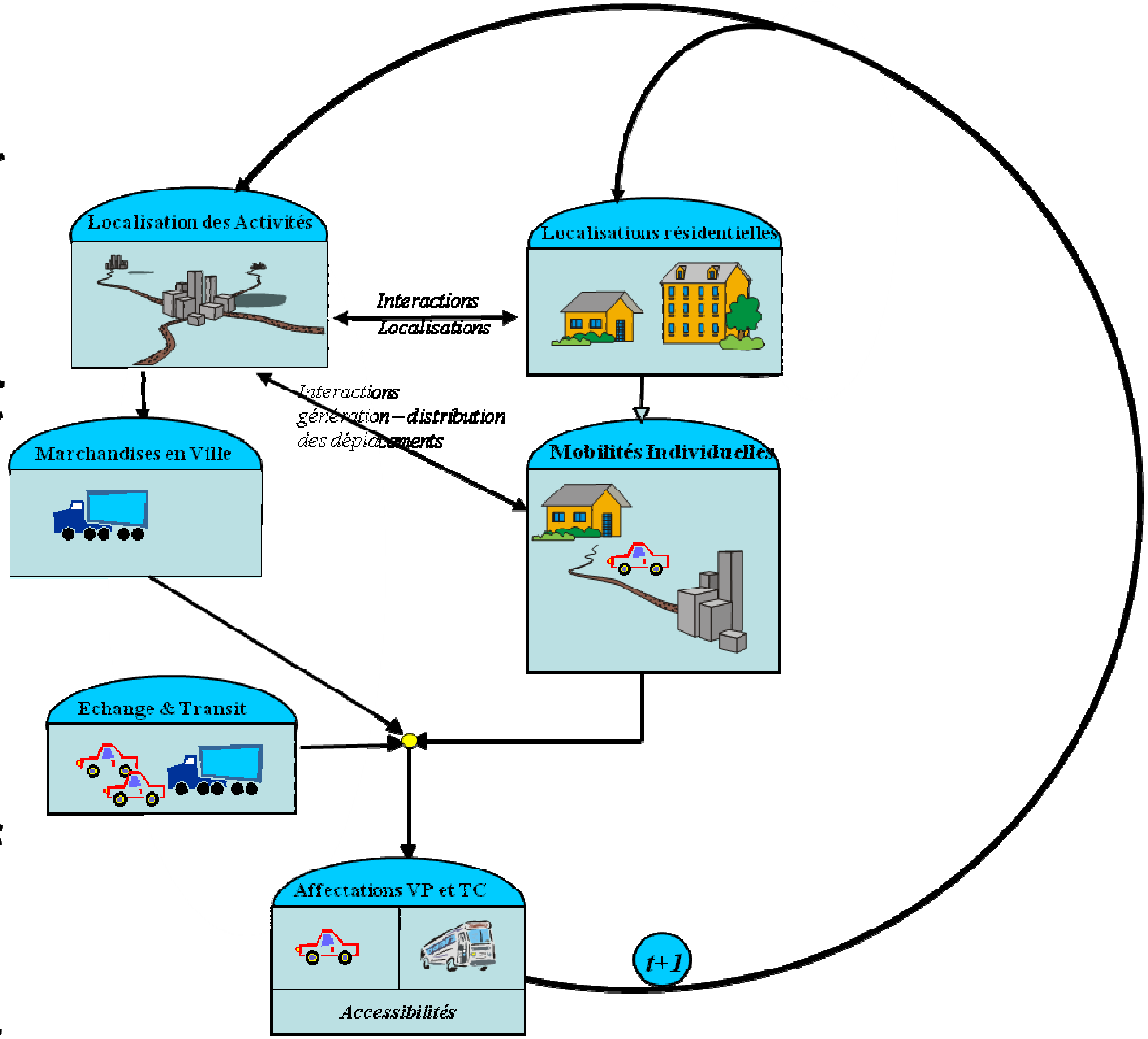
- Need to model the impact of GDP evolution (on cost, income, car ownership, housing price…)
- Need to model urban development (urban sprawl, real estate development…)
- Need to model transport investment policy (road/public transport investment…)
- Need to model travel cost policy (car purchase, car use, car parking, urban toll…)
- Need to model territorial divergent policy (differentiation of above policy indicators per territory)

Simbad: a classical structure

Localisation des activités et des ménages
Modules UrbanSim

Génération, distribution et répartition modale
Des modèles 'LET': FretUrb, prolongements Télescopage

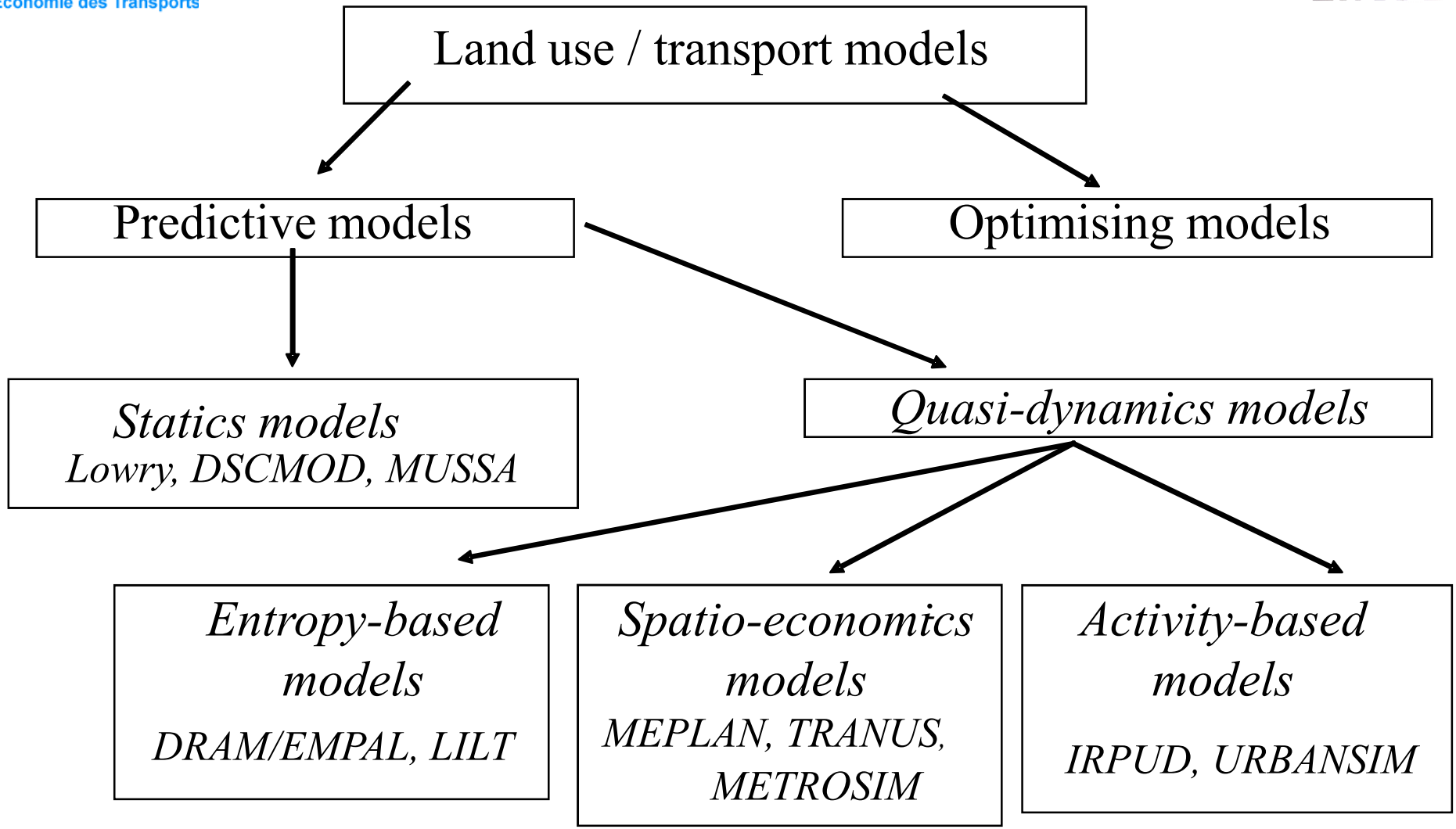
Affectation des trafics
Logiciel DaviSum



Simbad: but several developments

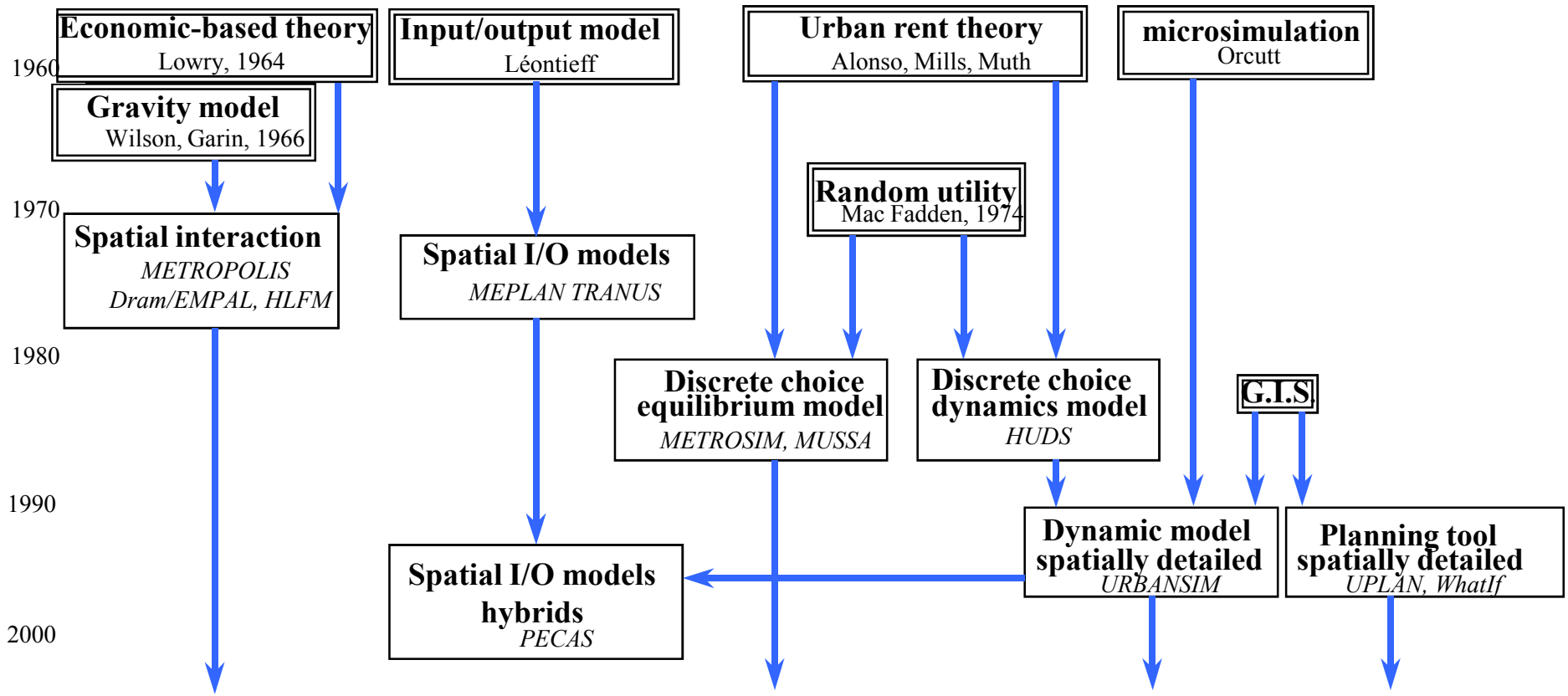
- Interaction land use – transport using Urbansim platform
- Integration of urban freight transport
- A random generation of individual trip
- Segmentation on income for the whole four-steps chain of models: results could be analyzed per income segment
- Network coding: use of existing network data bases (navteq and georoute for car; geolocalization of public transport stops)

LUTI: classification/ objectives



Source: Simmonds, Echenique, Bates, Oosterhaven, 1999

LUTI: classification/ theoretical foundation



Source: Paul Waddel, Urbansim

LUTI: theoretical foundation

Economic-based theory (Lowry model)

- Economic activities are divided into basic activities and inferred activities
- Development of basic activities (mainly for export) is correlated with exogenous hypothesis of economic development
- Inferred activities, on contrary are dependent of basic activities and are located in relation with basic activities
- Households locate in relation with job locations (gravity model) and generate employments in relation with household needs…

LUTI: theoretical foundation

Input-output Leontieff matrix

- Based on segmentation of the economy in sector: several sectors for the economy; household; administration…
- Urban economic system is described through an exchange matrix between economic sectors: output of a sector is the input of another
- Industry uses household, land… input
- Households uses industry services, land… input
- Exchanges are then translated in terms of travel needs

LUTI: theoretical foundation

Urban rent theory (Alonso, Mills, Muth)

- Land value results from a trade-off between accessibility to CBD and transport costs which increase with distance to CBD
- First monocentric model form leads to equilibrium model
- Dynamic models have been proposed with development in accessibility measurement, generalized transport cost, polycentric approach and the introduction of amenities (central or environmental)

LUTI: theoretical foundation

- 3 main approaches in terms of location theory are combined with other theoretical approaches:
  - Gravity model
  - Random utility theory
- Distinction between static model (using mainly equilibrium approach) and dynamic models
- Detail level of the zoning system (and spatial analysis)

URBANSIM

- Simbad development (household and activity location models, transport models) is integrated with Urbansim platform developed by Waddell team
- Urbansim is
  - based on most commonly used theory;
  - dynamic with a time period step of one year;
  - modular;
  - open source which allows specific developments;
  - used by several European teams

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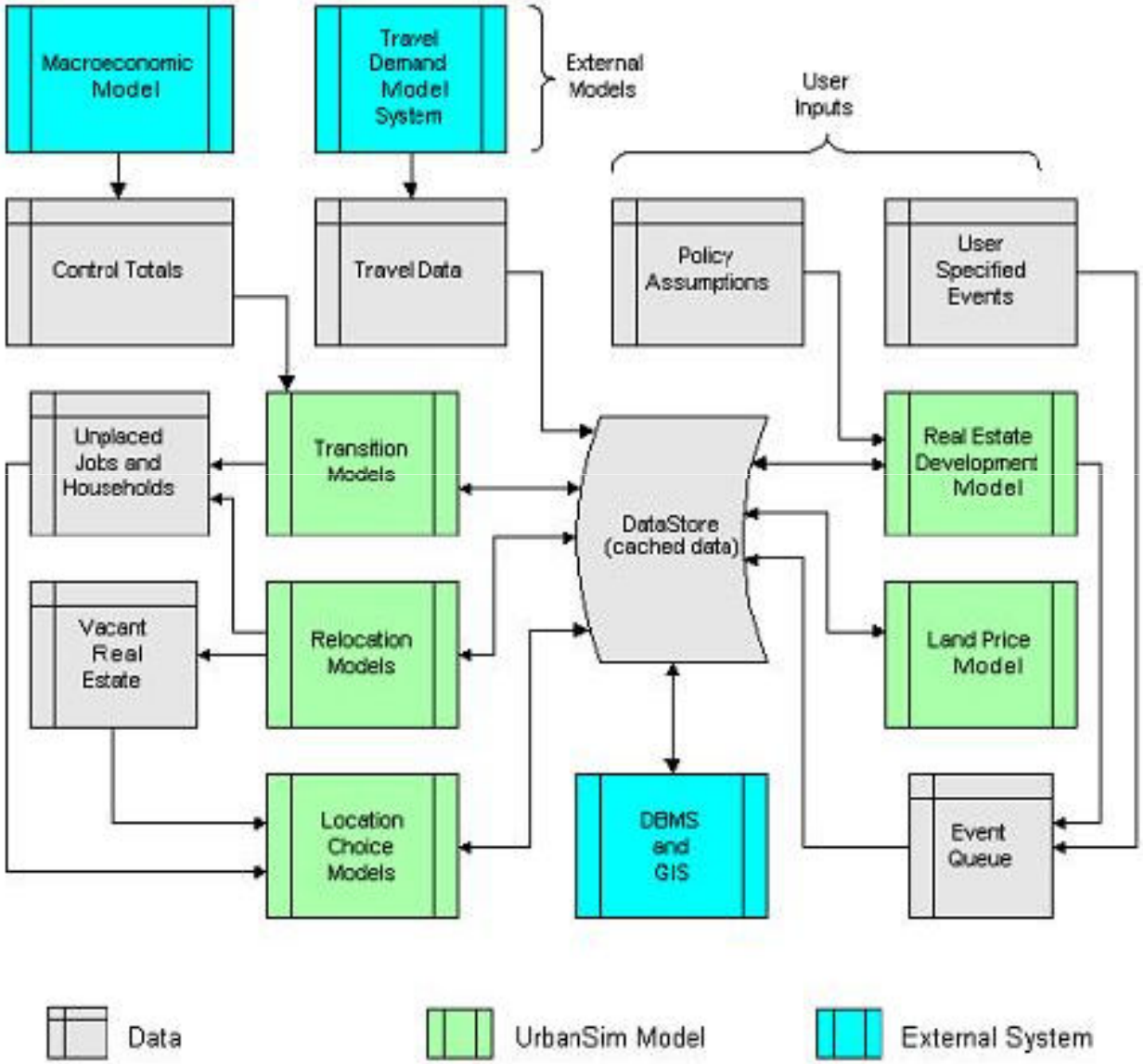
URBANSIM

Source : Center of Urban Simulation and Policy Analysis, 2009

Waddell



Household location model

- Location choice is divided in two independent stages:
  - Choice to change of home location
  - Choice to locate in a zone
- Choices are generally considered as independent because estimation of models generally uses different databases:
  - Housing survey (2002) which allows to estimate the probability to change location, but at a macro-zoning level
  - Census (1999) which allows to estimate location choice at a micro-zoning level (777 IRIS for Lyon) but does not contain enough data on location change and housing
- Theoretical background economic rent theory + discrete choice

Household location model

- Other data bases:
  - OTIF (Real-Estate Transactions database) and PERVAL (Notaries' Real-Estate Market) which allow to estimate real-estate price at micro-zoning level for Greater Lyon area and at macro-zoning level outside
  - SPOT Théma and other data bases to get residential surface area and amenities data at different zoning levels
  - Accessibilities : out put of transport model, several measurements are analyzed

Household location model: location change model

- 3 explanatory variables
  - Housing occupation status (owners/tenants)
  - Age of the household reference person
  - Household number of children which acts as a proxy (like Age) for life cycle position
- Model estimation results:
  - Observed rate of location change is 11,4%
  - 87% of households are well assigned (with/without location change)
  - And more important 42% of individual location change are well estimated

Household location model: location model

- Choice probability between 777 IRIS / 5810 small residential zones
- Accessibility variables appear important
- Household characteristics: income level, age of the household reference person, household number of persons
- Expected explanatory variables have a good p-value with the good sign
- Mac Fadden R^2 0.40
- But a significant (counter intuitive) positive coefficient for real estate price even if coefficient is very low. Price acts as a proxy for amenities especially for high income

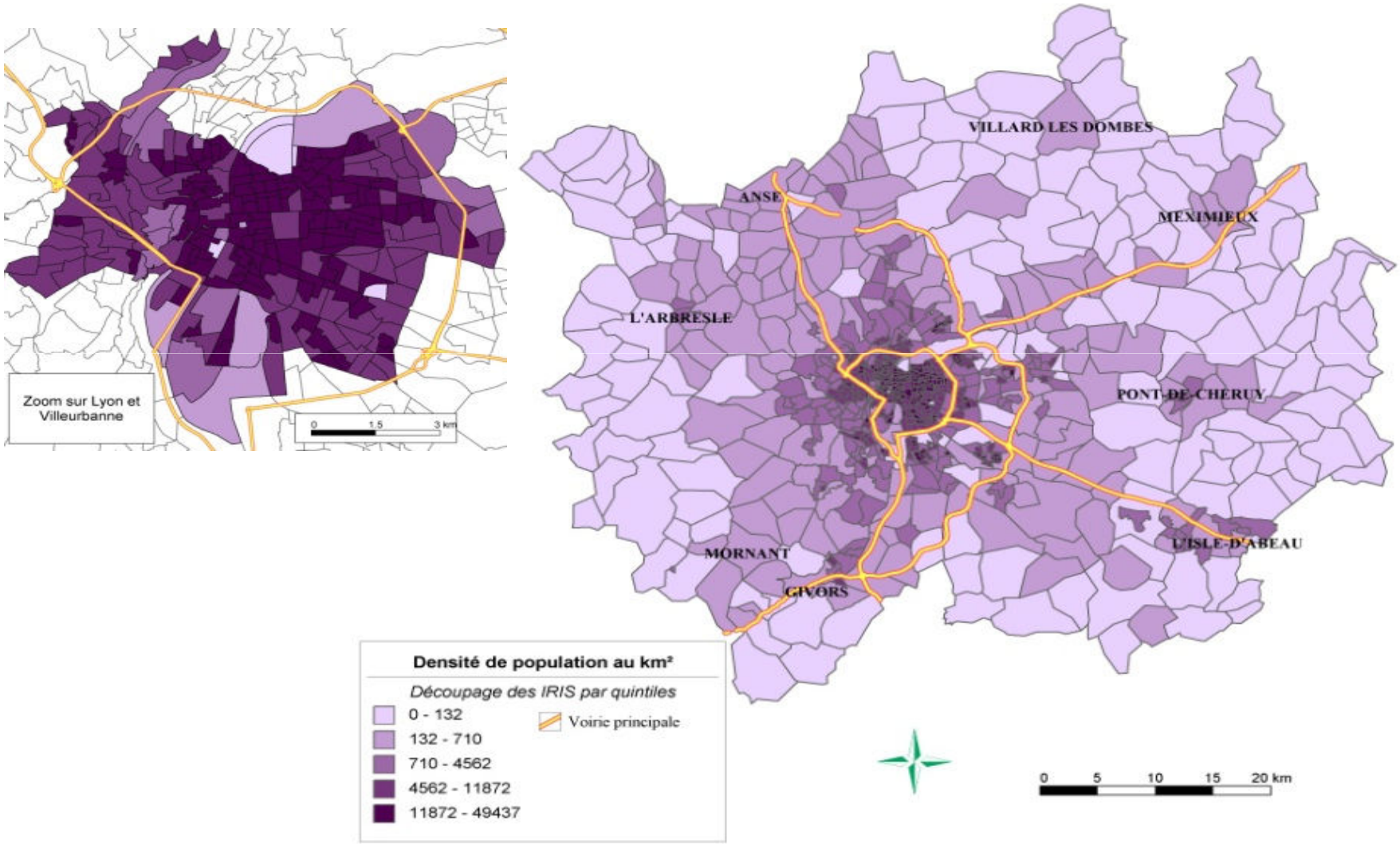
Household location model: accessibility measurement

- Access (generalized) time / distance to CBD
- Isochronal measurements: opportunities within 15/30 minutes: population, employment , tertiary-sector employment, major shopping facilities , high schools…
- Equipment / amenities / transport supply within 500m, 1000m
- Gravity accessibility indicators for population, employment…
- Distinction car / public transport
- Further development logsum gravity calculation to estimate more aggregated indicators

Aggregated accessibility measurement

- -0,119*time to CBD
- + 0,124*Number of motorway intersections within 15mn
- + 0,112*Number of bus stops within 1000 meters
- + 0,092* Number of subway stops within 1000 meters
- + 0,117* Number of train stations within 1000 meters
- + 0,129* Gravity accessibility for shopping facilities
- + 0,129* Gravity accessibility for high schools
- + 0,129* Gravity accessibility for employment
- + 0,130* Gravity accessibility for tertiary-sector employment

Out-put examples: population density

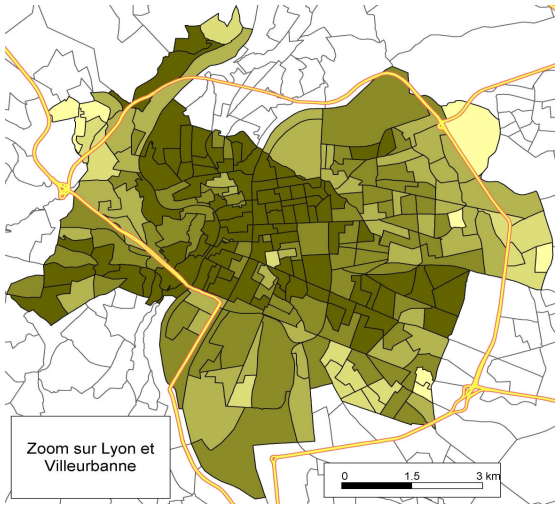


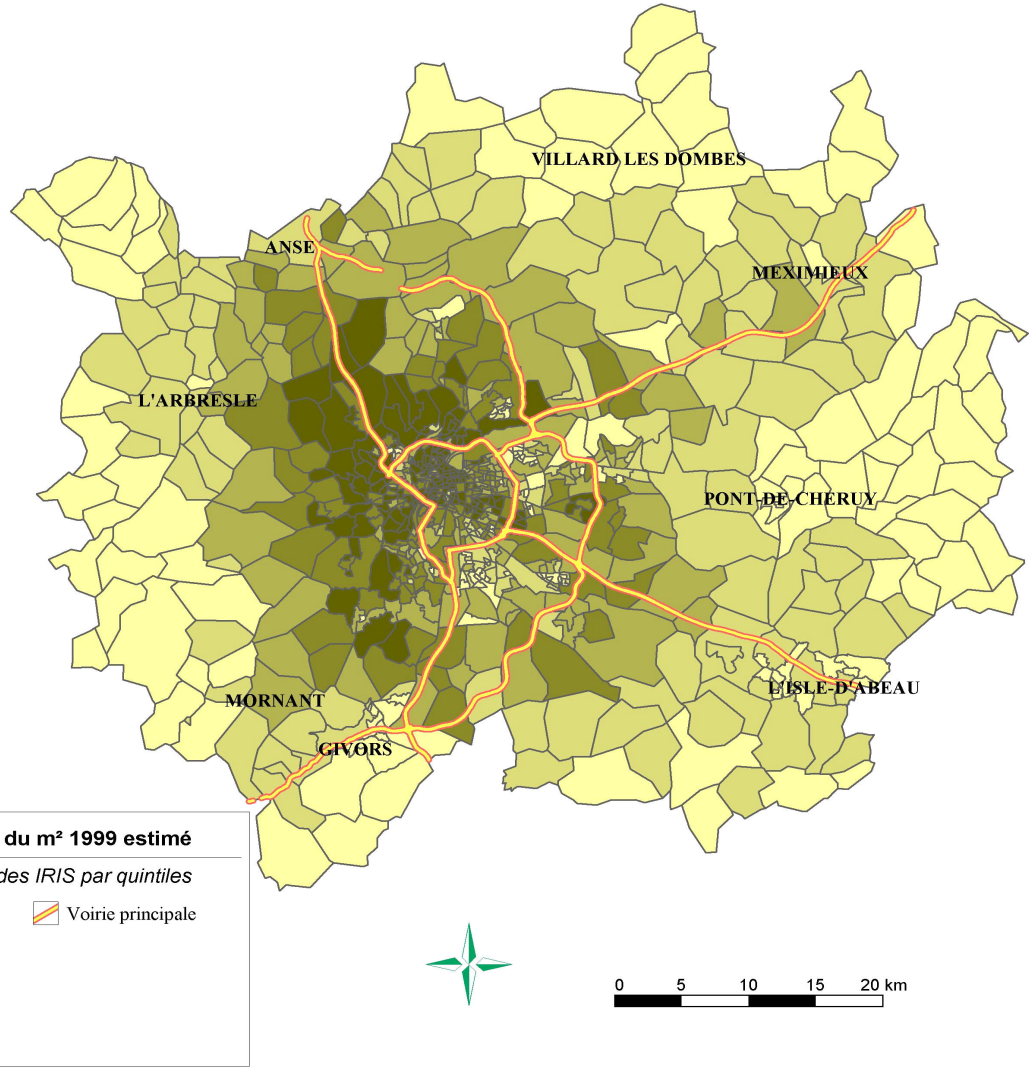
Real-estate price model

- Housing price rather than land price
- Problem of data availability and quality: building housing (not single house) for better quality
- Variables considered: accessibility, density, social diversity (income distribution)

$R^2 = 0.75$	**Coefficient**	**t Statistic**	**P Value**
Constant	935.2	23.7	$3.3\ 10^{-69}$
Car access time to CBD	-9.24	-6.11	$3.3\ 10^{-09}$
Share of household with Quintile 1 income	-5.44	-6.40	$6.4\ 10^{-10}$
Share of household with Quintile 5 income	10.63	12.84	$4.7\ 10^{-30}$

Real-estate price model





Household location model results

Variable	Coefficient	t Student	p-value
Gravity accessibility to employment	0.0004	33.03	0.000
Gravity accessibility to tertiary-sector employment	-0.0006	-33.96	0.000
Gravity accessibility to high schools	0.0661	30.25	0.000
Gravity accessibility to major shopping facilities	0.0070	38.49	0.000
Number of bus stops within 1,000 m	-0.0461	-32.57	0.000
Number of highway intersections within 15 minutes (private car)	0.0075	14.17	0.000
Number of rail stations within 30 minutes (private car)	-0.0257	-19.95	0.000
Number of subway stations within 1,000 m	0.1915	13.21	0.000
Access time to city center (private car)	0.0472	30.16	0.000
Average price per m² of old real estate	0.0007	29.93	0.000
Rate of households where the head of the household is under 30 years old (1)	3.3408	18.69	0.000
Rate of households where the head of the household is over 30 and under 45 years old (1)	1.1454	12.97	0.000
Rate of households where the head of the household is over 75 years old (1)	4.3011	6.01	0.000
Rate of low-income households (1)	-2.8740	-13.76	0.000
Rate of high-income households (1)	5.5761	25.40	0.000
Rate of one-person households (1)	1.8228	18.70	0.000
Rate of two-person households (1)	6.4583	20.94	0.000
Rate of households with 5 people or more (1)	-1.2431	-2.55	0.021

Activity location model

- Location choice is divided in two independent choices:
  - Choice to change of home location
  - Choice to locate in a zone
- Enterprise modeling rather than employment (like in Urbansim):
  - Link with urban freight model (FRETURB)
  - Decision unit = enterprise, not job
  - Data is available at enterprise level (SIRENE data base)
- Theoretical background economic rent theory + discrete choice

Activity location model: probability to move

- Rate of location change very small: 4,4%/year
  - Activity sector: from 7% services to enterprise to <2% services to household - Segmentation in 17 activity sectors
  - Enterprise size:
    - Less then 10 employees: 90% of enterprise movements
    - No employee: 50% of the movement
    - Final segmentation: No employees; 1-9; 10-19; 20-49; 50-99; 100-249; >249
- Data base:
  - SIRENE enterprise data base with activity sector, size, x-y location…
  - REE (enterprise repertory) with information on location change (all employment except administration)

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Activity location model: probability to move

Secteurs		*aucun salarié*	*TPE*		*PME*		
		0	*1 - 9*	*10 - 19*	*20 - 49*	*50 - 99*	*100 - 249*
Services aux particuliers	EP	2,30%	0,72%	0,37%	0,41%	0%	0%
Commerce de détail, réparation	J3	3,33%	1,62%	1,23%	1,30%	0%	2,78%
Activités immobilières	EM	6,64%	4,28%	7,02%	3,14%	0%	0%
Services aux entreprises	EN	8,02%	6,71%	6,18%	6,10%	3,97%	2,61%
Education, santé, action sociale	EQ	5,65%	2,54%	0,46%	0,32%	0%	0%
Industries des biens de consommation	EC	4,99%	5,61%	3,43%	5,07%	2,47%	0%
Industries agricoles et alimentaires	EB	4,25%	0,52%	0%	3,62%	1,85%	0%
Construction	EH	6,10%	5,81%	6,05%	4,47%	3,08%	4,63%
Commerce et réparation automobile	J1	4,25%	2,04%	2,03%	2,06%	3,92%	4,17%
Industries des biens d'équipement	EE	4,74%	6,29%	4,71%	5,10%	0%	2,08%
Industries des biens intermédiaires	EF	4,18%	4,63%	4,36%	1,07%	3,17%	3,17%(1)
Commerce de gros intermédiaires	J2	6,19%	6,58%	5,23%	4,07%	1,52%	2,78%
Transports	EK	6,31%	6,59%	7,03%	4,23%	3,43%	0,65%
Energie (2)	EG		4,43%			0%	
Industrie automobile (2)	ED		3,33%			0%	

Activity location model

Location choice explanatory variables

- Activity sectors (segmentation in 17 sectors)
- Enterprise size (0-49; 50-249; 250+)
- Proximity to population (employees or clients): population density
- Conurbation scale economy, proximity to other enterprises (same sector): enterprise and employment density; zone share dedicated to activity
- Accessibility (same indicators as for households location)
- Real-estate price

Activity location model - results

- 19 models:
  - 17 for enterprises with 0-49 employees, segmentation by activity sector
  - 1 for enterprise with 50-249 employees
  - 1 for enterprise with 250+ employees
- 3 activity groups:
  - 1- Most of tertiary sector: very good results ($\rho^2 > 0,50$)
  - 2- Secondary sector + transport + car services (good to average results $0,3 < \rho^2 < 0,50$
  - 3- Specific sector: energy, car construction, agriculture not very good results

Activity location model – group 1

	EP Serv. Part.	*J3* Com. détail	*EM* Act Im. Fi.	*EN* Serv. Ent.	*EQ* Educ, santé	*AD* Adm.	*EC* Ind BCons	*EB* Ind AgrAl
Gravity accessibility employment group 1	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ *
Gravity accessibility employment group 2	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ **
Gravity accessibility employment total	- ***	- ***	- ***	- ***	- ***	- ***	- ***	- **
Gravity accessibility to population	+ ***	+ ***	+ ***	+ ***	+ ***	+ **	n.s.	+ **
Population density	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***
Proximity to group 1 enterprise	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ *	+ ***
Proximity to group 2 enterprise	- ***	- ***	n.s	n.s	- ***	- ***	+ ***	- ***
Real estate price	- ***	- ***	n.s	+ *	- ***	- ***	n.s	- **
Access time to CBD	- ***	- ***	- ***	- ***	- ***	- **	- ***	n.s
Likelihood ratio index (pseudo-R^2)	**0,55**	**0,58**	**0,64**	**0,59**	**0,58**	**0,52**	**0,61**	**0,32**

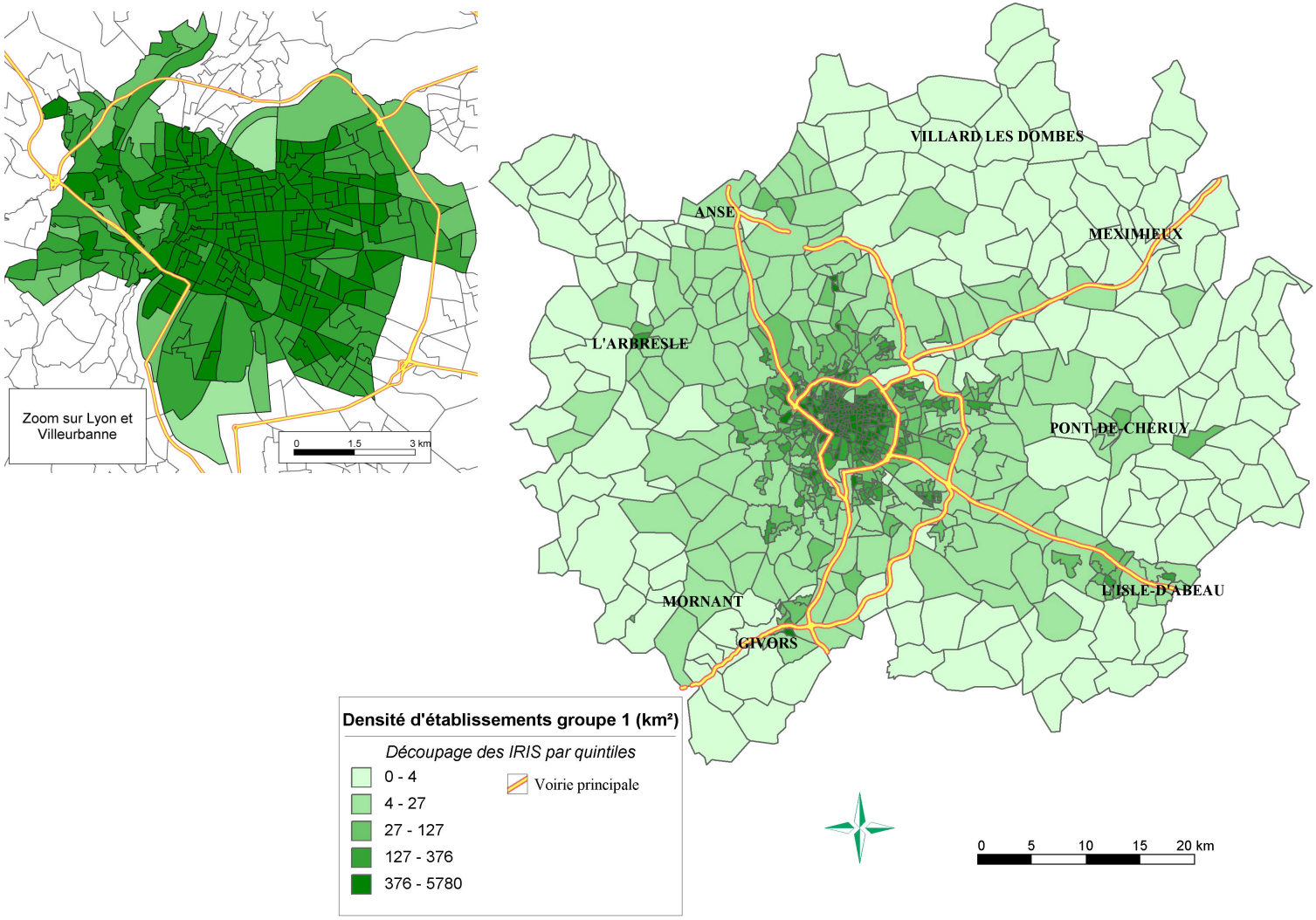
Activity location model – group 2

	EE Ind BEquip	***EF*** Ind BInt	***J2*** Com Gros Int	***EH*** Construction	***J1*** Com RepAuto	***EK*** Transports
Gravity accessibility employment group 1	+ *	+ ***	+ ***	+ ***	+ *	+ ***
Gravity accessibility employment group 2	+ **	+ ***	+ ***	+ ***	+ **	+ ***
Gravity accessibility employment total	- *	- ***	- ***	- ***	- **	- ***
Gravity accessibility to population	n.s.	n.s.	n.s.	+ ***	+ ***	n.s.
Population density	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***
Proximity to group 1 enterprise	- **	- ***	- **	- **	- *	n.s.
Proximity to group 2 enterprise	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***
Real estate price	- **	- **	n.s.	- ***	- **	- ***
Access time to CBD	- ***	- **	- ***	- ***	- **	- **
Likelihood ratio index (pseudo-R^2)	**0,38**	**0,35**	**0,51**	**0,29**	**0,41**	**0,37**

Activity location model – Size

	aucun salarié	*1à 9 salariés*	*10 à 19 salariés*	*20 à 49 salariés*	*50 à 249 salariés*	*plus de 250*
Gravity accessibility employment group 1	+ ***	+ ***	+ ***	+ ***	+ *	+ *
Gravity accessibility employment group 2	+ ***	+ ***	+ ***	+ ***	+ *	+ **
Gravity accessibility employment total	- ***	- ***	- ***	- ***	- **	- *
Gravity accessibility to population	+ ***	+ ***	n.s.	n.s.	+ **	n.s.
Population density	+ ***	+ ***	+ **	+ ***	+ **	n.s.
Proximity to group 1 enterprise	+ ***	+ ***	+ *	n.s.	n.s.	+ *
Proximity to group 2 enterprise	- ***	+ ***	+ ***	+ ***	+ *	n.s.
Real estate price	- ***	- ***	- ***	- ***	- *	- *
Access time to CBD	- ***	- ***	- ***	- ***	- ***	- **
Employment G1					+ ***	
Employment G2					+ ***	
zone share dedicated to activity						+ **
Pseudo -R²	**0,43**	**0,51**	**0,51**	**0,51**	**0,52**	**0,59**

Out-put examples: enterprise density (G1)



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Transportation models

- 3 transport models:
  - Person transport model: four steps model
  - Through and exchange traffic model
  - Urban freight model

But one assignment model (DAVISUM) with all three types of traffic through a multiclass assignment

Person transport: four steps model

Individual mobility of perimeter residents is modeled with a classical 4-steps model:

- Generation model:
  - production: development of a random micro-simulation model;
  - Attraction: classical regression with activity variables
- Distribution: 3 (income segmentation) * 6 (purpose) gravity models with exponential deterrence function
- Modal split: 2 independent logit models (for 18 segments):
  - Walk and bicycle / motorized modes
  - For motorized modes: split car / public transport
- Assignment model: multiclass wardrop equilibrium model
- Network: use of existing databases + “automatic” coding

Network codification

- Detailed zoning system: 777 IRIS zones (most precise census zoning system compatible with CNIL informatics and liberty act)
- Network coding: use of existing detailed network database: Navteq + géoroute (developed by French National Geographic institute)
  - High detailed level with all infrastructures including the smallest ones
  - But most link and junction attributes not available
- Only macro level analysis because precision is almost "illusory"

Car network codification

- Navteq database contains all infrastructures classed by level (from motorway to small local road)
- Very detailed network with 113,000 links
- But the network needs to be adapted to model objective
  - New link classification (more than 50 classes)
  - Control of the coherence of the hierarchy: only for most important road
  - Missing (or approximate) attributes: capacity, free flow speed, speed curve flow, type of junction, junction penalty…
- Control and coding have been as automatic as possible but still a time-consuming task (more than 6 months)

Car network codification: speed curve flow

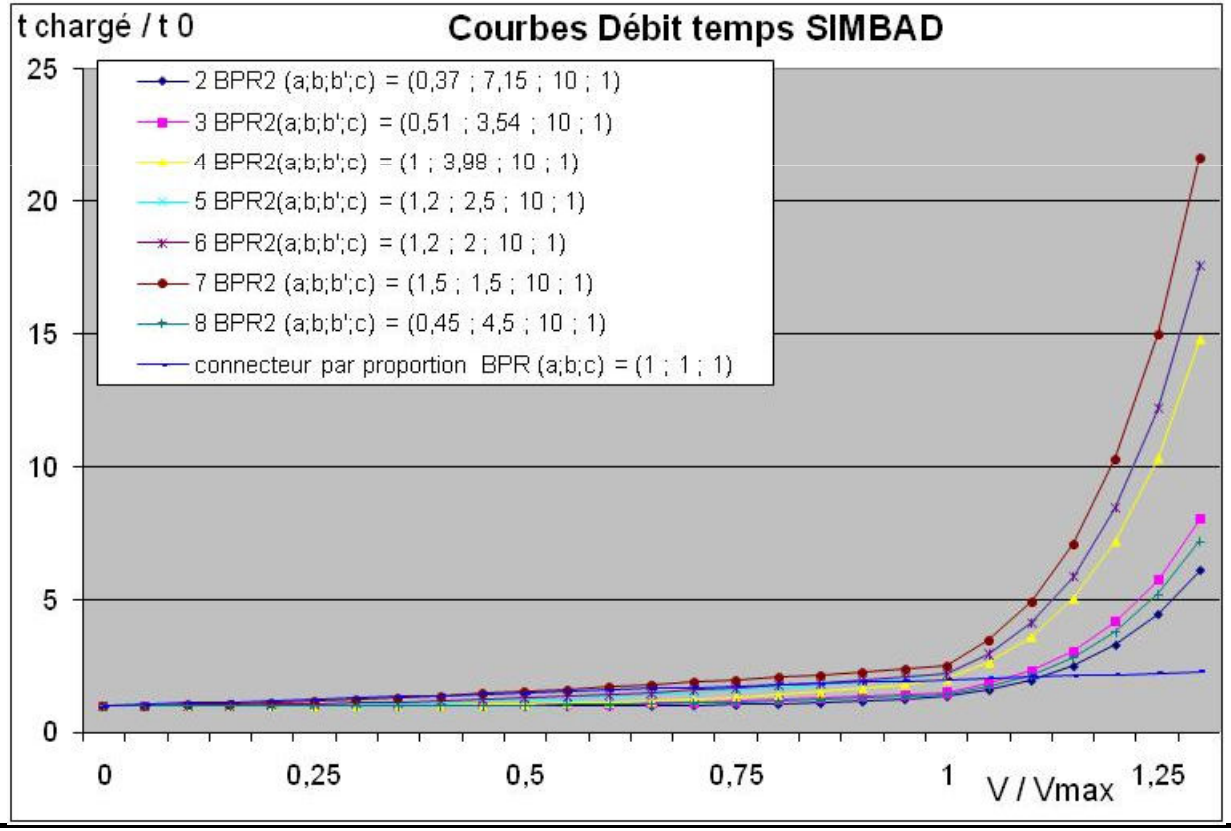
- Speed curve flow: use of BPR (US-FHWA) curve:

$$t = t_0\left(1 + a\left(\frac{V}{V_{max} * c}\right)^b\right)$$

V = volume; V_{max} = capacity

b different depending on $V/V_{max} \leq/> 1$

- One curve per link type (value of a, b, b', c)



Road network: junction penalty

- Three levels of codification:
  - Type of the junction (simple priority; stop; traffic light, roundabout…)
  - Definition of the flow level (Principal, Secondary: 4 classes: P-P, P-S, S-P, S-S)
  - Definition of the turning flow (4 classes: through, turn right, turn left, turn back): geometric definition
- Penalty is given in second for each junction based on the combination of the above dimensions

Road network: junction penalty (sec)

Junction type	Definition	S -> S				S -> P				P -> S				P -> P			
		d	td	g	dt	d	td	g	dt	d	td	g	dt	d	td	g	dt
11	Simple priority	5	10	15	15	10	20	25	25	5	10	15	15	5	10	15	15
12	Stop or traffic light	7	17	22	22	7	17	20	22	7	7	15	20	5	5	7	7
13	Urban junction	5	15	20	20	5	10	15	20	5	10	10	20	5	5	10	10
14	Round about	0	0	0	0	10	10	10	10	0	5	5	0	0	0	0	0
15	Motorway junction	0	0	0	0	30	30	30	30	30	30	30	30	0	0	0	0
…																	

Legend : P : main flow
S : secondary flow

d : turn right
td : through
g : turn left
dt : turn back

DAVISUM Software

Connector codification

- Automatic codification:
  - Elimination of nodes which cannot receive connector (like motorway entry, roundabout…)
  - Choice of 3 to 5 nodes for each zone centroïd
  - Control of link capacity to be sure that the total capacity of the links is big enough regarding production and attraction of the zone
  - Assignment of the demand matrix
  - Elimination of connectors without traffic

Road network calibration

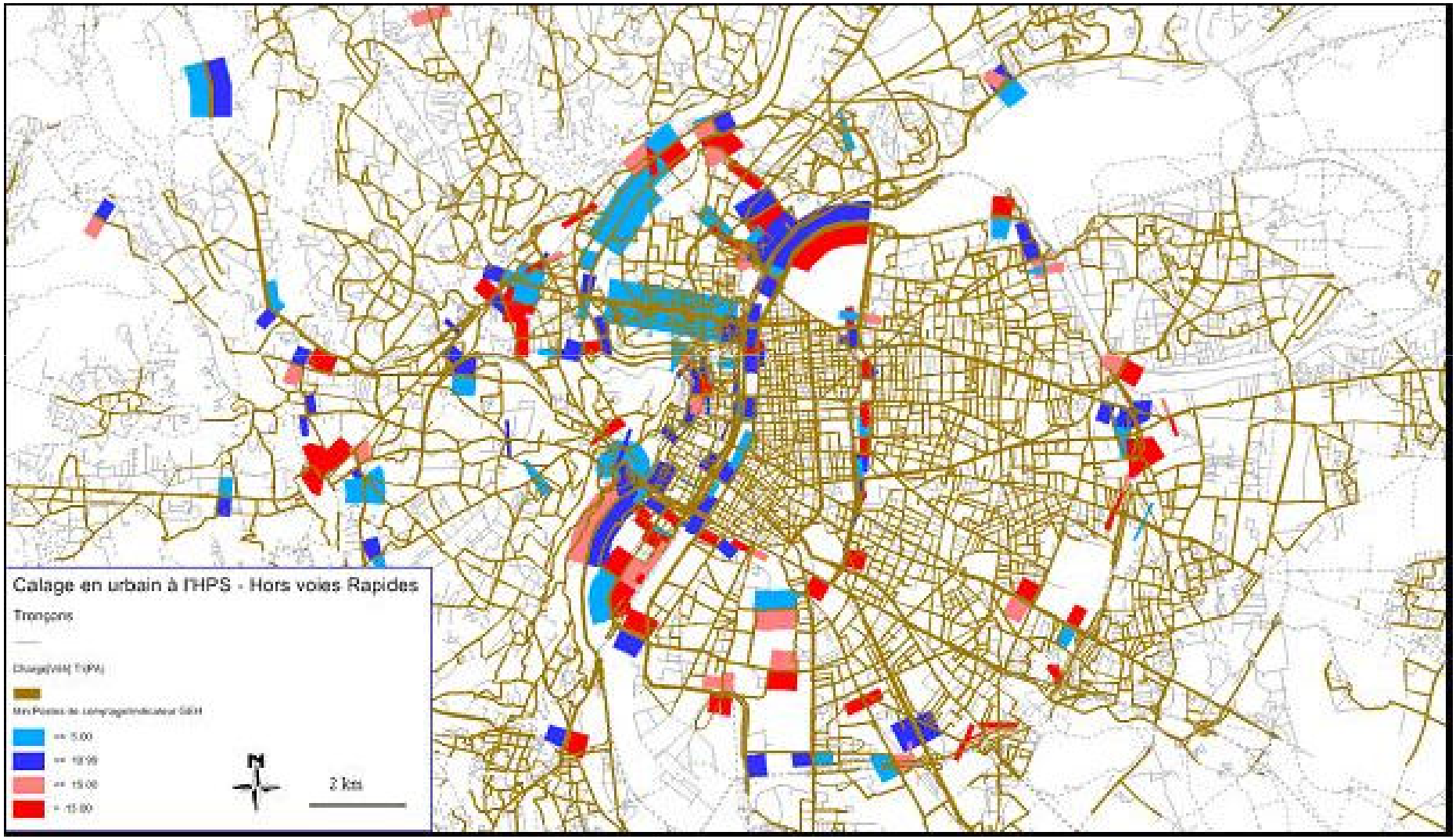
- Calibration of the network is performed with comparison of traffic assignments and traffic counts.
- Traffic counts are available for main roads (especially motorway), but also at some junctions with centralized traffic lights control.
- Indicator GEH (UK Highway agency) to compare estimated traffic and observed traffic (traffic counts)

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$$

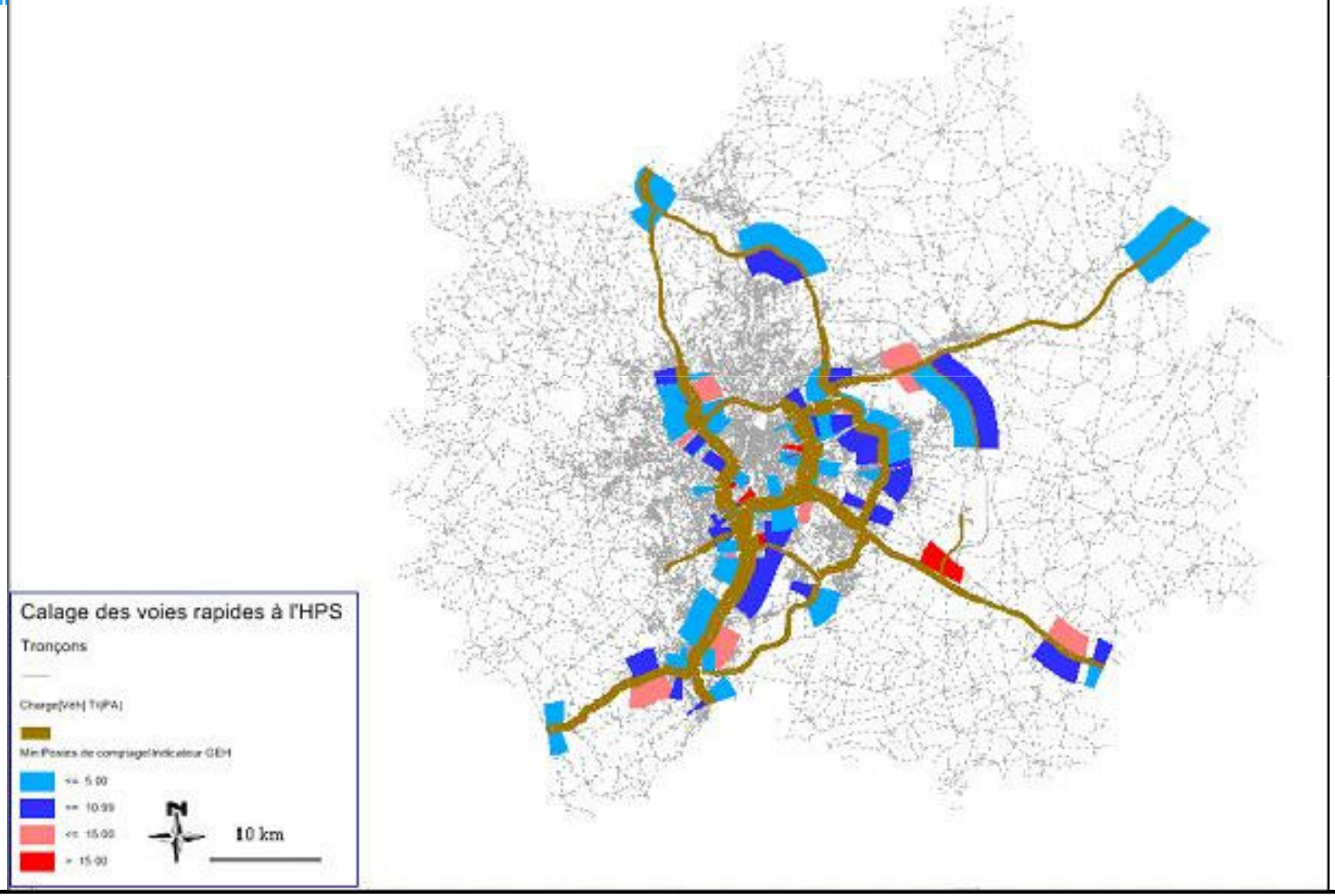
M estimated flow

C traffic counts

Road network calibration (GEH center)



Road network calibration (GEH suburb)



Public transport coding

- Same principle as road: use existing data base as much as possible:
  - Digitalization of all public transport stops (5,000 nodes)
  - Codification of all public transport lines (>150 lines)
  - Automatic connector coding (up to 8 connectors in central area; limit length of connectors different in urban area and in suburbs…)
  - Time between node is defined for each line from public transport time-table
  - Headway imported from time-table
- coding has been as automatic as possible but still a time-consuming task (more than 6 months)

Public transport: generalized time function

Time segmentation	coefficient
❖ In vehicle time	1
❖ Connectors walk (O+D)	1
❖ Connection time (walk + specific penalty)	1
❖ Waiting time	2
❖ Global penalty for connection (8 minutes)	1
❖ Modal penalty (metro 0'; tramway 2'; bus 10')	1

Specific connection penalty:

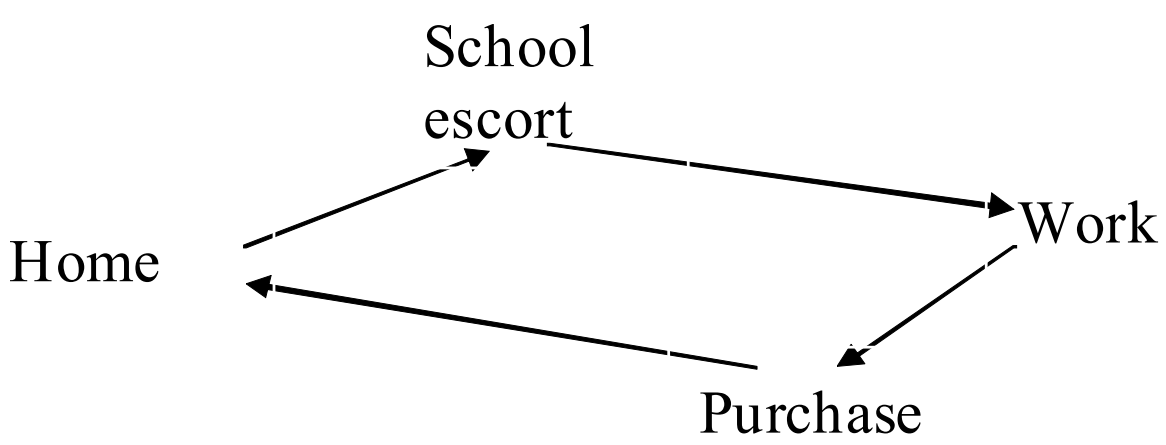
	Metro	Light rail	Bus
Metro	+ 0'	+ 1'	+ 2'
Light rail	+ 1'	+ 1'	+ 2'
Bus	+ 2'	+ 2'	+ 4'

Public transport network: calibration

		observed		Davisum simulation	
		load	%	load	%
Trip number	Matrix	217 296		217 296	
Modal split	Bus	121 651	39,0	130 408	40,0
	Funicular	3 150	1,0	4 040	1,2
	Metro	155 369	49,4	157 670	48,4
	Light rail	34 582	11,0	33 676	10,3
	Total	314 752	100,0	325 794	100,0
Load for main lines	T1	17 750	4,25	15 298	4,70
	T2	16 832	5,35	18 378	5,64
	A	57 737	18,34	56 604	17,37
	B	28 839	9,16	34 238	10,51
	C	8 356	2,65	10 018	3,07
	D	60 437	19,20	56 810	17,44

Generation: Random micro-simulation

- Approach in terms of tour rather than trips



4 trips
HB escort
HB purchase
2 NHB
~~work~~

- But 1 work tour
- 1 tour modal choice instead of 4 trips model choice
- Purpose of the tour: hierarchical definition work > school (by level) > purchase and administrative matters > escort trip > leisure > others

Generation: Random micro-simulation

- Principle:
  - Classical regression: 1 to 3 variables, but explanatory power limited due to strong individual variance
  - Micro-simulation:
    - Definition of a synthetic population (population enumeration)
    - For each individual with some socio-economic characteristic take a surveyed individual with same characteristic and applied his mobility characteristic
  - Application: need to define a typology of individual
- Advantages: allow to take into account evolution of socio-economic characteristic in the future (ageing, income or car ownership evolution, household size or structure…)
- Limit: but not behavior evolution (like for regression)

Generation: Random micro-simulation

- Typology definition:
  - Definition of a tour typology in order to define mobility profiles
  - Definition of an individual typology in order to segment individual regarding mobility profiles

- Tour typology
  - 18 tour types represent 80% of tours,
    but 59 (175) tour types represent only 90% (95%)
    Segmentation: 16 tour types (8 simple by purpose, 8 complex)
  - Tour types combination at individual level, segmentation:
    32 individual profiles (75% of population) + 1 for the rest

Generation: Random micro-simulation

- Individual typology based on:
  - Individual status (worker, school, student, retired, person at home, others)
  - Distance between home and work/school
  - Car ownership
  - Home location (4 classes)
  - Household structure
  - Household income
  - Age and gender
- In total 55 individual profiles

Generation: Random micro-simulation

- Application to Lyon 1995 household travel survey: good reproduction of individual behavior. Advantages:
  - keep all the diversity of tour behavior
  - keep individual characteristics, especially income
  - take into account demographic evolution
- Analysis of temporal evolution between Lyon 1985 and 1995 household travel surveys: work and school tours are well predicted, results are less good for other purposes, but always superior than classical regression

Trip distribution

- Gravity model (analogy with Newton law):
- $T_{ij} = a_i\, b_j\, P_i\, A_j \quad e^{-\beta C_{ij}}$
  P_i and A_j, production and attraction from generation model
- Population segmentation based on income (20%-60%-20%)

purpose	β		
	Low income	Medium income	High income
Work	0,17	0,11	0,11
School <12 age old	0,65	0,53	0,65
School 11 < age old < 18	0,35	0,25	0,39
Students	0,35	0,22	0,42
Purchase and administrative matters	0,31	0,27	0,29
Others	0,30	0,26	0,25

Modal split

- Two independent binomial logit:
  - Modal split between walk and cycle / motorized modes utility function:

$$(U_{walk} - U_{MM})_{ij} = k_1 + \tau_{walk} \cdot t_{ij}^{walk} + \tau_{MM} \cdot t_{ij}^{MM} + \delta_1 \cdot d_j$$

with t generalized time and d zone density (population + employment)

  - Modal split between car and public transport utility function:

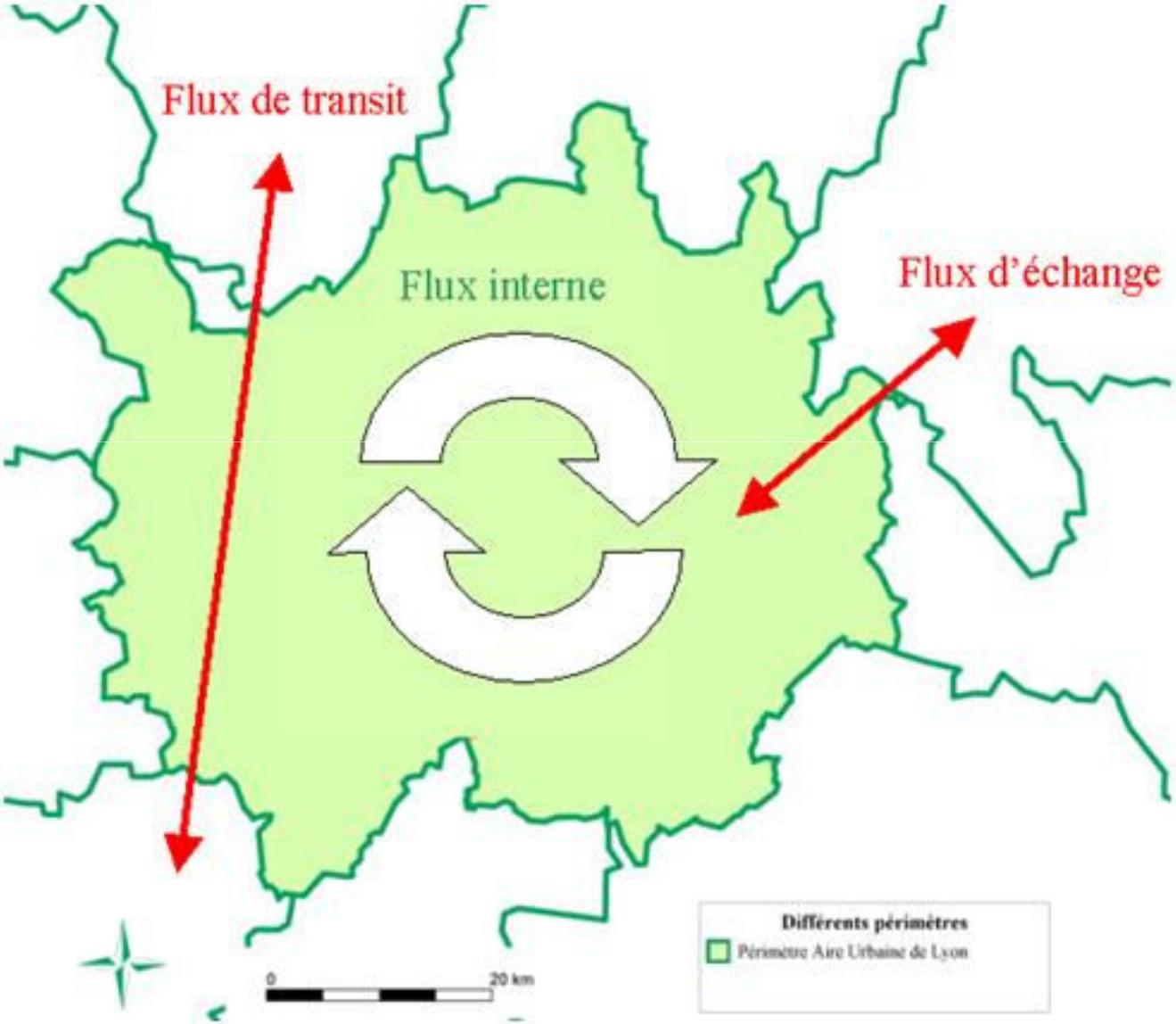
$$(U_{PT} - U_{car})_{ij} = k_2 + \tau_{PT} \cdot t_{ij}^{PT} \cdot mot_i + \tau_{car} \cdot t_{ij}^{car} / mot_i + \delta_2 \cdot d_j$$

with t generalized time, d density, mot car ownership

Logit modal split estimation

		Split walk/motorized				Split car / PT			
income	purpose	k_1	τ_{walk}	τ_{MM}	δ_1	k_2	τ_{PT}	τ_{car}	δ_2
high	walk	-0.090	-0.019	0.395	-0.008	2,554	0,036	-0,046	-0,006
	purchase +	-0,552	-0,038	0,506	-0,006	4,494	0,013	-0,101	-0,006
	Student	No walk trip				-2,486	0,051	-0,028	-0,002
	School > 11	-0.711	-0.027	0.414	-0.006	-			
	School < 12	-3.260	0.168	-0.113	0.002	-			
	others	-0,823	-0,065	0,681	-0,006	2,856	0,065	-0,109	-0,004
medium	walk	0,048	-0,030	0,456	-0,006	2,304	0,042	-0,056	-0,006
	purchase +	-1,471	-0,031	0,532	-0,004	3,451	0,028	-0,105	-0,005
	Student	-3,683	-0,029	0,362	0,018	-0,213	0,041	-0,041	-0,006
	School > 11	-0.711	-0.027	0.414	-0.006	-			
	School < 12	0.443	0.078	-0.355	-0.007	-			
	others	-1,021	-0,027	0,440	-0,004	3,877	0,039	-0,081	-0,010
low	walk	0.170	-0.015	0.351	-0.008	0,404	0,053	-0,021	-0,005
	purchase +	-2,033	-0,052	0,720	-0,003	1,245	0,051	-0,057	-0,006
	Student	-1,537	-0,053	0,583	-0,001	-3,420	0,079	-0,045	0,005
	School > 11	-0.711	-0.027	0.414	-0.006	-			
	School < 12	-2.757	0.150	-0.338	-0.002	-			

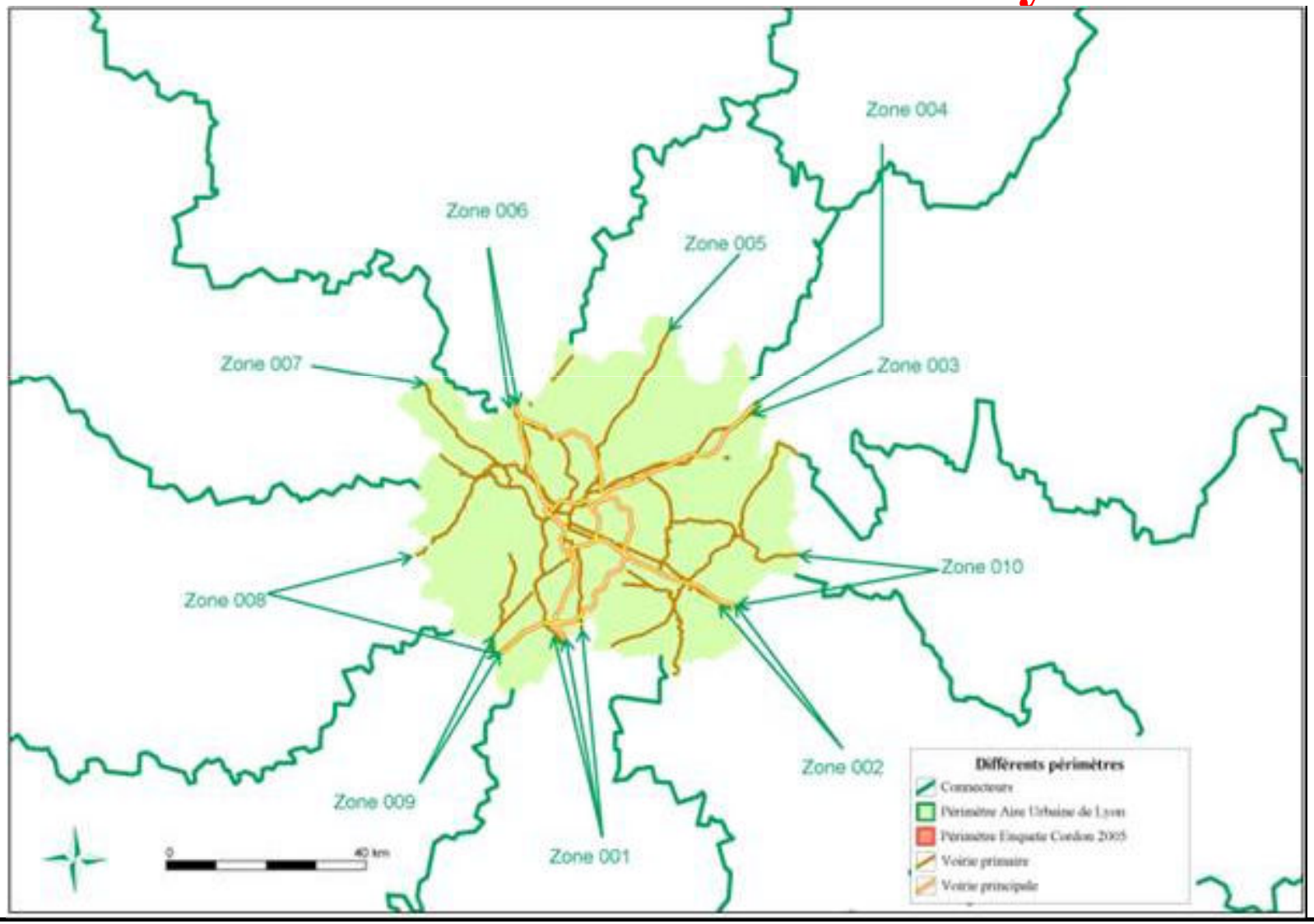
Trough and exchange traffic



Trough and exchange traffic

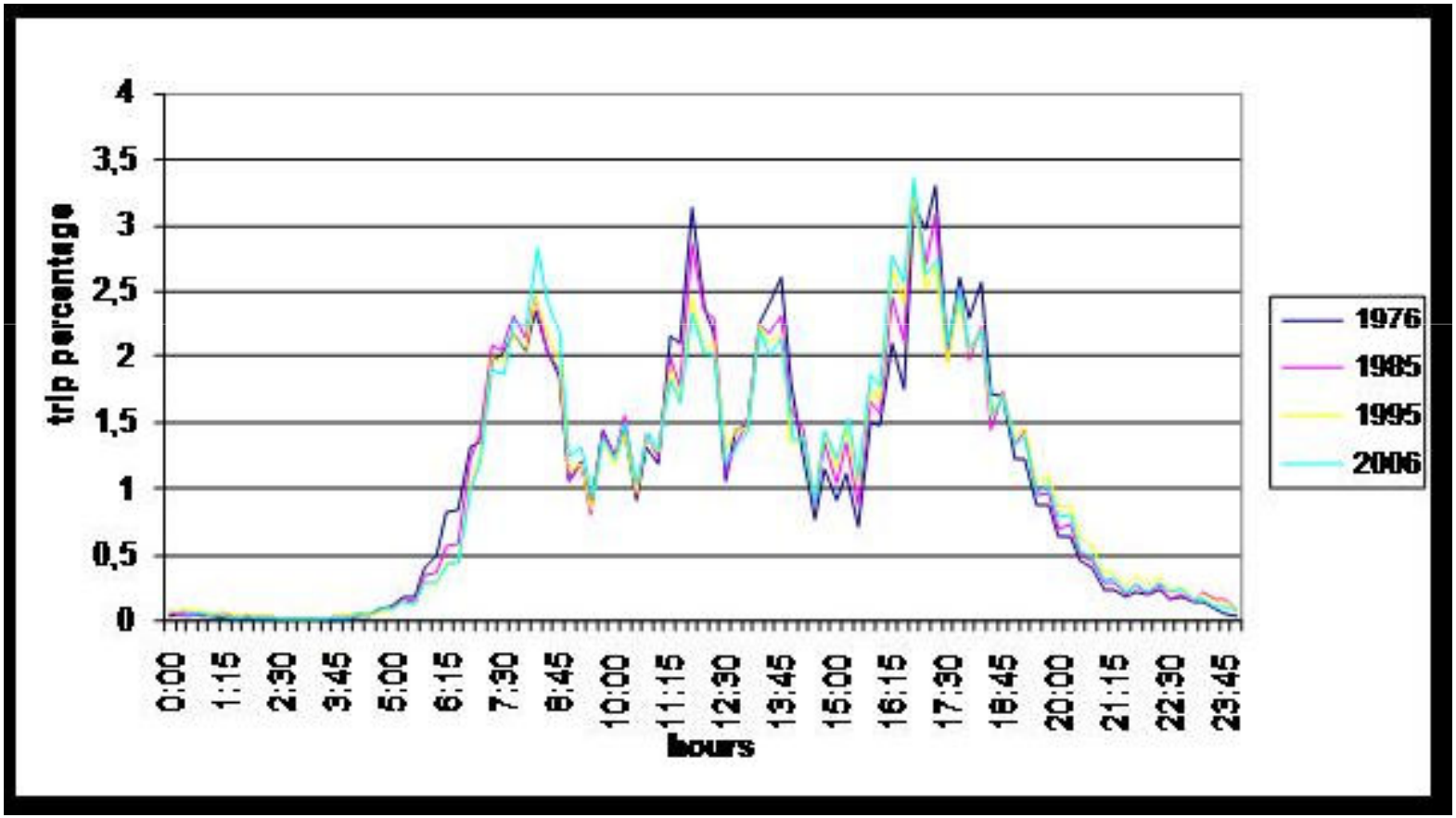
- Data base: cordon surveys 1990 and 2006
  - Definition of outer zones (out side perimeter) + entry zone (within perimeter)
  - Calculation of traffic volume in 2006
  - Calculation of traffic growth (from 1990 and 2006 surveys)
- Limits:
  - Cordon does not match model perimeter
  - Cordon zoning is aggregated
  - Only 2 surveys with 16 years between the two

Trough and exchange traffic definition of outer zone and entry road



Distribution peak / of peak

Individual internal trips distribution over the day is constant



source: Lyon household travel survey 1976, 1985, 1995, 2006

Urban freight model

- Development of FRETURB model based on specific surveys performed by LET
- Three surveys have been conducted in three French conurbations
- Sample unit: not the vehicle, not the merchandise nor the trip, but the operation of deliveries (unloading) or pick-up (loading) products in each establishment
- For each operation, data are collection on the trips, the vehicle , the merchandise, the establishment…
- Surveys performed in three French conurbations allow to calibrate generation models.

Urban freight model - generation

- Generation is estimated at establishment level (availability of data base at establishment level), with a distinction between:
  - Vehicle size (3 classes)
  - Own account / third party
  - Direct trip / trip within a tour
- Explanatory variables:
  - Activity sector and type of establishment
  - Enterprise size (number of jobs)
- Generation appears stable in the three conurbations and not dependent of the location of the establishment.

Urban freight model - distribution

- Gravity model cannot be applied because trips are most often organized in complex tour
- Distribution is performed through an iterative and probabilistic process in order to reproduce class of distances for each generation segment and each zone.
- Out put of the model furnishes O-D matrix by type of vehicle class which can be combined with other transport model for multiclass assignment