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SIMULATION OF URBAN RETAILERS' FREIGHT PROVISION THROUGH AN AGENT-BASED MODEL: THE CASE OF TURIN

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OUTLINE OF THE PRESENTATION

- Research framework
- Aim and research questions
- Methodology: ABM model
- Data: input and output of the model
- Tested policies and simulation scenarios
- Results of the simulation
- Conclusions

RESEARCH FRAMEWORK

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- Contribution to the **European project** (first call **Horizon 2020**; duration: June 2015-May 2018) **NOVELOG -** New cOoperatiVe business modEls and guidance for sustainable city LOGistics (http://novelog.eu/)
- **Aim of NOVELOG**: "NOVELOG will support the choice of the most optimal and applicable solution for urban freight and service transport, and will facilitate stakeholder collaboration and the development, field testing and transfer of best governance and business models"
- **Agent-Based Model (ABM) is one of the assessment tools** proposed to estimate the city logistics measures tested by NOVELOG pilot and case studies (municipality of Turin is one of the 12 pilot cities)

Research framework

- 28 partners and 12 case studies/pilots in different European countries

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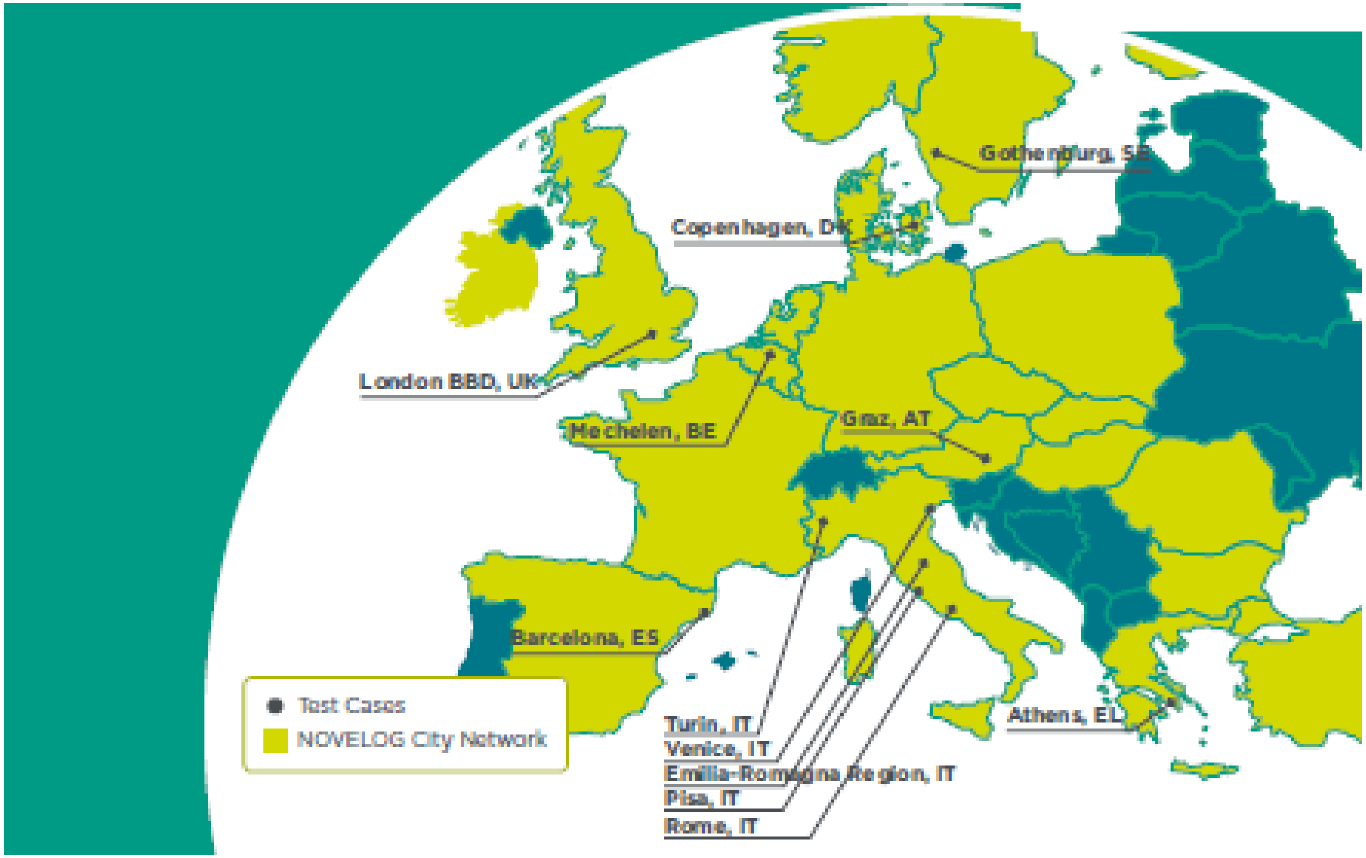


AIM AND RESEARCH QUESTIONS

AIM: to simulate the retailers' behaviour during the freight provision process, in order to test the effectiveness of some sustainable transport policies that can be applied by the city of Turin

RQ 1 which mechanisms have stronger influence on the retailers' decision-making process about ecological or non-ecological behavior for goods supply?

RQ2 to what extent NOVELOG-based policies implemented by the city of Turin may foster more ecological behaviors of retailers during the process of freight provision?

METHODOLOGY: ABM

- **What is an Agent-Based Model (ABM)?** A simulation tools able to analyze a complex environment, such as the urban freight, through the design of the features of each system components and the interactions among them.
- **Why an ABM?** Advantages:
  - Capability to consider high heterogeneity of agents (in terms of features, objectives, location,….)
  - Possibility to simulate feedback dynamics between agents and the events (representing social network)
  - Capability to observe the over time dynamics of the process and the differences between particular time steps (emerging properties estimation)
  - Bottom-up approach: from the interactions of agents at individual level it is possible to observe the emergent properties of the whole system
  - Strong flexibility (simulation of different policies in different contexts)
  - Both ex ante or ex post evaluation tool of the impact of policies
  - Low cost tool: software open-source, possibility to use virtual data

LITERATURE REVIEW

For more information see Maggi E., Vallino E. (2016), "Understanding urban mobility and the impact of public policies: The role of the agent-based models", *Research in Transportation Economics 55* (2016), 50-59.

- Few works focus on urban mobility: more on passenger transport than on freight transport
- Authors agree on the validity of ABM to simulate the complexity of urban mobility, trying to consider the single components as a part of a whole system
- Some ABMs test policies that improve services (e.g.: local public transport services); others test policies that provide incentives for the agents to modify their behaviour

LITERATURE REVIEW: ABMs AND FREIGHT URBAN TRANSPORT

Author(s)	Intention of the model	Type of variables and/or agents	Geographic dimension	Calibrated on actual data	Time horizon	Structure	Attitude	Maturity level
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
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
Tamagawa et al. 2010	Model for vehicle routing and scheduling problem with time window-forecasted	5 kinds of actors with different objectives on a test urban road network: Freight carriers; Shippers; Residents; Administrators; Motorway 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
Anand et al. 2012	Design of an ontology				Strategic	Dynamic	Both	Conceptual proposal
Van Duin et al. 2012	Investigation on the impact of policy measures for the success or urban distribution centres	Trucks and freight carriers; one type of goods; UDC operator; Retailers; Municipality; Road network	-	No	Strategic	Dynamic	Cooperative	Simulation experiment
Teo et al. 2014	Evaluation of the	Carriers' profit and cost, shippers' cost, distance travelled by trucks, n. of trucks, n. of	Osaka road network	No	Strategic and operational	Dynamic	Both	Simulation experiment

OUR MODEL: ABM-TO

- **What is ABM-TO?** An agent-based simulation (based on the open-source software NetLogo) of retailers' dynamics in freight transport provision within the Limited Traffic Zone in Turin ⇒ ecological or non-ecological behavior?
- **Ecological behaviour**: use of own-account transport with low pollutant vehicle (Euro 5 or electric or hybrid) or use of third-party transport providers
- **Non-ecological behaviour**: use of own-account transport with high pollutant vehicle.

OUR MODEL: ABM-TO

- **Assumption**: agents' incentives for behavioural change from non-ecological to ecological behaviour are based on
  1. personal motivation for environmental issues;
  2. comparison of perceived service quality and its price;
  3. network influence (imitation).

- A non-spatial **network structure** acts as a proxy of the social relations within the domain of the working and community context

INPUT: EMPIRICAL DATA

- 762 agents (30% of the 2,542 retailers in Turin LTZ)
- Vehicles crossing the entry points of the LTZ of Turin within 10 days in 2013: vehicle Euro class, own-account or third-party transport
- Commercial activities within the LTZ in Turin: commodity sector, location and size
- PM_{10} emissions of different Euroclass commercial vehicles

OUTPUT

- Timing of the diffusion of virtuous behaviors as effect of policies applied by the City of Turin («diffusion process» by Bass, 1969)
- PM_{10} decrease

Tested policies

- **"Pull" approach** ⇒ policies that incentive proactive attitudes by the beneficiaries, instead of punishing the rules' violation.
- 2 policies:

1. **Price policy**: indirect incentive to retailers (a permit that reduces the cost of freight provision) to shift from the non-ecological group to the ecological one:

   Examples of benefits from NOVELOG permit: an extended time-windows to access in LTZ, use of dedicated bus lanes and loading/unloading areas within pedestrian zones

2. **Motivation policy**: intervention on the agent intrinsic motivation for ecological behaviour (+ 10%) and on the desire to increase its reputation within the network (Fowler and Christakis 2010). Examples: educational campaign, eco-labeling.

Simulation scenarios

4 scenarios, with and without the motivation policy

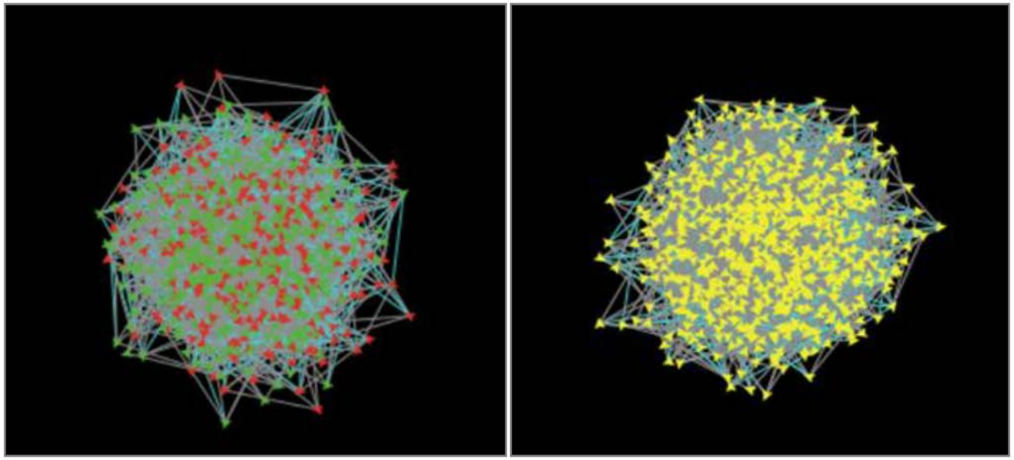
1. *Starting scenario:* no price- policy
2. *Soft own-account price policy*: light decrease of the price of own-account transport with low pollutant vehicle (OAE) and very low decrease of third-party solution price (TP)
3. *Strong own-account price policy:* consistent decrease of the price of own-account transport with low pollutant vehicle (OAE) very low decrease of third-party solution price (TP)
4. *Third-party price policy*: consistent decrease of the price of use of third party transport option (TP) and very low decrease of the price of own-account transport with low pollutant vehicle (OAE)

SIMULATION RESULTS/1

The model calculates for each scenario the unit of time needed to increase of 20% the n. of adopters (agents shifting from non-ecological behaviour to ecological one)

Scenario	Price levels	Initial share of adopters of ecological behavior (PM10 g/km)	Unit of time to reach +20% adopters (only price policies)	Time reduction (only price policies)	Unit of time needed to reach +20% adopters (price policy + motivation policy)	Time reduction (price policy + motivation policy)
1. No policy	TP: 2.5 OAE: 5 OANE: 3.5	57% (22)	1.83	-	1.54	-
2. Soft own-account policy	TP: 2.3 OAE: 3 OANE: 3.5	55% (23.43)	1.7	-7.1%	1.41	-9%
3. Strong own-account policy	TP: 2.3 OAE: 2 OANE: 3.5	59% (21)	1.56	-14%	1.4	-9%
4. Third-party policy	TP: 1.5 OAE: 4.5 OANE: 3.5	60% (20.18)	1.68	-8.19%	1.32	-14.28%

SIMULATION RESULTS/2



Retailers network before and after policies

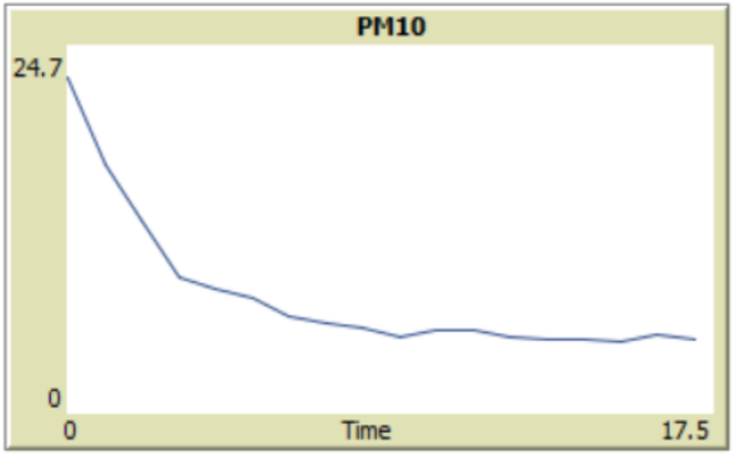
Green = retailers that started with ecological behaviour

Red = retailers with non ecological behaviour

Yellow=retailers that adopted ecological behaviour

- ✓ Agents progressively shift from non ecological to ecological behaviours
- ✓ The time for behavioural change and the consequent PM_{10} reduction differ according to the type and intensity of policy

In all the scenarios the environmental emissions always decrease by about 34% (from about 20-22 to 14.52 PM10 g/km)



Decrease of PM10 emissions (g/km) during the simulation

Conclusions

- In absence of motivation policy, agents react better to a policy that provides strong incentives to shift to a more ecological vehicle within the own-account option (scenario 3)
- In case of combination of price and motivation policies, the best results are given by a policy that provides incentives to the shift to third-party transport (scenario 4)
- Soft incentives for more ecological vehicles in own-account transport are more effective overtime than as initial shock and in combination with motivation policy (scenario 2)
- The simulation confirm the findings of the literature on reputation effects (Milinski *et al.*, 2002; Fowler and Christakis 2010): results come from the balance between the price policy effect and the network influence effect that is related to motivation policy
- **Further research**: To integrate the model with GIS tool, reproducing the real spatial network and to introduce the real time unit

THANK YOU FOR THE ATTENTION!

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