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A systematic evaluation of freight carrier response to receiver reordering behaviour

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ABSTRACT

The fields of behavioural transport modelling has been gaining momentum and many researchers have focused on incorporating some elements of stakeholder behaviour and decision making into their freight planning tools. However, investigation of the literature reveals that few papers are devoted to understanding and integrating logistics behaviour of freight *receivers* into urban transport simulations, and the impact of receiver reordering constraints on other freight agents in the urban transportation network has not been thoroughly investigated.

This paper is therefore concerned with evaluating the impacts that constraints set by freight receivers during reordering have on carriers' behaviour and cost in an urban freight transport simulation. To achieve this, three key receiver reordering constraints scenarios are simulated: delivery time window durations; delivery frequencies and its associated quantities; and delivery unloading or service time at receiver facilities. These scenarios are then implemented in an agent-based transport simulation and the carrier's behaviour and delivery cost are evaluated.

Results indicate that narrowing time windows could result in delivery and penalty cost increases of up to 93%. Extending unloading times can see costs and penalties increase by up to 111%. Delivery frequency (and therefore order quantity) also has a major impact of the carrier's cost, with cost increases of up to 142% when requesting more frequent deliveries of smaller quantities. These results confirm that carrier decisions are influenced significantly by changes in receiver reordering behaviour and unnecessary constraints imposed by receivers during reordering could have significant negative implications on the delivery cost of the carrier. This emphasises the importance of finding a balance between restrictions set by supply chain customers during reordering and the cost associated with those restrictions and highlights the importance of finding ways to urge freight agents, especially receivers, to change their current behaviour to lower the total delivery cost of the supply chain.

1. Introduction

In 2015 it was estimated that around 53% of the world's population resided in urban areas. Considering that this figure was around 43% in 1990, the rapid rate of urbanisation around the world is evident (Moreno et al., 2016). Increased populations in urban areas results in increased demand for passenger and freight transportation in these areas, which in turn increases the pressure on the urban transportation system.

Freight transportation is an imperative aspect of urban transportation systems around the world, and although representing a small proportion of the road users, commercial vehicles make a disproportionately large contribution to congestion, infrastructure deterioration, and emissions. It is therefore important to ensure proper planning processes are in place to minimise the impact of freight movements in urban areas.

Until recently, little attention was devoted to the planning of the transportation of goods within city boundaries, henceforth referred to as *urban freight*, despite its importance in the functioning of cities (Giuliano & and Dablanc, 2013).

In the context of urban freight, Boerkamps, Van Binsbergen, and Bovy (2000) identify the stakeholders associated with the creation, movement, and administering of the freight (and the organisations associated with it), collectively referred to as *freight agents*. Private sector freight agents include shippers, carriers and receivers, whereas public sector freight agents, such as authorities or municipalities, are referred to as administrators. Although these freight agents share the common objective of *transporting freight in an urban area*, they have conflicting

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individual interests that must be considered during freight transportation planning (Anand, Quak, van Duin, & Tavasszy, 2012).

Shippers are the suppliers or producers of goods ordered by *receivers*, such as shopkeepers, retailers, restaurants, etc. These goods are typically transported by freight *carriers*, such as freight forwarders, from the shipper's location to the receiver's store. It is important to understand the interaction between different urban freight agents during demand fulfilment, as it provides insights about factors driving the movement of goods in urban areas (Anand et al., 2012). In addition, understanding the effects of logistics decisions on freight transportation flows can allow decision makers to better estimate the effects of changes in logistics systems and related policies on future transportation flows (Tavasszy, Ruijgrok, & Davydenko, 2012). It is therefore necessary to understand the logistics behaviour of the different urban freight agents to better understand urban freight movements, and thereby enabling improved urban freight planning, management, and policy decision making.

Recognising this, many researchers have focussed their attention towards understanding and incorporating logistics behaviour into urban freight planning (De Jong & Ben-Akiva, 2007; Holguín-Veras, Xu, de Jong, & Maurer, 2011; Liedtke, Matteis, & Wisetjindawat, 2015; McCabe, Kwan, & Roorda, 2013; Wang & Holguin-Veras, 2008; Schroeder & and Liedtke, 2014; Liedtke, 2005). Most of these contributions focus on the logistics decisions familiar to transport modelling such as modal choice, route choice, fleet composition, shipment size, etc. These decisions are typically made by the shipper or carrier agents. However, understanding and incorporating receiver logistics behaviour, especially reordering behaviour, into urban freight planning did not receive much attention.

It is imperative to understand receiver reordering behaviour and incorporate such behaviour into urban freight transportation planning, since the receiver is a powerful freight agent whose reordering decisions generate a demand for freight movement in urban areas. This is confirmed by Holguín-Veras (2010) who notes that receivers mostly dictates how and when shippers and carriers must deliver their orders. Carriers must therefore plan their freight movements according to the reordering decisions made by the receiver since these decisions could potentially have a significant impact on the delivery cost.

Marcucci et al. (2017) also suggest that to be more efficient, urban freight policies should target receivers, as the generators of demand, instead of carriers. Understanding and considering receiver reordering behaviour during urban freight modelling can then enable urban freight planners and decision makers to consider the impact of such behaviour on the transportation network and its agents during urban freight planning and policy decision making more accurately.

This paper is therefore concerned with systematically evaluating the impact of constraints set by the receiver on carrier freight movements in an agent-based simulation model, to ascertain if model is sensitive to behavioural changes, and capable of representing the agents' behaviour accurately. More specifically, the paper investigates the receiver's time window restrictions, delivery times, and order frequency. These restrictions are measured in terms of their effect on a carrier's fleet composition and total delivery costs.

The remainder of the paper is structured as follows: Section 2 presents a discussion of the urban freight environment as well agent-based transport and logistics behavioural modelling advances in the literature. The multi-agent implementation and experimental setup for the simulation used to investigate carrier response to receiver constraints is presented in Section 3. Results and findings from the various experiments are presented in Section 4. The paper ends in Section 5 with concluding remarks along with directions for further development.

2. Literature review

The demand for freight movement in a transportation network is driven by the logistics decisions of freight agents (shippers, receivers, carriers and administrators) in that network. Understanding how these decisions influence freight demand and travel behaviour can enable various stakeholders involved in the planning, maintenance and utilisation of urban transportation networks to make better informed decisions.

Consider a scenario where a receiver places a product order at a particular shipper. The ordered product must then be transported from the shipper to the receiver during order fulfillment. Understanding how the receiver decides when and how much to order and what conditions to set for order delivery can enable planners to more accurately estimate freight movements between the shipper and receiver. Similarly, understanding the decision drivers of shippers during the selection of carriers, for example, can enable decision makers to estimate freight movements between shippers and receivers by different carriers, and along different modal corridors.

This could provide a more realistic picture of expected future urban freight movements which could provide a more realistic basis to evaluate the impact of changes to the urban freight systems and their associated policies, as well as the impact of logistics decisions made by freight agents interacting with those systems.

2.1. Agent-based transport modelling

Agent-based transport modelling is a technique that provides the capability to model large populations of heterogeneous agents. Agents, be it private individuals or freight stakeholders, have individual and autonomous behaviour, and interact with one another in a transportation system. One consequence is that congestion need not be modelled explicitly but rather emerges due to many decision-makers and travellers co-existing and relying on limited transport infrastructure (Balmer, Axhausen, & Nagel, 2006).

The suitability of agent-based modelling approaches in complex urban freight environments have been widely illustrated over the last two decades. Anand, van Duin, and Tavasszy (2014) conclude that urban transport policies analysed using agent-based simulation techniques are more robust because they are evaluated under the dynamically changing circumstances of urban freight transportation. Other advantages of agent-based modelling approaches other conventional transport modelling approaches include the availability of richer, disaggregate output.

Contributions like Hunt and Stefan (2007), Joubert, Fourie, and Axhausen (2010) and Nagel, Kickhöfer, and Joubert (2014) included freight vehicles, often along with private cars in the large scale implementations. However, the activity chains of the freight vehicles were derived from historically observed activity and include little autonomous behaviour on the part of the freight vehicles. As a result the inclusion of these vehicles were little more than realistic additional load on the network (Schroeder, Zilske, Liedtke, & Nagel, 2012). The modelling of adaptive logistics behaviour in transport simulation received increased attention in the last few years.

2.2. Logistics behavioural modelling in transport simulation

During a review of past urban freight logistics modelling contributions, Anand, van Duin, Quak, and Tavasszy (2015) found that despite the influence of private sector stakeholder decisions on freight movements, most of the earlier urban logistics modelling efforts were done from the administrator's perspective. Only recently did researchers start considering the logistics decisions of private urban freight transportation stakeholders, i.e. shippers, carriers and receivers, and its effect of the urban freight transportation system. Many of these researchers used agent-based simulation models to investigate and evaluate a wide variety of urban freight problems (Balmer et al., 2006; Boerkamps et al., 2000; Marcucci et al., 2017; Marcucci, Gatta, & Scaccia, 2015; Raney et al., 2003; Roorda, Cavalcante, McCabe, & Kwan, 2010; Rieser, 2010).

To date, most of the contributions that present working transport