Transportation Research Part D 57 (2017) 155–171

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Speed, travel time and delay for intersections and road segments in the Montreal network using cyclist Smartphone GPS data

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ARTICLE INFO

Keywords:
Cyclist
Speed
Delay
Smartphone GPS application

ABSTRACT

Very little is known about cyclist speeds and delays at the disaggregate level of each road segment and intersection in an entire city network. Speeds and delays serve as vital information for planning, navigation and routing purposes including how they differ for different times of the day and across road and bicycle facility types, after controlling for other factors. In this work, we explore the use of recent GPS cyclist trip data, from the *Mon RésoVélo* Smartphone application, to identify different performance measures such as travel time, speed and delay at the level of the entire network of roads and intersections on the island of Montreal. Also, a linear regression model is formulated to identify the geometric design and built environment characteristics affecting cyclist speeds on road segments. Among other results, on average, segment speeds are greater along arterials than on local streets and greater along segments with bicycle infrastructure than those without. Incorporating different measures of cyclist personality in the models revealed that the following characteristics all affect cyclist speeds along segments, each cyclist's average speed on uphill, downhill and level segments as well as geometric design and built environment characteristics. The model results also identify that the factors that increase cyclist speeds along segments include, segments which have cyclists biking for work or school related purposes, segments used during morning peak and segments which do not have signalized intersections at either end.

1. Introduction

Many cities have begun to see a rising number of cyclists and in response, have started to build and provide bicycle infrastructure. For instance, in Montreal, the bicycle facility network has almost doubled over the 10 years from 2000 to 2010 (Vélo Québec, 2013). In Montreal, over 700,000 people, representing 52% of the adult population, ride bicycles and in 2010, the modal share of cycling to work reached 2.2% (Vélo Québec, 2013). In the central neighbourhoods of the island during the summer months, the modal split of cycling reaches as high as 10% (Nosal et al., 2015; Zahabi et al., 2016). Currently in Montreal, some cycle tracks are so widely used that they have begun to become congested. With growing issues of climate change as well as energy and health concerns, we have begun to see a shift away from motor-vehicle dominance and a rise in active modes of transportation such as cycling. In response to the increasing number of cyclists, cities are changing their approaches to infrastructure and signal re-design to apply a multimodal perspective. In order to propose appropriate design changes and signal phasing modifications to account for cyclists and not only vehicles, reliable travel times, speeds, delays and other level-of-service measures are necessary for cyclists. Knowledge of the variation of these measures throughout the day is also vital for accommodating all modes.

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http://dx.doi.org/10.1016/j.trd.2017.09.001

While many studies in the literature look at vehicle speeds, travel times, delays and level-of-service (LOS), very little is known about cyclist travel times and speeds along roads and bicycle facilities, and through intersections in the entire network (Epperson, 1994; Harkey et al., 1998; Landis, 1994; Landis et al., 1997; Sorton and Walsh, 1994). Previous research that attempted to compute these measures, have been restricted by small samples of cyclists and study locations to draw meaningful conclusions. For the most part, these previous studies have focused specifically on arterials and have not tackled the complexity of intersections or other road types and bicycle facilities. Many studies have been based on surveys or GPS units for which both can affect cyclist behaviour and therefore affect these studies' results and conclusions about the speed and travel time measures. These measures serve as important information for cities regarding the quality of the infrastructure provided for cyclists and can identify whether or not they are sufficient. These measures also have navigation and routing applications for cyclists which, until now assume one value for cyclist speeds in the entire network regardless of the type of facility or segment, time of day, flow conditions or trip purpose.

This research explores the use of recent cyclist GPS trip data, coming from the *Mon RésoVélo* Smartphone application, to compute and evaluate different measures of cyclist performance in the road network of Montreal and validate the reliability and usefulness of this source of data. In other words, we are interested in quantifying cyclist travel times, speeds and delays along road segments, cycle tracks and through intersections and how these may vary by trip purpose and for different periods of the day. Due to the richness of the data, this work can be carried out at the entire network level and from a completely disaggregated approach, focusing on individual segments and intersections as the units of analysis. Also, unlike surveys and GPS units, this data is completely anonymous and therefore cyclist behaviour is unlikely to be affected by the tracking of their trips. As part of the contributions, this work proposes an approach to estimate cyclist speeds, travel times and delays in a road network using GPS data, and provides some empirical evidence about the factors affecting these performance measures.

2. Literature review

Cyclist delay, travel time, speed and level-of-service (LOS) are all vital components in determining how to best provide for cyclists along both road segments and at intersections. To date, studies addressing these components, have been carried out focusing on measures of cyclist LOS along arterial segments (Epperson, 1994; Harkey et al., 1998; Landis, 1994; Landis et al., 1997; Sorton and Walsh, 1994). Very few studies, if any, have addressed the complexity of urban intersections to determine these measures for cyclists. In order to be able to assess the quality of services provided for cyclists, measures of delay and LOS are required for both segments and intersections since both are road network elements that cyclists need to traverse to get from their origin to their destination. The Florida Department of Transportation (DOT) set out to develop a bicycle LOS measure for through movements at signalized intersections (Landis et al., 2003). This was achieved by recruiting participants to cycle along a specified course in Orlando, Florida, providing their opinions about each intersection they passed through. Using this data, the Florida DOT sought to develop a mathematical model to express cyclists' LOS and level of accommodation through intersections. A model having an R-squared value of 0.83 was developed which identified that the width of the outside through lane improves LOS whereas crossing distance and vehicle volume worsen LOS. One study in Albany, California, aimed to estimate intersection delays using a virtual trip line (VTL) method based on cell phone GPS data through one intersection (Ban et al., 2009). VTLs were installed both upstream and downstream of each intersection to obtain travel times between both points. Another study carried out in Minneapolis, Minnesota, used GPS data to study the travel speeds of a small sample of cyclists riding along different types of bicycle facilities (El-Geneidy et al., 2007). Travel speeds can be used as an input in determining accessibility measures for cyclists. A study in Bologna, Italy, was interested in determining the effects of non-stationary disturbances on cyclist travel speeds along road segments (Bernardi and Rupi, 2015). On facilities separated from traffic, cyclist speed was found to be most affected by the presence of pedestrians with a speed reduction of up to 30%. Cyclist speed was also found to reduce by about 5% when a second cyclist was present. For cyclists riding in mixed traffic, the presence of heavy vehicles was found to have the greatest effect on reducing cyclist speed. Another study in the city of Olomouc, Czech Republic, looked at the effects of pavement quality, in terms of vibrations, on cyclist comfort and speed (Bíl et al., 2015).

While these previous studies are useful in identifying the factors affecting cyclist LOS, these were identified for one intersection or a small sample of intersections and segments. New studies have been carried out to obtain travel times using emerging data collection technologies, such as Bluetooth (Mei et al., 2012). Also the impact of travel time on cyclist route choice has been investigated through stated preference surveys (Hunt and Abraham, 2007; Sener et al., 2009; Stinson and Bhat, 2003). However, other sources of data, such as Smartphone GPS data, have not been widely tested.

A new data collection method that has begun to gain popularity in the research is GPS data from Smartphone applications. These applications are still very new and few studies have been carried out looking into cyclist travel times, speeds, delays and LOS based on this source of data. GPS data has been used previously but by equipping a small sample of cyclists with GPS equipment. One study in Oregon, Portland, collected GPS data from 164 cyclists over 8 months of the year (Dill and Gliebe, 2008). Among other results, cyclists riding for utilitarian purposes were found to ride mainly on bicycle infrastructure and cyclists generally do not take the shortest path and deviate to ride on bicycle infrastructure and low-traffic streets.

Overall, previous studies have relied on a small sample of cyclists. Some previous studies have used GPS data to model cyclist route choices and preferences as well as speeds and travel times and some have even combined the GPS data with surveys to obtain cyclists' opinions about specific routes. One benefit of GPS data coming from Smartphone applications is that they have the potential to provide route data for all cyclists possessing a Smartphone, providing the potential for a much larger sample of cyclists and a much wider variety of routes to study and from which to extract travel times, speeds and delays. Also, the application is less intrusive than equipping cyclists with GPS units. With GPS units, the cyclists agreed to be part of a study with a specific goal and therefore this may influence their behaviour. Whereas with the Smartphone application, cyclists are logging their trips and benefit from obtaining a view