SIET - XVII Conference of the Italian Association of Transport Economics and Logistics –
Milan 30th june 2015

The contribution of the agent-based model to the simulation of urban mobility actors behaviour

Elena maggi, associate professor, university of insubria

elena vallino, post-doc, university of insubria

OUTLINE OF THE PRESENTATION

- Aim and methodology of the paper
- Characteristics of ABMs
- Potential role of ABMs for urban mobility simulation
- Results and taxonomy of the reviewed works on
  - urban freight mobility
  - urban passenger mobility
- Framework of an ABM on passenger urban mobility in the area of Varese

AIM OF THE PAPER

To provide a **critical review** of the **existing works** which use **Agent-Based Models** (ABM)

- for analysing urban freight transport, or urban passengers mobility, or both at the same time, and
- for predicting the impacts of the different urban public (or private) policies on the agent behaviours.

To provide the basis for agent-based modelling having the aim of integrating the whole system of mobility in cities

METHODOLOGY: THE TAXONOMY

- Development of a **taxonomy** (partially inspired by Davidsson et al., 2005), i.e. classification of the studies according to the following features:
  1. model intention,
  2. main variables used: stakeholders and elements of the environment represented by the variables,
  3. geographical dimension: restricted or large urban area,
  4. data calibration on actual data,
  5. time horizon: stage of the decision-making process (strategic, tactical or operational),
  6. dynamical or static structure,
  7. agents attitudes: kind of interactions among the agents (cooperative or competitive),
  8. model maturity level: (i) conceptual proposal, (ii) simulation experiment, (iii) field experiment, (iv) deployed system,
  9. type of use of the agent system: Automation system (self-acting mechanism) or Decision-Support System (support for the policy makers)

METHODOLOGY: WHY FOCUS ON URBAN ENVIRONMENT?

- Urban sustainability is crucial for present and future societies.
- Urban mobility accounts for 40% of all CO2 emissions and up to 70% of other pollutants from road transport.
- In urban areas freight and passengers flows are consistent and coexist, sharing the same scarce space.
- Public policies have an impact at the same time on the whole urban dimension.
- The majority of world population lives in urban areas (EU 60%; European Commission, 2007).
- 90% of Europeans think that the urban traffic is a problem.

Agent-based models

- ABM: a **computational method that attempts to model the complexity of social systems**. «It enables a researcher to create, analyse and experiment with models composed of agents that interact within an environment» (Gilbert 2008, p. 98).
- **Four elements**:
  - 1) an environment: set of objects
  - 2) a set of interactive agents
  - 3) a set of relationships linking objects and agents
  - 4) a set of operators that allow the interaction between the agents and the objects.
- **Bottom-up technique**: from the interactions of agents at individual level it is possible to observe the emergent properties of the whole system.
- **Possible application**: evaluation ex-ante or ex-post of the effects of possible or actual policies on the agents behaviour

Potentialities of ABMs for urban mobility simulation/1

ABMs may be an effective tool

- to consider an **high number of stakeholders** with **heterogeneity of needs and interests**
- to investigate the agents' interactions,
- to **simulate the complex system of urban mobility** and
- **to model complex planning problems**
- Also considering the **heterogeneity of cities** in terms of geographical and urbanistic characteristics (possible integration of ABMs with GIS tool)

Potentialities of ABMs for urban mobility simulation/2

- As regards **urban freight mobility**:
  - high fragmentation both of demand and supply of city logistics services
  - different Urban Supply Chains interact
  - => stakeholders act following their own goals, without any centralized control => often conflict arises
  - => low economic sustainability
  - => low environmental sustainability
  - Need to address systematically the organization of urban freight transportation

Potentialities of ABMs for urban mobility simulation/3

- As regards **urban passenger mobility**:
  - Urban structures have complex transportation networks
  - The performance of each network is influenced by interactions among heterogeneous agents and interactions between agents and their environment
  - Each commuter is an autonomous agent with specific attributes and states
  - Overtime behavioural patterns emerge

- Passenger and freight mobility strongly interact in urban areas on the same space and in the same time

Results and taxonomy of the reviewed works – urban freight mobility/1

- Few works focus on freight transport in urban areas
- Authors agree on the validity of ABM to simulate the complexity of city logistics, trying to consider the single components as a part of a whole system
- Some of them test policy measures, such as road pricing or urban distribution centres; others use the model in order to estimate transport demand and supply or to solve logistics problems (e.g. routing, scheduling)

Results and taxonomy of the reviewed works – urban freight mobility/2

Referring to the taxonomy, the main results are:

1. Intention of the model: different aims
2. Variables: stakeholders from the supply and demand sides of city logistics
3. Geographic dimension: mainly large urban areas
4. Calibration on actual data: the majority no
5. Time horizon: almost all strategic (in 2 cases also operational)
6. Structure: the majority dynamic
7. Attitude: all both cooperative and competitive (only 1 exception: cooperative)
8. Maturity level: conceptual proposals and simulated or field experiment
9. Type of use of the agent system: all decision support systems

Table II. Literature containing agent-based models on freight transportation in urban areas

Author(s)	Intention of the model	Variables	Geographic dimension	Calibrated on actual data	Time horizon	Structure	Attitude	Maturity level
Anand et al. 2012	Design of an ontology				Strategic	Dynamic	Both	Conceptual proposal
Donnelly 2007	Urban freight demand estimation and supply design	Economic drivers; Modal alternatives; Trans-shipment; Exports & Imports, Shipment generation, Destination choice, Carrier and vehicle choice, Tour optimization	Oregon	Yes	Strategic & operational	Static		Field experiment
Van Duin et al. 2012	Investigation on the impact of policy measures for the success or urban distribution centres	1 Type of trucks and freight carriers; 1 type of goods; 1 UDC operator; Retailers; Municipality;-Roads; Streets; Nodes	-	No	Strategic	Dynamic	Cooperative	Simulation experiment
Tamagawa et al. 2010	Model for vehicle routing and scheduling problem with time window-forecasted	5 kinds of actors with different objectives: Freight carriers; Shippers; Residents; Administrators; Motorway operators	-	No	Strategic	Dynamic	Both	Simulation experiment
Taniguchi and Tamagawa 2005	Evaluation of city logistics measures impacts on the stakeholders behaviour	Administrators; Residents; Shippers; Freight carriers; Urban expressway operators	-	No	Strategic	Dynamic	Both	Simulation experiment
Roorda et al. 2010	Development of a framework for a description of actor heterogeneity and interaction in freight system	Business establishments, firms and facilities; commodity production and business service facilities; logistics service facilities; End consumers Contracts; Commodity contracts; Business service contract; Logistics service contract; Shipments Time	Toronto Area	Yes 2006	Strategic	Dynamic	Both	Conceptual proposal
Teo et al. 2014	Evaluation of the short-term impact of distance-based road pricing on the major urban stakeholders	Carriers' profit and cost, shippers' cost, distance travelled by trucks, n. of trucks, n. of customer complaints, nitrogen oxide, NOx, carbon dioxide, CO_2, suspended particulate matter	Osaka road network	No	Strategic and operational	Dynamic	Both	Simulation experiment

Results and taxonomy of the reviewed works – urban passenger mobility/1

- Higher number of works with respect to freight transport domain, but still few
- Most of them deal with a specific sub-category of citizens (university commuters, work commuters, pedestrian)
- Some ABMs test policies that improve services
- Other ABMs test policies that provide incentives for the agents to modify their behaviour

Results and taxonomy of the reviewed works – urban passenger mobility/2

Referring to the taxonomy, the main results are:

1. Intention of the model: different aims
2. Variables: features of the agents, monetary aspects, information on travel time
3. Geographic dimension: whole cities or some neighborhood only
4. Calibration on actual data: the majority yes. Use of GIS.
5. Time horizon: all strategic
6. Structure: dynamic with two exceptions
7. Attitude: the majority only competitive (1 only cooperative and 1 both)
8. Maturity level: conceptual framework and field experiment
9. Type of use of the agent system: all decision support systems

Table III. Literature containing agent-based models on passenger transportation in urban areas

Author(s)	Intention of the model	Variables	Categories of people	Geographical dimension	Calibrated on actual data	Time horizon	Structure	Attitude	Maturity level
Salvini and Miller 2005	Simulation of the evolution of an integrated urban system over an extended period of time.	Demographic features; Transportation nodes and links; Travel times; Buildings; Location; Monetary values	City inhabitants	Greater Toronto Area, 5,700,200 inhabitants	Yes-Year not specified	Strategic	Dynamic	Both	Field experiment
Shukla et al. 2013	Predict university commuter behaviour and its impact on the transportation system	Demographic features; Info on the role in the Campus; Travel info	University commuters (students and staff)	Wollongong Campus, New South Wales, Australia	Yes 2011	Strategic	Dynamic	-	Conceptual framework
Benenson et al. 2008	Development of a model for parking space supply	Destination of the drivers; Search time; Walking distance; Parking costs	Inhabitants searching for parking	District of Tel Aviv, Israel	Yes 2005-2006 GIS	Strategic	Static	Competitive	Field experiment
Harland and Stillwell 2007	Simulation of daily pupil movements between schools and residences for planning support system	To be defined. Data are about school rolls; commuting distances; pupil mobility; residential migration; pupil gender; pupil ethnicity	Commuting to school, residential migration and movement between schools	Leeds, England, 700,000 Ihnabitants	Yes 2002-2007	Strategic	-	-	Conceptual proposal
Lu et al. 2008	Development of a simulation model to study the impact of six land use regulation scenarios on transit use for work and urban form	Metropolitan rail lines; Employment distribution; Residential location; Household income; Household size; Car ownership; Age; Gender	Work travel behaviour and Urban Form	Inspired to the Cook, DuPage, Kane, Lake, McHenry, Will Counties of Chicago, USA	YES 1995 GIS	Strategic	Dynamic	Competitive	Field experiment
Schelhorn et al. 1999	Investigating pedestrian behaviour in urban centres. Pedestrian movement is influenced by attractions' configuration and location	Socio-economic characteristics; income, gender Behavioural characteristics; speed; visual range; fixation on the schedule	Pedestrian behaviour in the city	None (simulated data)	YES GIS-based socio-economic data	Strategic	Dynamic	-	Simulation experiment
Smith et al. 1995	TRansportation ANalysis SIMulation System (TRANSIMS) as integration of transport system with environmental analysis	Socio-economic characteristics; Economic activities	Commuting choices	Dallas, USA, 1,200,000 Ihnabitants Albuquerque, USA, 555,417 ihnabitants	Yes From 1995	Strategic	Dynamic	Competitive	Field experiment
Natalini and Bravo 2014	Testing ex ante the impact of public policies willing to foster commuting choices with lower GHG emissions	Transport mode choice by the agent; price of the transport mode	Commuting choices of Inhabitants	USA: various cities	Yes 2009	Strategic	Dynamic	Cooperative	Field experiment

Conclusions

- Effort to develop ABMs for people or freight transport analysis increased in the last years.
- Their success is due to their capability to represent complex interactions, the diversity and the variability of urban transport mobility and system.
- Policy makers often fail in capturing problems at the roots of passengers and freight mobility. ABM can give an important contribution to fill in this gap.
- However, there is still a gap in ABM urban transport modelling.
- Most of ABMs dealing with freight consider regions broader than urban areas only.
- ABMs dealing with passengers mobility in urban areas are more numerous, but their number is still limited. Focused on sub groups of citizens.

Further research needs

- Few papers calibrate the model on real data. The heterogeneity of categories of actors makes difficult and expensive real surveys for calibration of the ABM on first-hand data
- Only an empirical work (TRANSIMS model) tries to integrate freight and passengers mobility (Smith et al 1995).
- The most useful frontier is the development of ABMs that integrate passengers and freight dimensions. => any public policy inevitably influences both spheres.

Next steps of our research

1. To develop an agent-based model for simulating urban passenger mobility
2. To extend this model to include the urban freight flows
3. To study the interaction between passenger and freight mobility in urban areas and test some public policies

First step: Overview of our ABM model on urban passenger mobility/1

<u>Aim</u>

- Reproducing transport choices of a sample of citizens
- Estimating greenhouse gas emissions of their daily commutes.
- Evaluating the impact of public policies for "greener" commuter choices

<u>Entities</u>

- The commuter
- The government
- In the first stage no representation of the space

First step: Overview of our ABM model on urban passenger mobility/2

- Agents receive heterogeneous preferences on the possible transport mean choice
- Agents decide whether to make Short Commute (SC) or Long Commute (LC).
- Agents choice the transport mean - private motorized vehicle (M), private non-motorized vehicle (NM) or public transport (PT) – on the basis of their heterogeneous preferences
- Social network is created according to the closeness of the initial preferences of the agents.
- Preferences are influenced by
  - the relative price of the different means of transport
  - the social network
  - intensity of the policies applied
- Preferences are inspired to real data (Census ISTAT, 2011 and Municipality of Varese, 2008)

First step: Overview of our ABM model on urban passenger mobility/3

- Each mean of transport has cost/km, relative cost, average CO_2 emission/km, environmental index
- The agent decides its means of transportation on the basis of:

1. **Total need = (personal need + social need)/relative price of the means of transport**

   Where

   personal need satisfaction = relation between past and present transport choice

   Social need satisfaction = proportion of members of the agent's network using the same means of transport of the agent

2. **Uncertainty = variation over time of agents' satisfaction**

First step: Overview of our ABM model on urban passenger mobility/4

- According to the thresholds of the agents toward need satisfaction and uncertainty, they use 1 out of **4 deliberative processes**:
  - **imitation**: they choose the means of transportation which is most common in his network.
  - **rational deliberation**: they choose the means of transportation that brings the highest satisfaction.
  - **repetition**: they repeat the choice of the previous time step.
  - **social comparison**: they use a combination of the "imitation" and "rational deliberation" processes.

First step: Overview of our ABM model on urban passenger mobility/5

- 2 kind of policies will be targeted either for all agents or for the less "environment-friendly" ones.

1. **Market-based policies**: increase in the price of the most polluting means of transportation.
2. **Preference-change policies**: increase in the tendency of adopting less polluting means of transportation.

- => changes in agents choices of transport means will be estimated
- The intensity of both policies is decided by the researcher.
- Test each policy alone, or different combinations of the two.

THANK YOU FOR THE ATTENTION!

elena.maggi@uninsubria.it