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Improving mobility by optimizing the number, location and usage of loading/unloading bays for urban freight vehicles

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ABSTRACT

The role of urban freight vehicle trips in fulfilling the consumption needs of people in urban areas is often overshadowed by externality-causing parking practices (e.g., double-parking associated with traffic delays). Loading/unloading bays are generally viewed as an effective way to avoid freight vehicles double-parking, but are often misused by non-freight vehicles. We assess the potential of reducing freight vehicles double-parking mobility impacts by changing: (a) the spatial configuration (number, location, size) of loading/unloading bays and, (b) the non-freight vehicles parking rules compliance levels.

Parking demand models were created with data from an establishment-based freight survey and a parking observation exercise. Two case studies were defined for 1 km^2 zones in the city of Lisbon, Portugal. Alternative bay systems were derived from an iterative implementation of the "maximize capacitated coverage" algorithm to a range of bays to be located. Parking operations in current and alternative bay systems were compared using a microsimulation. Bay systems' ability in reducing double-parking impacts was assessed via a set of indicators (e.g., average speed).

Freight traffic causes a disproportionate amount of externalities and the current bay configuration leads to greater mobility impacts than some of the proposed systems. Enforcement was a crucial element in reducing parking operations impact on traffic flow in one of the case-studies. Road network characteristics were demonstrated to play a role in the adequate strategy of arranging the spatial configuration of bays.

1. Introduction

Urban freight traffic is estimated as being 6–18% of total urban traffic flows (Russo and Comi, 2012; Muñuzuri et al., 2012a) but has greater impacts on noise, pollution levels and congestion (Giuliano et al., 2013; Schoemaker et al., 2006). Furthermore, there is a global trend for increased freight movements. Increasing population, and retail establishments aiming to hold smaller inventories and more product variety contribute to this trend. Thus, all else remaining constant,

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we can expect an increased impact of freight in congestion and in demand for parking infrastructure. Parking infrastructure, especially in city centers, has high demand and limited supply.

Illegal parking and/or parking in situations prone to causing traffic disturbances (e.g. double-parking, in-lane parking) is an important driver of congestion (Delaître, 2009; Aiura and Taniguchi, 2006; Dezi et al., 2010; Cherrett et al., 2012), thus reducing mobility. These parking practices can occur due to disregard for other drivers but most likely happens in zones where demand greatly exceeds supply (i.e. with limited/unavailable/non-existent freight parking supply). The alternative to double-parking would be cruising for parking (Shoup, 2006), resulting in an increase of expenditures due to delays in deliveries, additional fuel consumption and driving stress (Marcucci et al., 2015). On the other hand, when drivers are fined for double-parking, this behavior also results in extra expenditures (Nourinejad et al., 2014; Morris et al., 1999; Conway et al., 2013). Even then, it can be considered as a rational response (Tipagornwong et al., 2015).

Research suggests that freight-dedicated parking supply deficit can be related to (a) the scarcity/inexistence of loading/unloading bays (Delaître, 2009); (b) an inadequate spatial configuration, e.g., inappropriate location or size (Dezi et al., 2010; Morris et al., 1999); or (c) lack of enforcement targeting bay occupation by non-freight vehicles and/or overlong occupation by freight vehicles (Aiura and Taniguchi, 2006; Dezi et al., 2010). Bays can be defined as *"stop areas,* (. . .) *not suitable for parking, where the driver can stop his vehicle to perform freight loading and unloading operations, without disrupting traffic flows, to the commercial and industrial activities in a limited radius*" (Delaître and Routhier, 2010). The terms traffic-flow and mobility will be used interchangeably throughout the paper.

In Lisbon (Portugal), the existing freight parking system is inadequate for current needs, as acknowledged by the City Council (CML, 2005). Moreover, as there is no information about the criteria used in the creation of this system, it is very difficult to understand the reason for its design limitations and constraints. Consequently, it is important to focus on how to improve the parking system, particularly as carriers/drivers are willing to use it (Nourinejad et al., 2014; Debauche, 2008; Shimizu et al., 2007). In this process, enforcement plays an important role in the success of the parking system, by assuring the bays are solely used for loading/unloading activities by freight vehicles, hence allowing for better bay availability (Muñuzuri et al., 2006). This also avoids over-dimensioning of the system, i.e., providing more parking infrastructure than needed.

This rationale leads to the following research question: What is the potential of bays in reducing externalities caused by urban freight, when provided with an optimized distribution/capacity and combined with parking enforcement?

To explore this question, we argue that the spread of an obstruction caused by a double-parked vehicle depends both on spatial and temporal dimensions. The first dimension is related to a change in trajectory that vehicles must perform to overtake a double-parked vehicle. This obstruction is assumed to be dependent on: (a) the number of vehicles that are double-parked, (b) the position of the double-parked vehicles in the road section, and (c) the characteristics of the road (e.g., number of lanes, dimension of lanes, and existence of traffic lights). The second dimension is related to the duration of the obstruction and associated travel time influence, i.e., the difference in travel time on the link for a crossing vehicle that faces an obstructing vehicle *versus* the same situation without the obstructing vehicle. We assume that the combinations of these dimensions characterize the spread capabilities of the obstruction and that both elements should be represented when researching double-parking impacts.

We reviewed a selection of the most relevant interoperable models that using simulation and optimization techniques at least partially address the aforementioned dimensions. Interoperable models aim to represent a complex group of phenomena and, by replicating a simplified instance of those phenomena, allow a better understanding of the underlying behaviors. Munuzuri et al. (2002) developed, to the best of our knowledge, the first simulation model aiming to represent various parking types (e.g., double-parking, parking on sidewalks). Despite the promising theoretical background this model was tested in a road network with 4 nodes and 3 links. Hence, its output is not sufficient to support policy-making. Aiura and Taniguchi (Aiura and Taniguchi, 2006) developed a simulation/optimization model to determine the optimal location of bays in urban areas by minimizing the total cost of operations. This model considers the parking of passenger cars in bays but it does not allow freight vehicles to double-park. It was only tested for a single road in Kyoto. Delaître and Routhier (2010) studied the impacts of freight vehicle double-parking. Contrasting with the work of Aiura and Taniguchi (2006), this model does not consider the case when a private vehicle occupies the bay. However, assuming the model solutions are a lower bound of reality, the model revealed that one obstructing vehicle could affect from 10 to 30 other vehicles. McLeod and Cherrett (2009, 2011) represented freight operations in a microsimulation setting. Both studies represented double-parked freight vehicles, but their focus was not the bay system configuration and the vehicles were not modelled explicitly (i.e., instead of stopped vehicles, sections of the road would be closed to traffic). Kladeftiras and Antoniou (2013) have estimated the impacts of double-parking on traffic conditions and the environment using microscopic simulation. They demonstrated that all chosen traffic indicators would be improved even if double-parking was suppressed at least partially. Mimicking the use of enforcement, this study focused on a reduction of double-parking events and not on the re-arranging of the loading/unloading bay system.

To deal with the optimization of the bay systems, Dezi et al. (2010) proposed a method to optimize the size, number and location of bays in a limited-access zone of Bologna, Italy. The authors also contribute with a description of the data acquisition process and an analysis of the bay system, as well as of the system usage by freight vehicles. One of the innovations of this work is the identification of the number of bays that corresponds to the largest increase in hourly coverage. Optimizing the location of existing bays is reported to increase area coverage by 23%. Muñuzuri et al. (2012b) have modeled the location-selection of mini-hubs for freight vehicles aiming at relieving the effects of time-windows constraints. This model requires a lot of detail regarding freight traffic. Moreover, it is based on an extensive list of assumptions that might be too

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