On-street parking near the intersections: effects on traffic

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Introduction
An on-street parking maneuver often starts a temporary bottleneck, then some following vehicles might have to endure an extra delay. In most cases, the number of vehicles delayed by a parking maneuver is limited. However, if there is a signalized intersection nearby, such delay could affect vehicles during a single cycle, or it could linger over multiple cycles. In this case, parking maneuver becomes problematic because the scope of the perturbation may reach the intersection wasting some capacity there. In this paper, we try to define a minimum distance from the parking area to the intersection, so the traffic delay caused by parking maneuvers can be minimized without reducing the on-street parking supply.

Problem statement
On-street parking maneuvers can affect the discharge rate of intersections according to two different scenarios: by blocking the upstream intersection, or starving of flow the downstream intersection. Correspondingly, there are two minimum distances required, denote them as:

- Lu (when the intersection of interest is upstream of the parking area)
- Ld (when the intersection of interest is downstream of the parking area)

The two scenarios can be seen in figure 1(a) and 1(b). The layout and position of the intersection with respect to the parking area is shown on the left side; on the right side, a time-space diagram is given depicting the traffic when a parking maneuver happens.

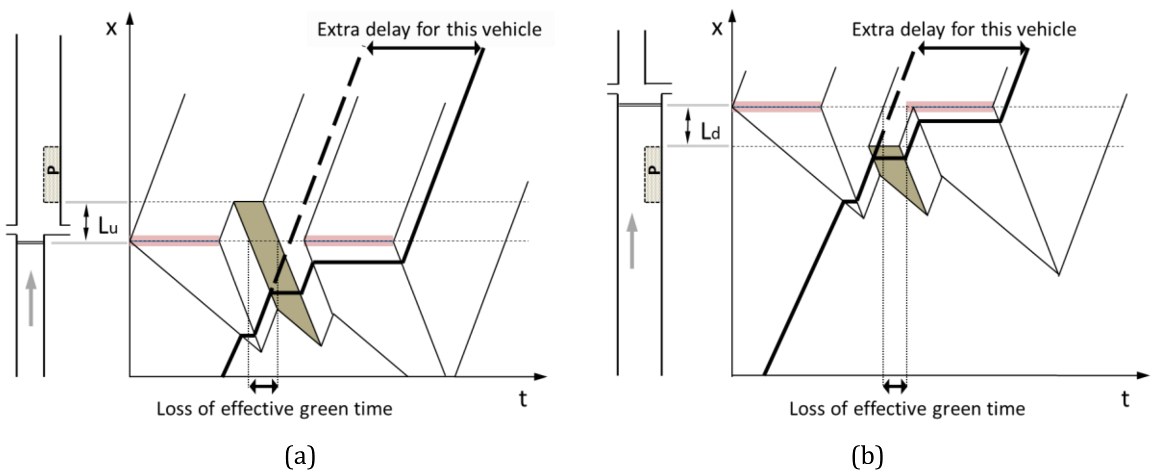

Figure 1 Scenarios regarding the location of an intersection with respect to the parking area. (a) Intersection upstream of the parking area. (b) Intersection downstream of the parking area.

In figure 1, the light lines show all the traffic waves. The dark area shows the resulting queue from the parking maneuver. The dark dash lines show the theoretical trajectory of a given vehicle in the absence of the parking maneuver, the dark continuous lines show the real trajectory for that same vehicle.

Notice that in both figures, the parking maneuver causes a lingering delay (i.e., a delay that lingers over multiple signal cycles). It is also possible for a parking maneuver to cause a local delay (i.e., a delay concentrated into a single signal cycle), or no delay at all. The goal of our study is to find under which conditions each of these cases appears, and the minimum distance between the parking area and the intersection needed to avoid lingering delays.

State of the art

Although traffic delay caused by on-street parking maneuvers have been studied, most of the existing literature focuses on other elements rather than the distance between on-street parking areas and intersections. For example, both Chick (1996) and Valleley (1997) calculated the road capacity reduction caused by on-street parking based on the number of parked vehicles; Yousif (1999) analyzed the delays caused by on-street parking maneuvers, and differentiated between parallel and angle parking. Ye (2011), analyzed delay as a function of, among other things, the distance between the parking area and the intersection. However, the study only considered one of the scenarios described above (how parking affects intersections downstream), and it focused on the improvement of the signal control scheme. More recently, Guo (2012) proposed a model to estimate the travel time under assumed conditions, including effective lane width and the number of parking maneuvers.

In short, no conclusions have been drawn yet regarding optimal distances between on-street parking and the neighboring intersections. In this study, we will fill that gap by providing generalized guidelines for this distance. We particularly focus on the distance because it is easier to modify in real situations than other elements (e.g., the number of lanes is limited by the road space, the signal control is limited by the traffic conditions).

Methodology

In this study, an analytical model is built to understand the effects of on-street parking maneuvers on the neighboring intersections. Two indicators are chosen to measure these effects: capacity loss at the intersection, and additional traffic delay. Through dimensional analysis, the relation between duration of parking maneuver, flow intensity (ratio of demand to intersection capacity), distance between parking area and intersection, and the two indicators is illustrated. The study is performed at two different levels: for an isolated intersection, and for an arterial.

For the intersection level, we use kinematic wave theory to analyze the delay caused by a single parking maneuver. With this simple procedure and some basic knowledge (e.g., the fundamental diagram of the link), we can find the conditions for which the negative effects can spread to the neighboring intersection. The analytical model is validated with empirical data collected in the city of Zurich. The data are also used to evaluate the on-street parking settings in the city, and make recommendations for improvements. Both the analytical model and the empirical data will be used to calibrate a microscopic traffic simulation for the same scenarios. The objective is to use the simulation later to analyze more complex situations, especially at the arterial level.

For the arterial level, given a fixed number of parking stalls (total number), we will evaluate how the specific location of parking stalls in between two intersections can affect traffic. To do so, we will scaled up the simulation which is calibrated at the intersection level. Figure 2 illustrates three possible cases (more will be tested). In 2(a), 2(b) and 2(c), the parking stalls are set near the upstream intersection, in the middle of the link, and near the downstream intersection, respectively.

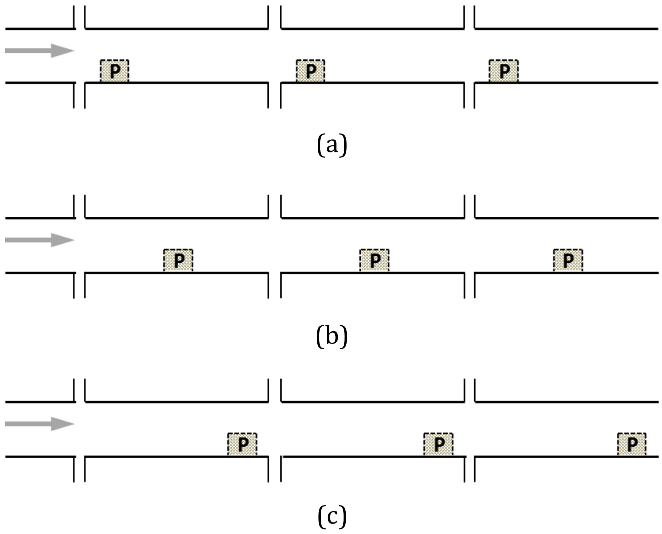

Figure 2 Examples of parking supply scenarios. (a)Parking near the upstream intersection (b) Parking in the middle of links (c) Parking near the downstream intersection

For this level as well, values of the two indicators will be calculated and compared. The goal is to draw generalized conclusions on the impact of on-street parking on traffic performance based on the distance between parking areas and the neighboring intersections. We will provide tools to determine whether a parking maneuver will cause a lingering delay, a local delay, or no delay at all, according to its location and duration. The results should apply to a broad range of cases, and could be used as a foundation for developing guidelines for the design of on-street parking areas, especially related to their location with respect to the neighboring intersections.

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