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# Multi-agent modelling approach for evaluating the city logistics dynamic in a vulnerability situation: An exploratory study in Belo Horizonte (Brazil)

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**Abstract**

This paper presents the results of a multi-agent modelling approach for evaluating urban goods distribution in a vulnerability situation. We analyse the impact of floods on urban freight transport. The model is based on stakeholders' relationships and behaviours and the results are presented with regard to the environmental and financial impacts. The consistency of the theoretical and analytical routines used was checked with the simulation results. The results showed the benefits of using multi-agent modelling analysis to reduce impacts on urban freight transport in flooding situations.


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*Keywords:* City Logistics; Urban Distribution of Goods; Multi-Agent Modeling; Vulnerability; Mitigating Measures; Rain; Flooding

## 1. Introduction

An increase in the volume of production, consumption and movement of goods and services in an urban region promotes its economic expansion, generating a significant rise in demand for transport, which in turn generates social, economic and environmental impacts on cities (Taniguchi and Heijden, 2000; Taniguchi and Thompson, 2003; Dablanc, 2007; Browne, 2007). Taniguchi et al. (2001), Anderson et al. (2005) and Benjelloun and Crainic (2009) also state that flows of goods and services, previously limited by distance, are today key activities in the

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development of cities with significant influence on people's lifestyle and the maintenance and competitiveness of industrial and commercial activities.

Dablanc (2009) defines urban freight transport as 'a segment of freight transport which takes place in an urban environment. Specifically, urban freight is the transport of goods by or for commercial entities (as opposed to households) taking place in an urban area and serving this area. This definition includes all movements of goods generated by the economic needs of a local business unit, i.e. all deliveries and pick up of supplies, materials, parts, consumables, mail and refuse that a business needs to operate. It also includes home deliveries to households, as they are generally done by means of a commercial transaction'. Castro and Kuse (2005) define urban goods distribution as the movement of goods, including transportation of finished goods, raw materials, goods distribution in urban centres, fast delivery services and home deliveries.

Czerniak et al. (2000) point out that urban freight transport is not an end in itself, but the result of an economic process. Ogden (1992) defines freight movement as the movement of 'things' (as distinct from people) in urban areas, including movements of things to/from the area or through the area, carried out by all means. Dablanc (2007) observes 'a large number of different types of freight flows constantly cross an urban environment'.

For Dablanc (2007) and Crainic et al. (2009), freight transport has no substantial share in the traffic flow in urban centres, as it ranges from only 10 to 30%. In Belo Horizonte (Brazil), to ensure market demand, a fleet of approximately 153,000 freight vehicles move between the main roads (Brasil, 2015), representing 2.3% of the vehicle fleet in the city (Oliveira, 2014). Despite the low representativeness, they are mainly responsible for the problems related to urban freight transport (Taniguchi et al., 2001; Oliveira et al., 2014): pollutant emissions (i.e. nitrogen oxide - NOx, carbon monoxide CO and suspended particulate material - PM), and noises that damage the environment and health; increased consumption of non-renewable resources; deteriorating urban infrastructure, increased costs associated with inefficiency of the logistics systems of urban goods distribution.

Allied to these factors, there is the uncontrolled growth process that cities are suffering. The urbanization is a global trend due to economic growth and increased expectation of quality of life. It has happened quickly, disordered and without an appropriate planning. This has resulted in a deterioration of living conditions, mobility and the urban areas. The urbanization requires more goods to be transported within densely populated areas, causing thus negative impacts on the environment.

Because urban freight transport is an important element in urban planning and is essential for the supply chain and sustainable economic growth (Taniguchi and Heijden, 2000; Lindholm and Behrends, 2012; Rodrigue et al., 2013), a new area dedicated to transportation planning known as urban logistics has emerged (Taniguchi et al., 2001; Ehmke, 2012), which must be dynamic to suit the current characteristics of the market and requires agility and flexibility in critical and unexpected situations defined as vulnerable (Chambers, 1989; Pelling, 2003).

City logistics consists of measures to reduce the social and environmental cost related to urban freight transport (Taniguchi and Thompson, 2003). Taniguchi et al. (2001) point out that city logistics is a key tool for optimizing the activities linked to the goods distribution in urban centres carried out by public or private entities and considering factors such as traffic congestion and energy consumption. Among the measures applied by city logistics are urban distribution, city distribution, urban logistic spaces, pick-up points, off-peak delivery and real-time information systems.

To assess the effectiveness of measures in the urban context, several researchers have considered urban freight transport and a multi-agent modelling approach (Wangapisit et al., 2014). Agent analysis is a promising approach in vulnerable situations of urban freight transport (Araguão et al., 2015). Such analyses are suitable for the management of processes in urban freight transport and can be used to understand the behaviour of agents in vulnerable situations.

A multi-agent model considers the interaction of each agent with its environment by following behaviours and pre-established goals. An agent can be understood as an autonomous system with a certain goal which operates asynchronously' however, when necessary, it can work with other agents (Fox et al., 2000). Wooldridge (2002) sees the agent as a software entity located somewhere, with autonomous and proactive behaviour oriented to the relevant goals. This agent has the characteristics of autonomy, the ability to perceive, think and act in its environment, and the ability to interact socially and communicate in order to perform tasks (Huhns and Singh, 1997; Weiss, 1999; Wooldridge, 2002; Teo et al., 2012; Wangapisit et al., 2014). Also, according to van Duin et al. (2012), agents can observe the environment, its parameters and information. This observation can change their internal state, which