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Simulating participatory urban freight transport policy-making: Accounting for heterogeneous stakeholders' preferences and interaction effects

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ABSTRACT

This paper proposes a novel approach to support participatory decision-making processes in the context of urban freight transport through the integration of discrete choice modeling and agent-based modeling. The methodology is based on an innovative multilayer network and opinion dynamics models and applied to the case study of Rome's limited traffic zone. Simulation results produce a ranking of plausible policies that maximize consensus building while minimizing utility losses due to the negotiation process. These results can be used to support real participatory decision-making processes on freight-related policies accounting both for stakeholders' heterogeneous preferences and their interaction effects.

1. Introduction

Urban freight transport (UFT) is a complex world characterized by multiple and conflicting interests. Policy-makers have to deal with the three main actors in the supply chain, i.e. (1) shippers and producers who supply the goods, (2) receivers representing the demand for goods and (3) transport providers, in charge of the transportation of the goods, as well as those actors not directly involved with freight transport movements, but that can be indirectly affected by the decisions, i.e. residents, tourists and visitors (MDS Transmodal, 2012). All of them can be considered UFT "stakeholders", according to the broad definition of Cascetta et al. (2015): "people and organizations who hold a stake in a particular issue, even though they have no formal role in the decision-making process". Public authorities should try to strike a balance between private and

Abbreviations: 2BCS, second-best case scenario; 3BCS, third-best case scenario; ABM, agent-based model; BCS, best case scenario; DCM, discrete choice model; EF, entrance fee; LC, latent class; LUB, number of loading/unloading bays; OA, own-account operators; OAS, own-account-oriented scenario; PC, policy change; PLUBF, probability of finding a loading/unloading bay free; RE, retailers; RES, retailer-oriented scenario; SP, stated preferences; SQ, *status quo*; TP, transport providers; TPS, transport-provider-oriented scenario; TW, time windows; UFT, urban freight transport; WCS, worst case scenario; WTC, willingness to change; WTP, willingness to pay; WTPS, willingness-to-pay-oriented scenario.

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public objectives. This, in general, implies: maximizing freight distribution efficiency, minimizing the related negative externalities, and fostering city sustainability and livability.

The importance of adopting a participatory decision-making process is, nowadays, widely recognized. This entails a direct involvement of all the interested actors during the definition of the policy measures to be implemented (Gatta and Marcucci, 2014; Quick, 2014; Cascetta et al., 2015). The whole living lab research stream is based on this assumption (Eriksson et al., 2005; CITYLAB, 2015; Quak et al., 2016) and also supported by all the arguments related to the Sustainable Urban Mobility Plans that the EU supports (Wefering et al., 2014).

Freight quality partnerships (FQPs) are effective means to involve local governments, freight operators, environmental groups and other interested stakeholders when addressing specific freight transport-related problems. Several examples of good practices can be cited in the UK (DfT, 2003). However, FQPs are not always easily implemented or capable of providing appropriate solutions to UFT problems, as Lindholm (2014) illustrates through examples of successes and failures. Not only it is important to get an active and direct involvement of all the interested parties in the decision-making process, one has also to find the most shared, and thus supported, policy emerging from a transparent deliberative process.

From a policy-maker's perspective, considering inter-agent heterogeneity is fundamental to account for the impact each policy component might have on specific agent behavior thus helping in taking better decisions (Taniguchi and Tamagawa, 2005). Besides, in a participatory decision-making process interaction among stakeholders through deliberation is fundamental to stimulate opinion exchanges towards a shared decision (Quick et al., 2015).

This paper jointly deals with inter-agent heterogeneity and stakeholders' interacting behavior via a novel agent-specific and dynamic modeling approach. The approach proposed integrates discrete choice modeling and agent-based modeling with the intent of providing a useful tool capable of supporting participatory decision-making processes in the context of UFT policy-making.

The remainder of the paper is organized as follows: Section 2 presents the research framework while Section 3 shows the contribution of the paper to the existing literature; Section 4 describes the modeling approach used; Section 5 illustrates the results of the agent-based simulations deriving policy implications and discussion; Section 6 concludes discussing future research endeavors.

2. Research framework

Stakeholders response to policy change is a hotly debated topic. Models are widely used to test what-if scenarios and perform *ex-ante* evaluations of stakeholders' behavior before implementing specific UFT policies (Taniguchi and Thompson, 2015). The majority of all decision problems in city logistics are multi-objective. Zhang et al. (2015) capture the conflicting objectives of different stakeholders solving a bi-level optimization problem of a multi-actor, multi-commodity multimodality freight transport network. However, the strong need to include more stakeholder-related behavioral issues in city logistics modeling has led to the development of many models aimed at describing, analyzing and predicting how a stakeholder may respond to a given scenario. Hensher and Puckett (2005) propose a stated choice experiment to reveal the preferences of interactive agents along the supply chain; Holguín-Veras (2008) discusses the necessary conditions required for receivers and carriers to agree to perform off-hour deliveries, and the effectiveness of alternative policies to foster such change in competitive markets; Marcucci and Gatta (2017) investigate the potential for off-hour deliveries in the city of Rome by exploring retailers' preferences inquiring their willingness to adopt specific prototypes; Nuzzolo and Comi (2014) propose a multi-stage model aimed at investigating the relations among city logistics measures, agents and choice dimensions; Stathopoulos et al. (2012) and Bjerkan et al. (2014) report the results of a survey about stakeholders' preferences and stated behaviors that would most likely be enacted if a given policy-mix were to be introduced to improve the current freight distribution scheme in Rome and Oslo respectively; Holguín-Veras et al. (2015) provide an economic interpretation of the interactions among freight agents to predict their response to pricing and incentives measures; Marcucci et al. (2015) and Gatta and Marcucci (2016b) use discrete choice models to analyze transport provider's preferences for alternative parking policy measures.

Nevertheless, some authors show that only few effective UFT measures are successfully implemented (Jones et al., 2009). This is mostly due to the lack of knowledge characterizing many local authorities with respect to different carriers' logistical operations, and also to the unsatisfactory accounting of the interaction between local authorities and carriers (Quak, 2008). Besides, the observed significant heterogeneity in stakeholders' preferences reduces the chance of an overall policy acceptability (Gatta and Marcucci, 2014). In fact, asymmetric power relations among suppliers, carriers and receivers are often detected and they are so strong that receiver-centered policies are more likely to produce successful behavioral changes with respect to carrier-centered ones (Holguín-Veras et al., 2015).

Modeling should allow the exploration of the various interconnected decision-making processes and patterns characterizing the different stakeholders in relation to regulations and policy measures tested. Gatta and Marcucci (2014) demonstrate how an agent-specific knowledge of the effects each policy component produces can increase decision makers' awareness thus helping taking better decisions.

Researchers have started exploring freight transport problems using agent-based models (ABMs), given their capability to reproduce communities of heterogeneous autonomous agents, with certain properties and behaviors, interacting in a common environment via a set of relationships and methods of interaction (Macal and North, 2010). Davidsson et al. (2005)