MODELING TRANSPORT LAND USE INTERACTIONS SIMBAD MODEL

Patrick BONNEL,
Transport Economic Laboratory
ENTPE (National School of Civil Engineering)

November 6, 2009
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 through 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

Patrick BONNEL, LET, ENTPE - Simbad model – land use – transport interaction
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

**Environmental**
- 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 output 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 input 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 Téléscopage

Affectation des trafics
Logiciel DaviSim

Patrick BONNEL, LET, ENTPE - Simbad model – land use – transport interaction
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**

- Land use / transport models
  - Predictive models
    - Statics models
      - Lowry, DSCMOD, MUSSA
    - Entropy-based models
      - DRAM/EMPAL, LILT
  - Optimising models
    - Quasi-dynamics models
    - Spatio-economics models
      - MEPLAN, TRANUS, METROSIM
    - Activity-based models
      - IRPUD, URBANSIM

Source: Simmonds, Echenique, Bates, Oosterhaven, 1999
LUTI: classification/ theoretical foundation

- Economic-based theory: Lowry, 1964
  - Gravity model: Wilson, Garin, 1966
- Input/output model: Léontieff
- Urban rent theory: Alonso, Mills, Muth
- microsimulation: Orcutt
- Random utility: Mac Fadden, 1974
- Spatial interaction: METROPOLIS
  - Dram/EMPAL, HLFM
- Spatial I/O models: MEPLAN, TRANUS
- Discrete choice equilibrium model: METROSIM, MUSSA
- Discrete choice dynamics model: HUDS
- Dynamic model spatially detailed: URBANSIM
- Planning tool spatially detailed: UPLAN, WhatIf
- Spatial I/O models hybrids: PECAS

Source: Paul Waddel, Urbansim
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
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)
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
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: output 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
Output 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)

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>t Statistic</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>-9.24</td>
<td>-6.11</td>
<td>3.3 × 10^{-09}</td>
</tr>
<tr>
<td>-5.44</td>
<td>-6.40</td>
<td>6.4 × 10^{-10}</td>
</tr>
<tr>
<td>10.63</td>
<td>12.84</td>
<td>4.7 × 10^{-30}</td>
</tr>
</tbody>
</table>
Real-estate price model

Patrick BONNEL, LET, ENTPE - Simbad model – land use – transport interaction
## Household location model results

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

<table>
<thead>
<tr>
<th>Secteurs</th>
<th>aucun salarié</th>
<th>TPE</th>
<th>PME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>1 - 9</td>
</tr>
<tr>
<td>Services aux particuliers</td>
<td>EP</td>
<td>2,30%</td>
<td>0,72%</td>
</tr>
<tr>
<td>Commerce de détail, réparation</td>
<td>J3</td>
<td>3,33%</td>
<td>1,62%</td>
</tr>
<tr>
<td>Activités immobilières</td>
<td>EM</td>
<td>6,64%</td>
<td>4,28%</td>
</tr>
<tr>
<td>Services aux entreprises</td>
<td>EN</td>
<td>8,02%</td>
<td>6,71%</td>
</tr>
<tr>
<td>Education, santé, action sociale</td>
<td>EQ</td>
<td>5,65%</td>
<td>2,54%</td>
</tr>
<tr>
<td>Industries des biens de consommation</td>
<td>EC</td>
<td>4,99%</td>
<td>5,61%</td>
</tr>
<tr>
<td>Industries agricoles et alimentaires</td>
<td>EB</td>
<td>4,25%</td>
<td>0,52%</td>
</tr>
<tr>
<td>Construction</td>
<td>EH</td>
<td>6,10%</td>
<td>5,81%</td>
</tr>
<tr>
<td>Commerce et réparation automobile</td>
<td>J1</td>
<td>4,25%</td>
<td>2,04%</td>
</tr>
<tr>
<td>Industries des biens d’équipement</td>
<td>EE</td>
<td>4,74%</td>
<td>6,29%</td>
</tr>
<tr>
<td>Industries des biens intermédiaires</td>
<td>EF</td>
<td>4,18%</td>
<td>4,63%</td>
</tr>
<tr>
<td>Commerce de gros intermédiaires</td>
<td>J2</td>
<td>6,19%</td>
<td>6,58%</td>
</tr>
<tr>
<td>Transports</td>
<td>EK</td>
<td>6,31%</td>
<td>6,59%</td>
</tr>
<tr>
<td>Energie (2)</td>
<td>EG</td>
<td>4,43%</td>
<td></td>
</tr>
<tr>
<td>Industrie automobile (2)</td>
<td>ED</td>
<td>3,33%</td>
<td></td>
</tr>
</tbody>
</table>

(1) Source: INSEE, Enquête Entreprises 2018

(2) Source: INSEE, Enquête Energie 2018
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

<table>
<thead>
<tr>
<th></th>
<th>EP</th>
<th>J3</th>
<th>EM</th>
<th>EN</th>
<th>EQ</th>
<th>AD</th>
<th>EC</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity accessibility</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>employment group 1</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Gravity accessibility</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>employment group 2</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Gravity accessibility</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>employment total</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Gravity accessibility</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>population</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Population density</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Proximity to group 1</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>enterprise</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Proximity to group 2</td>
<td>-</td>
<td>-</td>
<td>n.s</td>
<td>n.s</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>enterprise</td>
<td>***</td>
<td>***</td>
<td>n.s</td>
<td>n.s</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Real estate price</td>
<td>-</td>
<td>-</td>
<td>n.s</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>n.s</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>n.s</td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Access time to CBD</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>n.s</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Likelihood ratio index</td>
<td>0.55</td>
<td>0.58</td>
<td>0.64</td>
<td>0.59</td>
<td>0.58</td>
<td>0.52</td>
<td>0.61</td>
<td>0.32</td>
</tr>
<tr>
<td>(pseudo-R²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Patrick BONNEL, LET, ENTPE - Simbad model – land use – transport interaction
## Activity location model – group 2

<table>
<thead>
<tr>
<th></th>
<th>$EE$</th>
<th>$EF$</th>
<th>$J2$</th>
<th>$EH$</th>
<th>$J1$</th>
<th>$EK$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ind BEquip</td>
<td>Ind BInt</td>
<td>Com Gros Int</td>
<td>Construction</td>
<td>Com RepAuto</td>
<td>Transports</td>
</tr>
<tr>
<td>Gravity accessibility employment group 1</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>*</td>
<td>***</td>
</tr>
<tr>
<td>Gravity accessibility employment group 2</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Gravity accessibility employment total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Gravity accessibility to population</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>+</td>
<td>+</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>***</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Population density</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Proximity to group 1 enterprise</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>**</td>
<td>***</td>
<td>**</td>
<td>**</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Proximity to group 2 enterprise</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Real estate price</td>
<td>-</td>
<td>-</td>
<td>n.s.</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>**</td>
<td>**</td>
<td>n.s.</td>
<td>***</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Access time to CBD</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td><strong>Likelihood ratio index (pseudo-$R^2$)</strong></td>
<td>0.38</td>
<td>0.35</td>
<td>0.51</td>
<td>0.29</td>
<td>0.41</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Patrick BONNEL, LET, ENTPE - Simbad model – land use – transport interaction
## Activity location model – Size

<table>
<thead>
<tr>
<th></th>
<th>aucun salarié</th>
<th>1 à 9 salariés</th>
<th>10 à 19 salariés</th>
<th>20 à 49 salariés</th>
<th>50 à 249 salariés</th>
<th>plus de 250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity accessibility employment group 1</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Gravity accessibility employment group 2</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Gravity accessibility employment total</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Gravity accessibility to population</td>
<td>+</td>
<td>+</td>
<td>n.s.</td>
<td>n.s.</td>
<td>+</td>
<td>n.s.</td>
</tr>
<tr>
<td>Population density</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>***</td>
<td>***</td>
<td>n.s.</td>
</tr>
<tr>
<td>Proximity to group 1 enterprise</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>n.s.</td>
<td>n.s.</td>
<td>+</td>
</tr>
<tr>
<td>Proximity to group 2 enterprise</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Real estate price</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Access time to CBD</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Employment G1</td>
<td>+</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
</tr>
<tr>
<td>Employment G2</td>
<td>+</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
</tr>
<tr>
<td>zone share dedicated to activity</td>
<td>+</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
</tr>
</tbody>
</table>

| Pseudo -R²                        | 0,43          | 0,51           | 0,51             | 0,51             | 0,52              | 0,59        |

Patrick BONNEL, LET, ENTPE - Simbad model – land use – transport interaction
Out-put examples: enterprise density (G1)
MODELING TRANSPORT LAND USE INTERACTIONS SIMBAD MODEL

Patrick BONNEL,
Transport Economic Laboratory
ENTPE (National School of Civil Engineering)

November 6, 2009
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:
  \[ t = t_0 \left( 1 + a \left( \frac{V}{V_{\text{max}}^c} \right)^b \right) \]
  \( V = \) volume; \( V_{\text{max}} = \) capacity
  \( b \) different depending on \( V/V_{\text{max}} \leq/> 1 \)

- 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)

<table>
<thead>
<tr>
<th>Junction type</th>
<th>Definition</th>
<th>S -&gt; S</th>
<th>S -&gt; P</th>
<th>P -&gt; S</th>
<th>P -&gt; P</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Simple priority</td>
<td>5 10 15 15</td>
<td>10 20 25 25</td>
<td>5 10 15 15</td>
<td>5 10 15 15</td>
</tr>
<tr>
<td>12</td>
<td>Stop or traffic light</td>
<td>7 17 22 22</td>
<td>7 17 20 22</td>
<td>7 7 15 20</td>
<td>5 5 7 7</td>
</tr>
<tr>
<td>13</td>
<td>Urban junction</td>
<td>5 15 20 20</td>
<td>5 10 15 20</td>
<td>5 10 10 20</td>
<td>5 5 10 10</td>
</tr>
<tr>
<td>14</td>
<td>Round about</td>
<td>0 0 0 0</td>
<td>10 10 10 10</td>
<td>0 5 5 0</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>15</td>
<td>Motorway junction</td>
<td>0 0 0 0</td>
<td>30 30 30 30</td>
<td>30 30 30 30</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- **P**: main flow
- **S**: secondary flow
- **d**: turn right
- **td**: through
- **g**: turn left
- **dt**: turn back
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)
Time segmentation coefficients:

- 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:

<table>
<thead>
<tr>
<th>Metro</th>
<th>Light rail</th>
<th>Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro</td>
<td>+ 0’</td>
<td>+ 1’</td>
</tr>
<tr>
<td>Light rail</td>
<td>+ 1’</td>
<td>+ 1’</td>
</tr>
<tr>
<td>Bus</td>
<td>+ 2’</td>
<td>+ 2’</td>
</tr>
</tbody>
</table>
Public transport network: calibration

<table>
<thead>
<tr>
<th>Modal split</th>
<th></th>
<th>observed</th>
<th></th>
<th>Davisum simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>load</td>
<td>%</td>
<td>load</td>
<td>%</td>
</tr>
<tr>
<td>Trip number</td>
<td>Matrix</td>
<td>217 296</td>
<td>217 296</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bus</td>
<td>121 651</td>
<td>39,0</td>
<td>130 408</td>
</tr>
<tr>
<td></td>
<td>Funicular</td>
<td>3 150</td>
<td>1,0</td>
<td>4 040</td>
</tr>
<tr>
<td></td>
<td>Metro</td>
<td>155 369</td>
<td>49,4</td>
<td>157 670</td>
</tr>
<tr>
<td></td>
<td>Light rail</td>
<td>34 582</td>
<td>11,0</td>
<td>33 676</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>314 752</td>
<td>100,0</td>
<td>325 794</td>
</tr>
<tr>
<td>Load for main lines</td>
<td>T1</td>
<td>17 750</td>
<td>4,25</td>
<td>15 298</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>16 832</td>
<td>5,35</td>
<td>18 378</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>57 737</td>
<td>18,34</td>
<td>56 604</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>28 839</td>
<td>9,16</td>
<td>34 238</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>8 356</td>
<td>2,65</td>
<td>10 018</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>60 437</td>
<td>19,20</td>
<td>56 810</td>
</tr>
</tbody>
</table>
Generation: Random micro-simulation

- Approach in terms of tour rather than trips

- 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
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)
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):
  \[ T_{ij} = a_i b_j P_i A_j e^{-\beta C_{ij}} \]
  
- Population segmentation based on income (20%-60%-20%)

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Low income</th>
<th>Medium income</th>
<th>High income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>0.17</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>School &lt;12 age old</td>
<td>0.65</td>
<td>0.53</td>
<td>0.65</td>
</tr>
<tr>
<td>School 11 &lt; age old &lt; 18</td>
<td>0.35</td>
<td>0.25</td>
<td>0.39</td>
</tr>
<tr>
<td>Students</td>
<td>0.35</td>
<td>0.22</td>
<td>0.42</td>
</tr>
<tr>
<td>Purchase and administrative matters</td>
<td>0.31</td>
<td>0.27</td>
<td>0.29</td>
</tr>
<tr>
<td>Others</td>
<td>0.30</td>
<td>0.26</td>
<td>0.25</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Income</th>
<th>Purpose</th>
<th>$k_1$</th>
<th>$\tau_{walk}$</th>
<th>$\tau_{MM}$</th>
<th>$\delta_1$</th>
<th>$k_2$</th>
<th>$\tau_{PT}$</th>
<th>$\tau_{car}$</th>
<th>$\delta_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>walk</td>
<td>-0.090</td>
<td>-0.019</td>
<td>0.395</td>
<td>-0.008</td>
<td>2.554</td>
<td>0.036</td>
<td>-0.046</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>purchase +</td>
<td>-0.552</td>
<td>-0.038</td>
<td>0.506</td>
<td>-0.006</td>
<td>4.494</td>
<td>0.013</td>
<td>-0.101</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>Student No walk trip</td>
<td>-2.486</td>
<td>0.051</td>
<td>-0.028</td>
<td>-0.002</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>School &gt; 11</td>
<td>-0.711</td>
<td>-0.027</td>
<td>0.414</td>
<td>-0.006</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>School &lt; 12</td>
<td>-3.260</td>
<td>0.168</td>
<td>-0.113</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>others</td>
<td>-0.823</td>
<td>-0.065</td>
<td>0.681</td>
<td>-0.006</td>
<td>2.856</td>
<td>0.065</td>
<td>-0.109</td>
<td>-0.004</td>
</tr>
<tr>
<td>medium</td>
<td>walk</td>
<td>0.048</td>
<td>-0.030</td>
<td>0.456</td>
<td>-0.006</td>
<td>2.304</td>
<td>0.042</td>
<td>-0.056</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>purchase +</td>
<td>-1.471</td>
<td>-0.031</td>
<td>0.532</td>
<td>-0.004</td>
<td>3.451</td>
<td>0.028</td>
<td>-0.105</td>
<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>Student</td>
<td>-3.683</td>
<td>-0.029</td>
<td>0.362</td>
<td>0.018</td>
<td>-0.213</td>
<td>0.041</td>
<td>-0.041</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>School &gt; 11</td>
<td>-0.711</td>
<td>-0.027</td>
<td>0.414</td>
<td>-0.006</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>School &lt; 12</td>
<td>0.443</td>
<td>0.078</td>
<td>-0.355</td>
<td>-0.007</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>others</td>
<td>-1.021</td>
<td>-0.027</td>
<td>0.440</td>
<td>-0.004</td>
<td>3.877</td>
<td>0.039</td>
<td>-0.081</td>
<td>-0.010</td>
</tr>
<tr>
<td>low</td>
<td>walk</td>
<td>0.170</td>
<td>-0.015</td>
<td>0.351</td>
<td>-0.008</td>
<td>0.404</td>
<td>0.053</td>
<td>-0.021</td>
<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>purchase +</td>
<td>-2.033</td>
<td>-0.052</td>
<td>0.720</td>
<td>-0.003</td>
<td>1.245</td>
<td>0.051</td>
<td>-0.057</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>Student</td>
<td>-1.537</td>
<td>-0.053</td>
<td>0.583</td>
<td>-0.001</td>
<td>-3.420</td>
<td>0.079</td>
<td>-0.045</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>School &gt; 11</td>
<td>-0.711</td>
<td>-0.027</td>
<td>0.414</td>
<td>-0.006</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>School &lt; 12</td>
<td>-2.757</td>
<td>0.150</td>
<td>-0.338</td>
<td>-0.002</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
Trough and exchange traffic
Trough and exchange traffic

- Data base: cordon surveys 1990 and 2006
  - Definition of outer zones (outside 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

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