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Investigating Impacts of Pickup-Delivery Maneuvers on Traffic Flow Dynamics

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Abstract

Even if urban logistic has been extensively investigated in the literature, its effects on traffic flow dynamic remain mostly unknown. This paper aims to assess the impact of pickup-delivery trucks on traffic conditions. To this end, we resort to a theoretical but realistic urban arterial where deliveries are completed in double-park. The study first focuses on traffic flowing at capacity and determines the analytical formulation of the effective capacity when neglecting the effects of traffic signals. This formulation only depends on the characteristics of the arterial, the average time headway between truck arrivals and the average stop duration. It turns out that the pickup-delivery maneuvers strongly reduce the capacity. Then, this modeling framework is extended to other traffic conditions. The use of the macroscopic fundamental diagram (MFD) makes it possible to incorporate effects of traffic signals. To this end, an existing MFD estimation method is adapted to the case of double-park deliveries. The comparison of the MFD estimates highlights that logistic activities have a major impact for traffic conditions near the maximal capacity. It confirms that creation of dedicated delivery areas and related logistic policies (pre-booked area, off-pick hours deliveries, etc.) are very promising solutions to improve both the efficiency of the transportation network and the logistic system.

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Keywords: urban logistic; traffic flow; simulation; pickup-delivery manoeuvers; KW model; Macroscopic Fundamental Diagram; Multimodal;

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1. Introduction

In urban environments, there are now many challenging problems concerning freight transport. As cities around the world grow rapidly, there is an increase in pickup-delivery truck traffic in urban areas. It turns out that commercial traffic is now a major source of externalities in metro areas, including congestion, noise, air pollution (small particulates, NOx, greenhouse gas emissions), and traffic incidents (Dablanc, 2013).

To overcome these issues, many interesting and innovative strategies have been developed in Europe and other parts of the world. Especially, some researchers proposed the idea of city logistics to solve these difficult problems (Taniguchi and Thompson, 2002; Dablanc, 2012). The idea of this concept is to rationalize the freight activities in cities by optimizing operations considering the traffic conditions and the congestion issues. Consequently, public authorities strongly need decision support frameworks to evaluate urban logistics planning and management.

It turns out that a key point in predicting the impacts of city logistics is the influence of freight on traffic flow dynamics. Particularly, pickup-delivery maneuvers generate road capacity reduction and lead to delay for individual drivers. Although this is a crucial topic, the literature rarely addresses this issue. This paper aims to fill this lack of understanding by incorporating the effects of urban freight in an aggregated traffic flow model.

To this end, we seek to introduce a general modeling framework to assess the effects of city logistics actions on traffic flow dynamics. This goal can be achieved in two steps. The study focuses on a theoretical but realistic urban arterial. (i) First, we focus on traffic flowing at capacity. Analytical formulations depending on the characteristics of the urban site and the logistic system to anticipate the capacity reduction generated by pickup-delivery maneuvers are determined. (ii) Then, this work is extended to account for the whole range of traffic conditions. To this end, we resort to the Macroscopic Fundamental Diagram (MFD). It furnishes equivalent mean states to understand the dynamics of the system and to quantify its performance. To tackle this issue, it is necessary to refine the existing estimation MFD methods to incorporate the effects of urban freight. Eventually, this permits to analytically compare the efficiency of different city logistics solutions such as the creation of dedicated areas, parking regulations, off-hour deliveries or consolidation programs (Jaller et al., 2013; Holguin-Veras et al., 2011).

Section 1 introduces a theoretical but realistic case study. Section 2 focuses on the general modeling framework to estimate the capacity reduction generated by double-park deliveries. Section 3 extends this method to estimate MFD and/or aggregated models that account for effects of urban freight. Existing estimation method is extended to reproduce the effects of pickup-delivery trucks at this larger scale. Actually, this approach will permit to predict the performance of different city logistics solutions and to determine their optimal domain of application. Section 4 is devoted to a conclusion.

2. The case study

In this paper, we consider here a hypothetic urban arterial (see Figure 1a) composed of n successive links with traffic signal and p lanes. The length of link i is l_i and its signal settings are: green g_i, red r_i, cycle c_i and offset o_i from a common reference. The total length of the arterial is L. In the remaining of the paper, we assumed n=11 links, p=2 lanes and l_i=200 m. Concerning the traffic signal settings, g_i is equal to 50s and c_i to 100s. For the sake of simplicity, we supposed that there is no offset, o_i=0. Moreover, we do not consider turning movements.