A SIMULATION-BASED APPROACH TO ASSESS IMPACTS OF URBAN LOGISTICS POLICIES ON TRAFFIC FLOW DYNAMICS

EXTENDED ABSTRACT

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BACKGROUND

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 [1].

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 [2-3]. 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 trucks 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 a traffic flow model.

To this end, we seek to introduce a general framework to assess the effects of city logistics actions on traffic flow dynamics. Based on the recent work made by the authors at the urban arterial scale [4], we aim to extend this methodology to use it at a larger scale. The key issue is to quantify the performance of transportation networks when pickup-delivery maneuvers occur. To reach this goal, we resort to estimation of the Macroscopic Fundamental Diagram (MFD). This function captures the traffic dynamics at the city scale. To this end, we resort to a micro-simulation software. Therefore, the capacity reductions and the ensuing delays generated by urban freight can be determined. It makes it possible to estimate MFD from the simulation results. This permits to compare the efficiency of different city logistics solutions such as parking regulations, off-hour deliveries or consolidation programs [5].

THE PAPER CONTENT

Section 1 is devoted to a brief background on urban freight and city logistic. Section 2 describes the methodology. We first introduce the car-following model that is used in the micro-simulation software. This software makes it possible to reproduce the effects of pickup-delivery trucks. Then, MFD formulation is specified such as the estimation method that is used in the remaining of the paper. Section 3 focuses on an urban network. MFD are estimated from the simulation results. It permits to predict the performance of different city logistics solutions and to determine their optimal domain of application.

Methodology

In this paper, we resort to Newell's car-following model [6]. This model is the Lagrangian formulation of the kinematic wave model inspired by fluid dynamics. It has been implemented in the SymuVia software package. Moreover, the model has been refined to take into account bounded acceleration, lane-changing phenomenon, relaxation after lane-changing phenomenon signalized intersections, heavy trucks, etc. [7-8]. Thus, the simulation software is able to accurately reproduce the impacts of pickup-delivery maneuvers on the remaining of the traffic of a city.

Various theories have been proposed to reproduce traffic stream on an aggregate level. Among this existing body of works, models that are adapted to characterize traffic in arterials have to account for (i) traffic signal and (ii) transit systems. Many of these papers are based on the key idea that it exists a macroscopic fundamental diagram (MFD) able to reproduce both free-flow and congested traffic conditions (see Figure 1). Evidences of existence of MFD have been exhibited only very recently [9-10]. On their seminal works, the authors pointed out a major insight: the MFD is an intrinsic property of the network itself and remain invariant when demand changes. MFD is thus a reliable tool for traffic agency to manage and evaluate solutions for improving mobility. It is thus appealing to estimate an accurate MFD for various urban sites and traffic. MFD can be directly estimated with the simulated results. We used the trajectories-based approach proposed by [11]. It turns out this method provides results that perfectly match MFD definition [12].

Case study

We focus on a theoretical but realistic case study: a meshed urban network (see Figure 1). The urban logistics system is characterized by the frequency, the duration and the location of pickup-delivery maneuvers.

As already mentioned, how local distributions of pickup-delivery maneuvers impact the traffic dynamics and the transportation network performance are investigated. To this end, MFD are estimated using data coming from micro simulation. In order to compare the different logistic policies, we first estimate the MFD when no delivery occurs, then, we can focus on the sensitivity of the MFDs to the logistics system parameters.

It is thus appealing to relate these modifications of MFD shapes directly to the parameters. Indeed, obtaining a MFD in simulation is a tedious task because several runs have to be performed to reproduce the whole range of traffic conditions. Therefore, we aim to approximate the estimated MFDs with a function to determine a general formulation that can hold for any case study.

Finally, various city logistics solutions such as consolidation programs are tested and compared. The optimal domain of application of these strategies can be identified using the MFD estimates.

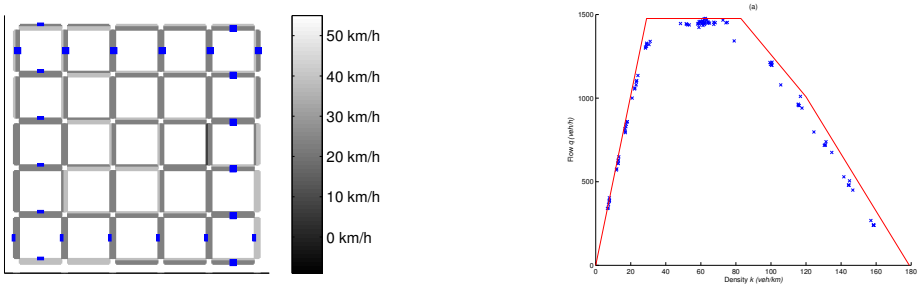

Figure 1: (a) Effects of pickup-delivery trucks (in blue) on the average speed of an urban network (b) associated MFD

CONCLUSION

This study is a key to quantify effects of urban freight on traffic flow dynamics at the city center scale. It highlights the link between the activity of the city and the fluidity of the traffic. Moreover, it promotes the characterization of city logistics actions.

This work will be more deeply studied and integrated in a decision support system in the frame of an ANR project (ANNONA project).

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