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Understanding urban mobility and the impact of public policies: The role of the agent-based models

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ABSTRACT

This paper provides a critical review of research on Agent-Based Models (ABMs) focusing on urban mobility, dealing either with passengers or with freight transport. The work concentrates on urban areas where public policies aiming at improving the sustainability of city systems necessarily affect both passengers and freight dimensions. Traffic in towns is responsible for a high share of congestion and pollution and consequently, it contributes to the climate change problems. The following conclusions can be derived. ABMs present important advantages for analysing urban transport and its sustainability but more efforts are needed in order to test and improve their use. In the literature, there is still a gap in urban transport AB modelling. The number of developed models is limited and they are often applied in broader geographical areas than urban ones. Only some of the works includes the estimation of environmental impacts as a result of certain types of agents' behaviour. Despite their potential effectiveness to represent the impacts of different public policies on agent behaviour and on the environment, none of the ABMs have been implemented in the real word by the researchers and there is no evidence of application of any model by policy-makers.

1. Introduction

Recently the role of Agent-Based models (ABM) for studying city logistics and passenger mobility in urban areas is highly debated in academic literature. However, the emphasis given at a theoretical level to the potential advantages of these types of models has not yet been translated in an intensive production of agent-based models addressing urban mobility (Tamagawa, Taniguchi, & Yamada, 2010). The aim of this paper is to provide a review of the existing works which utilize this tool for analysing either freight transport, or passengers mobility, or both at the same time, in cities and for predicting the impact of the different urban public policies on the agents' behaviour. By simulating the effects of the policies on stakeholders' transport choices, it could be also possible to estimate the potential environmental improvements and the ability of the regulation to meet sustainability and climate change goals.

The paper focuses on the urban environment because, in practice, freight and passenger flows co-exist and share the same physical scarce spaces. Public policies have an impact at the same time on the whole urban dimension, affecting the entire transport system. Moreover, the majority of world population lives in urban areas and continues to increase, supporting the negative externalities (pollution, noise, vibration, energy consumption, congestion, etc.) coming from transport and other social and economic activities.

In the European Union, over 60% of the population lives in urban areas and a car runs 75% of its mileage in and around cities. According to a recent opinion poll, 90% of Europeans think that the traffic situation in their area should be improved (European Commission, 2007). In Europe increasing traffic in the city centres is leading to permanent congestion. The delays and other damages caused by traffic jams cost the European Union 1% of its Gross Domestic Product. Many European citizens are exposed to high levels of air pollution, especially from the concentration of PM10, NOx and SOx (European Commission, 2009). The combustion of gasoline and diesel from people and goods transport accounts for 31% of total U.S. CO_2 emissions and 26% of total U.S. greenhouse gas

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emissions in 2013 (United States Environmental Protection Agency 2015). In particular, the domination of oil as a transport fuel generates CO_2 and air pollutant emissions in towns. In fact, urban mobility accounts for 40% of all CO_2 emissions of road transport and up to 70% of other pollutants from road transport (European Commission, 2007). This kind of phenomena contributes to the wider and highly debated process of climate change. However, in turn, climate change has consequences on the transport sector itself. For example, global warming producing a rise in sea level may amplify the vulnerability of coastal infrastructures. Extreme weather occurrences may affect the safety of all modes (European Commission, 2009). There is urgency for the transport sector to mitigate its negative impact on the environment both at local and global level. The EU adopted a package that sets a target of reducing greenhouse gas emissions within its area by 20% with respect to 1990 (European Commission, 2009). Within this framework it is clear that urban sustainability is one of the most important challenges of the present and future societies.

According to the analysis of this paper, agent-based modelling can be an effective instrument able to describe in a dynamic way the behaviour of each stakeholder or group of homogenous stakeholders and their relations. Nevertheless, the use of ABMs for the analysis of urban mobility issues is at relatively initial stages. The literature on city logistics and urban passenger transport has concentrated its attention on other models and tools different from ABM, as briefly explained at the end of Section 2.2, but their analysis is beyond the scope of this paper.

The contribution of the paper to the transport economics literature is to develop a critical review and a classification, according to specific features, of the works focused on the use of ABMs for the analysis of urban systems, considering one or both the dimensions of passengers and freight flows. Therefore, the intention of the work is to identify a space in the academic literature to provide the basis for agent-based modelling, having the aim of simulating the whole system of mobility in cities and evaluating the effectiveness of public policies in terms of sustainability and climate change goals.

The paper is structured as follows. In the next section an overview on the complexity of the urban mobility system and on the potential role of ABMs in analysing this complexity is provided. Moreover, the possibility to integrate ABMs with Geographical Information Systems (GIS) in order to better describe the actors' spatial interactions is underlined. In Section 3 a framework for the creation of a taxonomy of existing research about ABMs and urban systems is presented. Section 4 is dedicated to the analysis of the surveyed literature according to this taxonomy, while in the last section some conclusions are drawn and further research needs are suggested.

2. The urban system and the agent-based models

2.1. The complexity of the urban mobility system

Urban mobility presents all the characteristics of a very complex system: a high number of stakeholders, very heterogeneous and with different roles, needs and aims; strong interactions between these numerous agents and between them and the environment in which they act; very complex transportation networks used for mobility often at the same time. Moreover, the system and the environment are evolving over time; agents evolve continuously, changing their specific behavioural patterns, according to their interactions and time-based feedback and following the dynamics of the urban context and structure.

In this system the performance of each network is influenced by individuals choice and behaviours and vice versa. Moreover, each stakeholder group has particular decision-making processes (Anand, Duin, Quak, & Tavasszy, 2011; Anand, Yang, Van Duin & Tavasszy, 2012; Buliung & Kanaroglou, 2007). Particularly, as regards passenger transport, commuters aiming to reach the work place quickly, on time and comfortably interact with tourists, shoppers and other city users with specific and different transport choices. The single transport mode and infrastructure used by the passengers are components of complex chains and networks.

Referring to freight transport, the economic services offered are fragmented in a high number of small activities and the decision-making process is highly distributed. In cities different Urban Supply Chains (UBCs), i.e. the last mile of the supply chain in charge of delivering goods to urban areas, interact (Danielis, Maggi, Rotaris, & Valeri, 2013). They have a very complex nature and can assume different profiles, according to the characteristics of the urban area and of the other economic activities and to the product and the structure and organisation of the whole distribution system. Also from the demand side of urban logistics services, there is high fragmentation, since citizens often derive high benefits by buying items in small local shops or ordering the goods online. The level of demand fragmentation is higher in some countries, such as in Italy, where the large-scale retail trade in the cities is less widespread while the urban sprawl is great (Maggi, 2007).

As summarized in Table 1, the different categories of actors involved in freight urban mobility domain have different roles that generate different kinds of needs and interests, often conflicting. As a consequence, these actors follow their own goals without any centralized control, creating both economic and environmental inefficiency: a higher number of vehicles and trips per day than the optimal one, very low average load factor per vehicle and higher levels of pollution and congestion. For example, shopkeepers order small but frequent deliveries, because they have very small space for warehousing in order to contain the total logistics costs. In this way they reduce the inventory cost, but at the same time they limit the capacity of operators delivering the goods to maximize the vehicle loading factor. On the other hand, local administrators impose rules such as weight restrictions to mitigate the disturbance from commercial vehicles, but these limits may damage the efficiency and the quality of services supplied by the transport carriers.

For these reasons, in the last two decades a specific transport economic domain has been developed, called city logistics, that can be defined as “the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic conditions, congestion issues and combustible consumption, with a view to reduce the number of vehicles on the cities, through the rationalization of its operations” (Institute for City Logistics, www.citylogistics.org).

City logistics and urban passenger mobility analyses need to be supported by economic models and tools, helpful in creating a knowledge base about freight and people flows and behavioural issues of the different stakeholders (Taniguchi, Thompson, &

Table 1
Interests of stakeholders involved (Macário, Galelo, & Martins, 2008).

Stakeholders	Interests
Residents	Products and services
	Negative environmental impact
Retailers	Competitiveness and profitability
Authorities and public service	Accessibility
	Governance and legislation
	Negative environmental impact
Suppliers	Market growth
	Profitability
Carriers	Congestion
	Cost effectiveness

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