IMPACTS OF ILLEGAL ON-STREET PARKING ON TORONTO'S CBD CONGESTION

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Introduction

The City of Toronto Central Business District (CBD) experiences the highest volumes of traffic during the A.M. and P.M. peak periods, when travel demand is at its maximum value for the day. During these peak periods, congestion resulting from high traffic volume arises, causing significant delays to passenger vehicles, commercial vehicles, streetcars and buses. In an effort to alleviate these congestion levels, the City of Toronto, like many major cities around the world, restricts on-street parking on most major streets during the peak periods in the CBD. This policy ensures that the streets' full capacity is utilized since on-street parking effectively blocks the right-most lane. A vehicle parked on-street forces the vehicles behind it to merge into the next lane, causing a bottle-neck at that location.
However, as with any parking policy, the compliance rate is not a 100%. Between the years 2008 and 2014, 2.7 million parking infractions per year on average were recorded in the City of Toronto (City of Toronto, 2015). The offenders that do not comply to the rush hour parking restrictions, either by standing, stopping or parking on prohibited streets, exacerbate the already critical traffic situation in the CBD. In addition to the delays caused by illegal parking, the conflict resulting from vehicles switching lanes and cyclists exiting the bike lanes can pose a safety concern. In an effort to try to discourage this phenomenon, a parking enforcement blitz was launched in January 2015 and again in October of that year. Extra parking enforcement officers were dispatched during morning and afternoon rush hours. Offenders were ticketed then towed. The cost of the ticket is $150 and towing costs $200, in addition to the inconvenience encountered by drivers to recover their towed vehicles. Between January and October, more than 61,000 vehicles were ticketed and more than 12,000 towed (Shum, 2015).

This paper uses traffic microsimulation to study the impact of illegal parking on congestion during the A.M. peak period in Toronto's CBD. Although simulation models for Toronto's road network exist, these models omit illegal parking and therefore do not account for their adverse effects on network travel times and delays. This research builds on an existing microsimulation model and tries to improve its accuracy and realism by incorporating illegal parking into the model.

The paper is organized as follows: After the introduction, a review of past literature discussing the impacts of illegal parking is presented, followed by an explanation of the data used to generate the microsimulation model and the methodology involved. Then, the preliminary results of the study are revealed, ending with a discussion of the results and a conclusion derived from the findings.

Background

Illegal parking arises as a result of insufficient parking supply, whether on-street or off-street, near locations where parking is at high demand. Barter argues that there are 2 paradigms at play when deciding the parking supply level at a location (Barter, 2015).

The first is whether parking is managed on a site by site basis or as an infrastructure item that serves its surrounding area. The second paradigm is whether parking should be treated as an infrastructure item that is regulated as such or whether it should be treated as a market item where its price and supply level is determined by market dynamics.

Illegal parking can be discouraged if a mode shift can be induced, pushing drivers to a zone to shift to other modes of transportation. The lesser the number of drivers to a zone the lower the demand for parking and the lesser the chances are of illegal parking. A multinomial logit model used in a study by Simićević et al. predicted that as the price of parking in an area is increased, existing drivers are likely to give up driving to that zone (Simićević, Vukanović, & Milosavljević, 2013). Arnott & Inci (Arnott & Inci, 2006) and Shoup (Shoup, 2006) suggest that increasing the price of on-street parking specifically reduces the number of drivers cruising for on-street parking therefore reducing the probability of illegal on-street parking. Kobus et al. (Kobus, Gutiérrez-i-Puigarnau, Rietveld, & Van Ommeren, 2013) also suggests that increasing the price of on-street parking encourages drivers that are going to park for longer durations to park off-street, making legal on-street parking more readily available to drivers that are going to park for shorter durations, thus reducing illegal on-street parking incidents since illegal parking is mostly a result of vehicles that park for short durations near their destinations for pick-up, delivery or short stop activities. Arnott et al. (Arnott, Inci, & Rowse, 2015) concluded in their study that off-street parking should be provided when the demand for parking in an area, such as a CBD, is high.

The familiarity of drivers with an area, and the amount of information about the availability of parking in an area available to drivers can have a significant impact on the amount of cruising for parking as well as parking choices. Cools et al. (Cools, van der Waerden, & Janssens, 2013) discuss that the lack of drivers' mental knowledge of parking facilities has a negative impact on local roads and parking lots, such as overcrowded "famous" lots and increased cruising for parking around the destination. The frequency of driving to a location, in addition to the age and education of the driver were found to be the only significant contributors to the drivers' mental knowledge. Therefore, parties involved in parking management should be concerned with providing parking availability information to drivers that do not frequently visit the area, and are therefore unfamiliar with the available parking infrastructure. These drivers are the most probable culprits to illegal parking incidents since drivers with high familiarity of an area are more likely to plan their parking choices around parking facilities that were deemed convenient to them in previous trips. A parking guidance system (PGS) can be very useful in helping drivers plan their parking in advance and therefore avoid illegal parking resulting from lack of adequate information as drivers arrive to their destination. Moini et al. (Moini Ph D, Hill Ph D, Shabihkhani, Homami, & Rezaei, 2013) evaluated the impact of PGSs on mobility and emissions. A PGS was found to significantly improve mobility and reduce cruising for parking.

Parking search analysis can be used to study the behavior of drivers during a parking search scenario, enabling parking policy makers to improve their understanding of the parameters involved in the parking decision making process, resulting in more informed decisions when formulating new parking policies. The conventional data collection method for the analysis involves using surveys that ask drivers to self report their searching time, walking distance, etc. Self reporting can be quite inaccurate since it heavily relies on drivers' recollection of minute details that are not usually of concern to the drivers. Using GPS data, as suggested by Montini et al. (Montini et al., 2012) can serve as a more reliable alternative to conventional driver surveys.

Microsimulation involves creating a virtual model of a city's transportation infrastructure. The interaction between unique entities, such as vehicles, buses, pedestrians and cyclists is simulated microscopically by utilizing algorithms capturing car following, lane changing and gap acceptance behaviors (Quadstone Paramics, 2016). A microsimulation based assessment was conducted by Kladeftiras and Antoniou to study the impact of double parking, a form of illegal parking, on traffic conditions in the city of Athens, Greece (Kladeftiras & Antoniou, 2013). The sensitivity analysis concluded that limiting double parking by means of increasing enforcement or adding strategically placed cones to prevent double parking may result in an increase in vehicle speeds by 10-15% and a 15-20% decrease in delay and stopped time. The study also concluded that eliminating double parking completely may result in a 44% increase in vehicle speeds and a 33% decrease in delay as well as a 47% decrease in stopped time.

Another microsimulation study by Lu and Viegas explained that some drivers in Lisbon, Portugal choose to park illegally when the designated roadside parking lot is fully occupied during high demand periods (Lu & Viegas, 2007). The authors discovered that the practical scenarios to be simulated are complex, as a result of the varying parking duration as well as the varying proximity of an illegal parking incident from the upstream and downstream intersections of a link. The study concluded that the effect of illegal parking is increased with higher traffic flows and that illegal parking results in increased conflicts leading to decreased safety and higher chances of accidents.

Jia et al. used the cellular automata traffic flow model, a form of traffic microsimulation, to study the effect of bottlenecks, illegal parking being one of its types, on traffic flow (Jia, Jiang, & Wu, 2003). The simulation results revealed that the capacity of the bottleneck is slightly lower than the maximum flow rate of a single-lane road.

Parking enforcement is considered to be the main deterrent of illegal parking, as drivers are less likely to exhibit illegal parking behavior if they perceive a higher chance of getting caught by an enforcement agent. The most traditional and widely used enforcement agent is the enforcement officer. However, the high cost and limited number of these agents limit the enforcement level of that method. One of the emerging methods of enforcement is image processing from fixed surveillance cameras. Lu and Li developed an algorithm that reduces the computational complexity and overcomes low visibility scenarios in outdoor environments with the help of 1-D transformation (Lee, Ryoo, Riley, & Aggarwal, 2009). Kashid and Pardeshi develop another algorithm for detection, extraction, localization, segmentation and recognition of vehicle number plates from surveillance videos (Kashid & Pardeshi, 2014).

Data

The study area is the Toronto Waterfront network (Figure 1). The area is bordered by Dundas Street in the North, Woodbine Avenue in the east and Parkside Drive in the west. This research uses two sets of data as inputs to the microsimulation model: Travel demand and parking citation data. Travel demand within the simulated waterfront network is obtained from the Origin-Destination matrices from the 2011 Transportation Tomorrow Survey (TTS). The TTS is a comprehensive travel survey that is conducted every five years in the Greater Toronto and Hamilton Area (GTHA) by the data management group at the University of Toronto (Data Management Group, 2011). Parking citation data is published by the City of Toronto in its open data website (City of Toronto, 2015). The citation data is published on a yearly basis and contains a list of all the parking tickets issued in the City of Toronto for that year. Parking citations for the year 2011 are used in this research to be consistent with the 2011 travel demands obtained from the TTS. The parking citations record contains the following details about a parking citation:

- Date of infraction
- Time of infraction
- Type of infraction
- Location of infraction
- Fine amount

The total number of infractions recorded in the year 2011 was 2,805,492 infractions. Out of these infractions, 882,956 were for vehicles parked or stopped on a street at a prohibited time of day (220,763 in the waterfront area). The distribution of infractions over the different periods of the day (AM Peak, Mid-day, PM Peak, Off-peak and overnight) is shown in Figure 2.

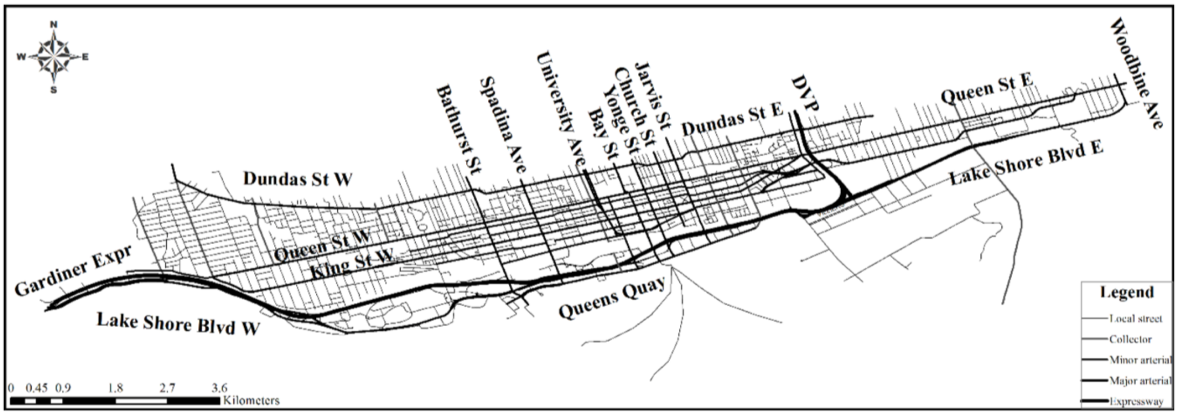

Figure 1 Toronto Waterfront Network

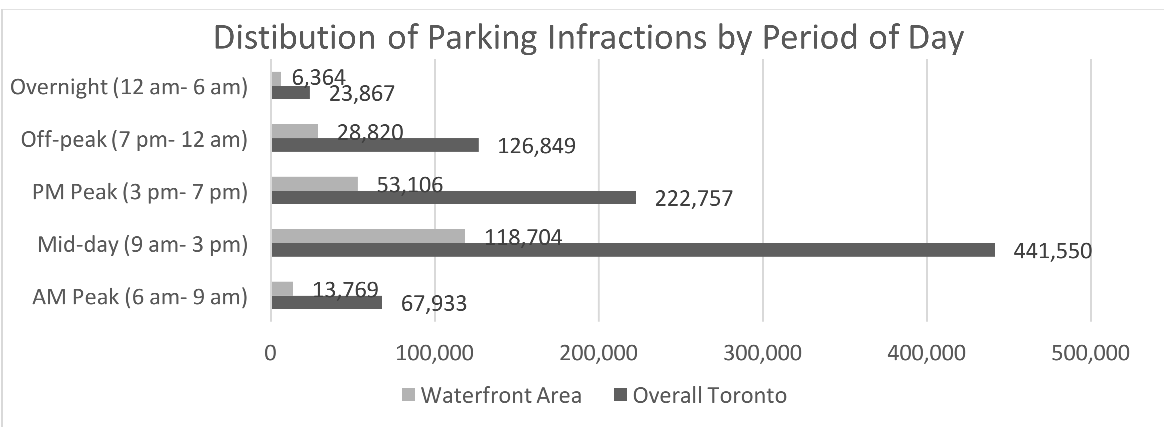

Figure 2 Distribution of Infractions by Period of Day

Methodology

In order to simulate the traffic conditions for the morning rush hour, travel demands for the AM peak period on the Toronto waterfront network are used. The Toronto parking citation record is used as a representation of the current state of drivers' non-compliance to the AM period parking restrictions. Incorporating these illegal parking incidents into the microsimulation model provides an evaluation of network performance that more closely resembles actual traffic conditions. The following filters are added to the parking tickets dataset to extract illegal on-street parking for the desired time period:

1. Infraction Type- only parking infractions involving vehicles parked or stopped on-street on roadways that prohibit such parking activity during the AM peak period are extracted.
2. Infraction Time of Day- Only citations recorded between 8 a.m. and 9 a.m. are considered since the simulation lies within this hour.
3. Infraction Location- Only tickets issued within the Toronto Waterfront boundaries are considered.

The 10 days with the highest number of tickets issued are simulated in this study. For each day, the following 2 scenarios are considered:

A) Base Case Scenario: The network is simulated without adding the illegal parking incidents
B) Illegal Parking Scenario: The network is simulated with illegal parking incidents included

In each scenario, the following metrics are extracted for the links on which illegal parking has occurred:

1) Link Delay: Defined as the average difference between the actual travel time and the free flow travel time for all vehicles on the link for a given time interval
2) Link Flow: Defined as the flow of vehicles transferring from the downstream end of the link for a given interval
3) Link Speed: Defined as the average speed of a vehicle traversing the link for a given interval
4) Link Travel Time: Defined as the average time taken by all vehicles to traverse the link for a given time interval

Each simulation day is simulated 10 times with different seeds, which accounts for randomness of the simulation process. The infractions are divided into 2 types: type 1 and type 2. Type 1 is assigned to vehicles that are parked when ticketed (driver is not available in the vehicle at the time the ticket was issued), while type 2 is assigned to vehicles that are stopped (driver is inside the vehicle at the time the ticket was issued). The difference between the 2 types is the duration of the incident. Type 1 vehicles tend to spend more time stopped than type 2 vehicles because drivers that park and leave their vehicles tend to conduct an activity, while drivers that stop while remaining in the vehicle tend to do drop-off or pick-up activities which consume less time. Therefore, a duration of 10 minutes is assumed for type 1 incidents and 5 minutes of type 2 incidents. At the time of writing this paper, and to the authors' best knowledge, there has been no studies about the distribution of illegal parking durations. Therefore, these arbitrary values have been assumed for the purpose of this study.

Discussion of Results

The simulation results collected for type 1 and type 2 infractions are summarized in table 1 and table 2 respectively. It is observed that for both types, the link delay and travel time increases while the speed and flow decreases, implying a reduction in the level of service of links experiencing illegal on-street parking. The increased delay and travel time is encountered by all drivers on the link affected by illegal parking, resulting in worsening traffic conditions that propagate downstream.
The reduced link speed can be attributed to the merging activity caused by the lane blockage created.

On the other hand, reduced link flow indicates a reduction in the capacity of the link experiencing an illegal on-street parking activity. Since unimpeded traffic flow across all lanes of a link is no longer possible due to lane blockage at the location of an infraction, the link operates below capacity and consequently the number of vehicles able to clear the link in a given interval reduces.
It should be noted, however, that type 2 infractions increase delay and travel times and decrease flow to a lesser extent compared to type 1 infractions. This may be attributed to the fact that type 1 infractions have double the duration of type 2 infractions, and as a result, the bottleneck created by type 1 vehicles lasts longer and its effects are exacerbated the longer it lasts.

Table 1 Summary of Results - Type 1 Infractions

	Link Delay (sec)	Link Flow (veh/hr/ln)	Link Speed (km/hr)	Link Travel Time (sec)
Base Case	9.8	396.7	29.4	17.7
Illegal Parking Added	16.6	298.8	27	24.9
% Increase	+69.4	-24.7	-8.2	+40.7

Table 2 Summary of Results - Type 2 Infractions

	Link Delay (sec)	Link Flow (veh/hr/ln)	Link Speed (km/hr)	Link Travel Time (sec)
Base Case	7.3	732.7	30.6	16.4
Illegal Parking Added	9.9	694.9	26.6	19
% Increase	+35.6	-5.2	-13.1	+15.9

Conclusion and Future Research

Illegal on-street parking during peak periods considerably deteriorates an already critical traffic condition. The increase in travel time is experienced by all drivers in the area, which results in lost productivity time that is a multiple of that travel time increase. The social cost of this phenomenon cannot be ignored, and more policies and solutions need to be devised to curb its existence. This research can be expanded in the future to include more accurate parking durations that are obtained from field surveys or GPS Data. The impact of the proximity of an infraction to upstream/downstream intersections on link performance metrics and the correlation between higher travel demand on a link and the increase in travel time as a result of an illegal on-street parking incident can be studied. This simulation model can also be used to identify the most critical links that should be a priority for parking enforcement.

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