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Analysis of the environmental impacts of unloading bays based on cellular automata simulation

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A B S T R A C T

Urban freight transport contributes to a number of environmental problems, such as poor air quality, noise and greenhouse gas emissions. Analysing the impact of UFT measures is particularly important, since improving the situation for freight deliveries more often than not will be at the expense of the citizens. Unloading bays are one of the most popular and simple solutions to implement to support the development of a sustainable urban freight transport system. This measure is aimed at reducing the congestion in busy city streets, which is often caused by delivery vehicles parking directly on traffic lanes to perform their (un)loading operations. The analysis, presented in this paper, is aimed at emphasising the advantages of unloading bays for the public, and thus enhancing the arguments in favour of popularisation of unloading bays. We simulate the traffic in areas of Szczecin and Oslo, and compare the situation without unloading bays to the situation with unloading bays. This is used to predict the benefits of unloading bays in terms of traffic flow and emissions. The basis of the analysis is utilization of a scenario-based approach and cellular automata simulation.

1. Introduction

Freight deliveries in cities involve a wide variety of challenges. Congestion, narrow areas for freight deliveries and a large number of stakeholders in a limited area contribute to reducing the efficiency of logistics systems. At the same time, freight deliveries contribute to a series of environmental problems, like poor air quality, noise and emissions of greenhouse gases. Analysing the impact of urban freight transport (UFT) measures is particularly important, since improving the situation for freight deliveries more often than not will be at the expense of the citizens. For instance, designated spaces for loading/unloading operations in city centres will usually be at the expense of public parking spaces. Therefore, UFT solutions are to a considerable extent resisted by the public, and for this reason, local governments often give up on implementing such solutions. This is also observed in the urban areas in which the analyses in this paper are conducted, namely Szczecin (Poland) and Oslo (Norway).

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The analysis of urban freight transport systems is a difficult research area, due to a number of factors that prevent a clear definition of its characteristics and lack of data regarding the traffic flows, classification of vehicles, vehicles routes, etc. This contributes to difficulties in analysing the efficiency of urban freight transport measures and its impact on city environments. However, vehicle traffic is based on space-time links, which may be represented by mathematical functions. Computer simulation can be helpful in this research area. Therefore, simulation allows for mathematical models to be built, which link input parameters to obtain a certain results as system outputs (Gordon, 1974). Numerous publications on this subject are focused especially on traffic research and modelling, developing theory and traffic models as well as the research on behaviour of traffic participants (Chowdhury et al., 2000; Helbing, 1997; Kerner, 2001; May, 1990; Daganzo, 1993; Wolf et al., 1996; Wolf and Schreckenberg, 1998).

The analysis of efficiency of urban freight transport measures is particularly important in view of the fact that the popularisation of this solution is to a considerable extent resisted by the public, which is caused by the need to designate spaces dedicated to loading/unloading operations at the expense of parking spaces for cars in city centres. For this reason, local governments often give up on implementing this solution.

The analysis, presented in this paper, is aimed at emphasising the advantages of unloading bays for the public, and thus enhancing the arguments in favour of the provision of unloading bays. We simulate the traffic in areas of Szczecin and Oslo, and compare the situation without unloading bays to the situation with unloading bays. This is used to predict the benefits of unloading bays in terms of traffic flow and emissions. We compare the potential benefits for Szczecin and Oslo, two cities of similar size and structure, but with different infrastructure. An additional contribution of the paper is to provide recommendations for both cities with regard to developing sustainable, environmentally-friendly urban freight transport systems.

2. Unloading bays as a solution for sustainable urban logistics

Unloading bays are one of the most popular and simple to implement solutions to support the development of sustainable urban freight transport systems. This measure is aimed at reducing congestion in busy city streets, which is often caused by delivery vehicles parking directly on traffic lanes to perform their (un)loading operations. When special bays are designated for the purposes of unloading operations, the traffic is undisturbed, which helps avoid consuming additional energy and fuel, extra pollution, wasting time and costs incurred as a result of downtimes in traffic jams. Therefore, the most important benefit of this solution is its impact on reducing traffic congestion, and consequently a perceptible reduction of pollutant emissions. Research studies undertaken in the French city of Bordeaux have shown that the implementation of unloading bays has decreased CO_2 emissions by as much as 40 kg per day (Roche-Cerasi, 2012).

Moreover, an analysis made in Szczecin has revealed that delivery vehicles drivers have to drive 1.8 km (on average) more in order to find a parking space, or they stop directly in the traffic lane. A similar research study performed in Oslo has found that the distance covered by delivery vehicle drivers in order to find a parking space to unload their cargo is as much as 2 km.

Gatta and Marcussi (2016) investigate the impact of loading and unloading bays number, the probability of finding bays free and entrance fees have on retailers' and transport providers' utilities. Willingness to pay measures are used to test and quantify possible non-linear attribute variation effects.

Ma et al. (2015) describe a discrete choice model to estimate the demand of the use of loading/unloading bays. This study was conducted in Shanghai, a giant metropolis compared with European cities.

Important from the point of view of determining the needs of different stakeholders, research conducted by McLeod and Cherrett (2011), highlighted the different factors that would need to be taken into account when evaluating a managed loading bay system, from the standpoints of the various actors involved, including the traffic authority, freight operator, driver, retailer and other road users. Planning and managing delivery spaces requires consideration of the roles and objectives of various stakeholders, including carriers, shippers and receivers (Johansen et al., 2014b).

Truck drivers have been observed spending less time looking for a parking space when on-street parking facilities are established (Odani and Tsuji, 2001). Auira and Taniguchi (2006) developed a model for determining the optimal location of loading-unloading space by considering the costs of and behaviour of pickup and delivery vehicles as well as passenger cars.

An analysis and modelling framework has been proposed to assess reduce the impacts on congestion from trucks double parking on-street (Alho et al., 2014). A number of survey and modelling approaches for determining the optimal size and location of on-street loading and unloading bays were outlined.

Another loading/unloading approach has been applied as a solution of CityLog project (CityLog project website, 2016). The BentoBox, designed within the project CityLog, with the participation of TNT Express, has been developed with the aim of resolving the second disadvantage of pack stations. It is composed of a fixed docking station, and six removable modular trolleys. Trolleys are consolidated at the UDC. A new small container has been proposed within the CityLog project to accommodate the trolleys: BentoBox trolleys are loaded into a small container in the UDC and unloaded at the docking station. The unloading of the BentoBox container is again automatic but the BentoBox trolleys should be manually moved from the unloading unit to the docking station. Therefore the unloading time at the docking station is reduced to the minimum and operative costs are minimized. However, as for Pack stations, the number and the locations of the BentoBox docking stations are fixed for a given urban area and do not depend on the current freight demand.