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Breakdown of weather, intersection and recurrent congestion impacts on urban delay in New York City

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Abstract

A vehicle traveling in an urban network exhibits a fluctuating speed profile, affected by signals, congestion and other factors. Therefore, it is very difficult to determine the volume, speed for multiple intersections without extensive instrumentation. Moreover, urban networks do not show relatively homogeneous sections like freeways where delay calculations can be more complex due to local bottlenecks and multiple queueing patterns. Along the same lines, isolating the impacts of various factors also become problematic. In this paper, an ad-hoc delay calculation approach is employed using the green and yellow taxi GPS dataset (augmented with weather information) in New York City (NYC), which has the aforementioned dense urban street network with controlled intersections –signalized or stop-signs. Using this approach, delay patterns associated with both NYC green and yellow taxi trips are investigated using their fare structure rather than conventional data sets such as volume, speed and signal timings. Results indicate that the intersection delay patterns differ spatially between different boroughs of NYC. Major delays in the lower Manhattan during the day especially seem to be critical since these delays not only affect the overall traffic flow but also have explicit adverse effects such as elevated air pollution and noise, which is a critical problem in NYC.

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Keywords: Traffic Delay; Urban Roads; Probe Vehicles; Big Data

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1. Introduction

Traffic delay is mainly discussed in two main categories in the literature: recurrent and non-recurrent delay. Day-to-day congestion (i.e. rush hour traffic) is one of the main reasons of recurrent delay. Reasons of non-recurrent delays

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are mostly random events, such as accidents, vehicle breakdowns, adverse weather, and so on. Overall, crashes are found to be the main contributors of delay with contribution of 45.9%, followed by roadwork (24.3%), breakdowns (12%), weather (9%), signal timing (8.1%), toll facilities (0.6%), railroad crossings (0.1%), and commercial pick-up delivery operations (0.03%). When broken down into facility type (i.e. freeway and urban roads) the causes of delay and their contributions vary. For instance, no signal delay can be accounted for freeways whereas in urban roads the signal timings are stated as one of the main causes of delay (Liu et al., 2005). Similarly, commercial pickup-delivery would have an impact on urban roads but no impact on freeway delay. Considering that 40% (Shih-Miao et al., 2004) to 60% (Schrank et al., 2012) of the delay occurs in urban roads, it is crucial to understand the contribution of potential causes to urban delay.

In general, roadway delay is calculated using queuing theory and shock wave related formulations. For this purpose, mainly certain capacity reductions with respect to different events are assumed and processed among with volume profiles and signal timings (Shih-Miao, 2004). Some agencies set speed thresholds (varying based on locality) and assume any average speed lower than the threshold to be a part of the traffic delay (Cambridge Systematics and Texas Transportation Institute, 2005; Skabardonis et al., 2003; Hallenbeck et al., 2003). More recently, researchers employ emerging mobile technologies such as mobile sensors (Hao and Sun, 2011), mobile phones (Thiagarajan et al., 2009), Bluetooth (Rajasekhar and Lakshmi, 2011) and global positioning systems (GPS) devices (Qin et al., 2011), probe vehicle data (Herring et al., 2010), and wireless sensors (Cheung et al., 2007). Although new technologies such as sensors help a great delay to calculate traffic delay in, the dense urban networks still exhibit challenges due multiple consecutive signalized intersections.

This paper follows the exactly same methodology employed by Yazici et al. (2014) in which NYC yellow-taxi trip data was used along with historical weather information gathered from Weather Underground website. Their findings showed the distribution of additional charges for different time-of-day periods were as intuitively expected, i.e. lower during night and higher during day. One caveat of their study is the geographical coverage of taxi trips. Although yellow taxis are licensed to work in all boroughs of New York City, taxi drivers mainly look for customers in Manhattan where they make more frequent trips and earn more money than other boroughs, i.e. Brooklyn, Queens, Bronx and Staten Island. Hence, the delay findings based on yellow taxi data mainly apply to Manhattan which is the borough with more business districts and tourist attractions. In this paper, methodology employed in Yazici et. al (2014) is utilized on a recently available taxi trip dataset which covers the missing geographical regions (boroughs other than Manhattan) in NYC (please see below for details). Moreover, Manhattan was also divided into "Lower" and "Upper" in order to differentiate the business district setup of lower Manhattan. In these respects, this paper does not offer a new methodology but extends the spatial coverage of an existing approach and compares the findings obtained from different urban setting (e.g. business district vs. more residential) within NYC.

Note that Manhattan's urban road network is also very famous with its ordered grid structure which inspired the concept of "Manhattan-mesh" in academia. All vehicles traveling in Manhattan have to pass through consequent intersections which are almost fully signalized, except few arterials that crosses edges of Manhattan, freeways pass through the city, and stop-sign controlled intersections at upper parts of Manhattan. Meanwhile, the percentage of stop-sign controlled intersections are higher in other NYC boroughs, e.g. Brooklyn, Queens, and Bronx. In these respects, the road network provides a very good experimental setup to study intersection delay as it is very difficult to avoid controlled intersections in any trip. Moreover, the large number and 24/7 coverage of trip records help overcome the need for extensive instrumentation and help isolate the impacts of signals, rush hour traffic and weather.

Recently, in order to increase the taxi service in those relatively less served boroughs, New York City Taxi and Limousine Commission (NYC TLC) introduced "Green Taxis" in summer 2013. These taxis can make pickups only from the regions shown as green in Fig. 1 – basically anywhere but in Manhattan below 110th street on west side of Central Park and 96th street on east side of Central Park. The trip data for green taxis have been recently made available. This dataset makes it possible to understand the differences in delay patterns in outer boroughs in NYC, where the land use is more residential and intersection densities as well as the type of intersection control (signalized vs. stop-controlled) are different than Manhattan. Hence, the green taxi trip dataset allows a more detailed analysis with respect to localities and understand the components of delay in urban settings with varying land use and intersection density. In order to take advantage of the newly available data, the green taxi dataset has been processed to separate trips in Manhattan, as well as other boroughs. The main premise of the current paper is to extend the proposed analysis for different spatial setups and provide aforementioned comparisons. The results are anticipated to help our understanding