Simulation-Based Assessment Of Double-Parking Impacts On Traffic And Environmental Conditions

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ABSTRACT

The objective of this research is to estimate the impacts that a specific pattern of illegal parking (double-parking) has on traffic conditions and the environment, using microscopic simulation. Through a sensitivity analysis, the impacts of illegal double-parking on average speed, delay and stopped time were estimated. Results show that the existence of the phenomenon entails a severe decrease on average speed and an important increase of delay and stopped time. Through the case study the impacts that a reduction or an elimination of the phenomenon will have in a real network were evaluated: all traffic indicators would be improved if double-parking were suppressed partially (e.g. through an intensification of enforcement) or, even better, completely. The results show that limiting double-parking could result in an increase in speeds of about 10-15% and a decrease of about 15% and 20% for delay and stopped time respectively. However, even greater improvements may be achieved if double-parking is eliminated: average speed can increase by up to 44%, while delay and stopped time can decrease by up to 33% and 47% respectively. Based on the results extracted from the case study, an assessment of the impacts for the whole district of the Municipality of Athens, as well as for the entire Athens region was conducted, using several indices and performance measures. Savings from lost time and reduced CO_2, CO and HC emissions were calculated. Directions for future research are also proposed.

METHODOLOGY

The modeling approach was based on how the drivers that follow a double-parked vehicle respond to the restrictions in their right of way. Vehicles double-park in road segments where the simultaneous crossing of other moving vehicles is possible. However, the reaction of the drivers that follow is based on the road characteristics and the available options. Subfigures 1(a) and 1(b) represent the real phenomenon that is being simulated in the case of a single lane per direction (subfigure 1(a) shows a road with a single lane, while subfigure 1(b) shows a road with one lane in each direction). Subfigure 1(c) demonstrates how the introduction of the auxiliary lane helps model this situation. Subfigure 1(d) shows that in the case of more than one lanes per direction, no auxiliary lane is required for modeling this phenomenon.

If the lane width in their traffic flow is such that it makes it possible for the following vehicles to overtake the illegally stopped vehicle, then drivers will maneuver within the available limits (Figure 1a). Nevertheless, depending on the available space, drivers will have to reduce speed in order to overtake the double-parked vehicle.

In other cases, the lane width available in the traffic flow where the phenomenon occurs does not provide the necessary space for a maneuver. Ongoing vehicles have to use the opposite traffic flow in order to continue their trip (Figure 1b). This results to reduction in speed and increase of delay in the traffic flow of the double-parked vehicle as well as the opposite one. Queues can form in both traffic flows when volumes are high.

Finally, the phenomenon is met in cases where more than one lane is available to the ongoing traffic flow. Vehicles that double-park block the far-right lane and hence vehicles that follow have to maneuver in order to overtake it (Figure 1d), thus affecting vehicles in the other lanes, leading to a reduction in speed and increase of delay.

The modeling approach was applied using microscopic simulation. The software used [TransModeler] features facilities for modeling parking which include legal on-street and illegal parking. In order to accommodate the modeling approach described above, extensions were considered to the double-parking model of the software. Since when double-parking occurs the lane in the simulation network is completely blocked by the illegally parked vehicle, an auxiliary lane was introduced and designated as a special-use lane (Figure 1c). This lane is not used by vehicles under normal traffic conditions, but -once a vehicle double-parks- the vehicles that follow use this special use lane in order to overtake it. This special, auxiliary lane naturally has different traffic characteristics, and therefore delays are introduced (as in reality), due to the lower speed and need to change the trajectory of the vehicle. This extension, however, does not capture the impact that overtaking vehicles would have in the traffic conditions of the opposite directions (as in the case shown in Figure 1b). When more than one lanes are available per direction, no auxiliary lane was used.

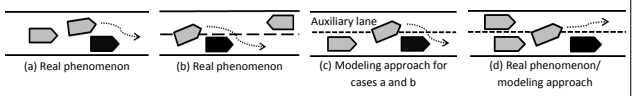

Figure 1: Modeling approach of double-parking impact on traffic conditions

SENSITIVITY ANALYSIS

A sensitivity analysis was conducted in order to estimate the impacts of double-parking in (a) average speed, (b) delay and (c) stopped time in a simple road network through a series of scenarios in single building block edges. Note that these measures are aggregated for the total traffic volume that passes in the simulated period (1 hour), as the point of this study is to estimate overall impacts (and not per-vehicle impacts).

The experimental setup of this analysis includes the following dimensions:

- Type of road: one-lane streets (per direction) and two-lane streets (per direction)
- Traffic flow: ranging between 100 and 700 vehicles per hour for the one-lane case, and 100 and 1200 vehicles per hour for the two-lane case
- Intention to double-park: ranging between 1% and 10% for the one-lane case and 1% and 70% for the two-lane case (0% results in the base case of no double-parked vehicles).

Intention corresponds to the percentage of vehicles that seek to park illegally. The duration of the illegal double-parking was assumed to be normally distributed with a mean of 300 seconds and standard deviation of 100 seconds (these values were obtained after field observations).

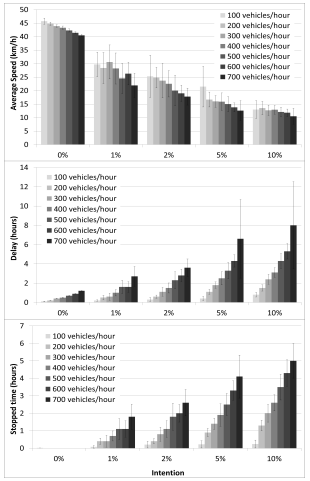

Figure 2: The impacts of double-parking in average speed, delay and stopped time (one-lane street per direction)

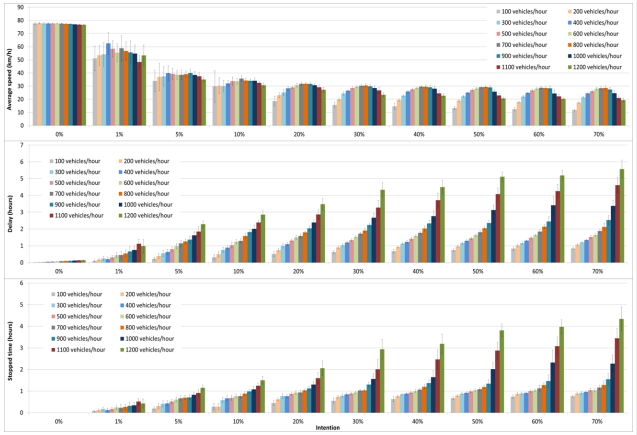

Figure 3: The impacts of double-parking in average speed, delay and stopped time (two-lane street per direction)

CASE STUDY

The area selected is a part of Kolonaki, a high-density neighborhood of downtown Athens, Greece, and perhaps the main shopping attractor in Athens. The area of the study (Figure 4) covers 0.22 square kilometers and trips are generated and attracted throughout the day, six days a week, since land uses provide job-related as well as entertainment-related activities. Data regarding traffic volumes, legal parking maneuvers, double-parking characteristics and public transport system characteristics were collected.

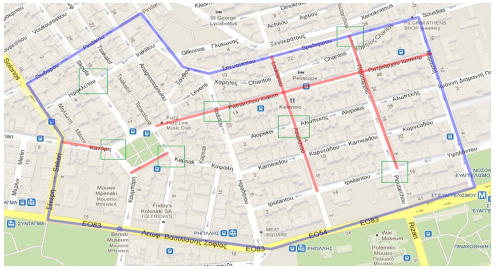

Figure 4: The area of the case study, showing the road segments where double-parking occurs (red lines) and locations of data collection (green squares)

A series of scenarios were tested in order to estimate the impacts of double-parking under many possible conditions and in the cases where the phenomenon is reduced or eliminated. The parameters altered in every scenario were traffic volume and intention of (illegal) double-parking.

Figure 5: Results of the case study

CONCLUSION AND DISCUSSION

Based on the results extracted from the case study, an assessment of the impacts for the whole district of the Municipality of Athens, as well as for the entire region was conducted using different indicators. Data and therefore results correspond to a typical morning rush hour. For the Municipality of Athens delay could be reduced of up to 3310 hours, while an economic benefit of up to 23.2 thousands euros can be gained. Environmental benefits can be estimated as well. CO_2 emissions can be reduced of up to 15.2 tones, CO of up to 5.1 kilograms and HC of up to 2.8 kilograms. For the case of the entire Athens region a maximum benefit of 260.9 thousands euros can be gained. Reduction in CO_2, CO and HC emissions can reach 171.3 tones, 128.9 kilograms and 40.2 kilograms respectively.

The results suggest that a reduction or an elimination of illegal double-parking could result to significant traffic, economic and environmental benefits and point to the necessity of legal enforcement. Yet, further study regarding the modeling of the phenomenon could lead to better estimation of the impacts that parking violations have.

The findings of this research may be a first step towards better linking parking violations with traffic flow theory. In particular, as double parking reduces capacity, it forces the links to operate at a different flow density diagram, which could be considered equivalently to a temporary bottleneck. This creates various backward propagating shockwaves.