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Powered-Two-Wheelers kinematic characteristics and interactions during filtering and overtaking in urban arterials

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ABSTRACT

The present paper focuses on the Powered-Two-Wheelers (PTWs) kinematic characteristics and their interactions with the rest of traffic in urban arterials. The factors that may affect the likelihood of PTW drivers to accept critical spacing during filtering and overtaking are also investigated using trajectory data collected from video recordings. The distributional characteristics of the PTW kinematic parameters showed that the patterns of filtering and overtaking have several differences. Further results using Logit models show that PTW speed difference with the rest of traffic, spacing, the existence of heavy vehicles and the occurrence of platoon of moving PTWs (in which the leader is the reference PTW) are significant factors related to the probability of driving in critical spaces through traffic. The likelihood of accepting critical lateral distance from the vehicle being overtaken may be related to the adjacent lane spacing, the speed difference and the existence of a platoon of PTWs. A comparative study between Logit models and equivalent structures of neural networks showed that, in the specific application, neural networks were found to perform better than the Logit models in terms of the model's discrimination power.

1. Introduction

Differences in the structural, mechanical and driving dynamics between the Powered Two-Wheelers (PTWs) and the rest of the vehicles impose a unique maneuverability that is magnified in urban road networks due to the reduced free space in roads and the increase of the interactions with the rest of the traffic. Differences may also arise from the manner PTW users perceive driving when compared to the rest of road users. PTW unique characteristics also attract drivers who are risk-takers and may exhibit different hazard perception and behavior during driving from other vehicle drivers (Di Stasi, Contreras, Cándido, Cañas, & Catena, 2011). Usually PTW drivers are found to exhibit extreme behaviors on the road, such as speeding, disobeying traffic signals, give-way or stop sign, non-compliance to overtaking restrictions or pedestrian crossing, making illegal turns, maintaining short gaps with the following vehicles and so on (Broughton et al., 2009; Mannering & Grodsky, 1995, Vlahogianni, Karlaftis, & Orfanou, 2012).

PTW drivers may show non-cooperative behavior with the rest of the traffic, especially in near to capacity traffic conditions. In such conditions PTW drivers will most likely attempt to position themselves in front of queues (e.g. in signalized intersections), avoid heavy vehicles involvement, change lane, or just maintain their speed when facing a downstream

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bottleneck. This behavior may have significant effects on traffic conditions, such as speed reduction in the rest of the traffic, or increased risk of accident occurrence. The above are usually reflected to erratic driving patterns and trajectories that diverge from typical travel lanes. Especially in dense traffic, PTW drivers have been systematically observed to engage in complex maneuvers in order to filter through traffic by taking advantage of the lateral distances that the rest of the vehicles that move on typical travel lanes allow (Lan, Chiou, Lin, & Hsu, 2010; Nikias, Vlahogianni, Lee, & Golias, 2012). Literature has systematically underlined the differences between PTW flow and the rest of the traffic; these differences may be codified into the following categories (Lee, Polak, & Bell, 2009): (i) traveling alongside another vehicle in the same lane, (ii) Moving to the head of a queue, (iii) Filtering, (iv) Swerving or weaving, (v) tailgating, (vi) Oblique following, (vii) Maintaining a shorter headway when aligning to the lateral edge of the preceding vehicle, (viii) Traveling according to the virtual lanes formed dynamically by the vehicles in surroundings and (ix) Self-organization phenomena.

On the modeling of PTW traffic, literature has underlined the inability of conventional theories to cope with such complex driving patterns (Lan et al., 2010; Lee et al., 2009). The focus has been mainly shifted to car following theories and the deployment of cellular automata models for inhomogeneous traffic (Lan & Chang, 2005; Meng, Dai, Donga, & Zhang, 2007; Nakatsuji & Nguyen, 2001; Lan et al., 2010). Regarding the road space accepted by the PTW drivers for maneuvering, most models adopt a static approach on the manner to describe the space that each PTW user occupy on the road (Lan & Chang, 2005), or refer to the behavior of PTW drivers at the stop line of a signalized intersection approach (Minh & Sano, 2005; Nakatsuji & Nguyen, 2001, Haque, Chin, & Huang, 2008) using, again, static width for the lanes dedicated to the PTW traffic. Meng et al. (2007) proposed a single-lane cellular automaton model to simulate mixed traffic with motorcycles based on fixed width virtual lanes; they used both automobile lanes of typical width and lanes of decreased width dedicated to PTW drivers. Recently, Lan et al. (2010) developed a cellular automaton model based on lanes with width equal to the PTW width; in this model the automobiles are to occupy more than one lane.

These approaches have a conceptual shortcoming, as PTW trajectories may – more convincingly – be considered as complex and dynamically changing with respect to the space PTW drivers use to navigate; this space may define a path or a lane both virtual and dynamically changing with respect to its width depending on the manner the rest of the traffic is positioned on the actual travel lane. Arasan and Koshy (2005) and Dey, Chandra, and Gangopadhaya (2009) have emphasized on the need to take into consideration the space each vehicle category occupy on the road in order to improve the simulation of heterogeneous traffic. A previous study has related the physical width of a static motorcycle and the width of the operating space (Hussain, Radin, Ahmad, & Dadang, 2005). Recently, Lee et al. (2009) proposed an oblique and lateral headway model to describe the safety distance that a motorcyclist maintains when he/she follows another vehicle obliquely or laterally. Moreover, Lee (2008) and Minh, Sano, and Matsumoto (2010) provided linear relationships to describe the relation between the width of the virtual lane and the speed of the motorcycle. Nikias et al. (2012) underlined that filtering and overtaking from a free lane in an urban arterial with two lanes per direction of travel are the most frequently observed patterns and extended the approach of Lee (2008) and Minh et al. (2010) by introducing additional parameters in the linear regression, such as the speed difference with the rest of the traffic and the spacing, but with no clear-cut results due to the low performance of the models.

With the utilization of enhanced video based data collection techniques, the present paper extends past research in investigating the determinants of PTW drivers' behavior in urban arterials under the driving conditions of filtering and overtaking. Filtering – or else moving through the lateral clearances between slow moving or stationary vehicles – may be considered to create a virtual lane; its width should be dynamically changing and dependent on the traffic characteristics in both lanes. Overtaking is straightforward and requires that one of the two lanes is free of traffic; in this case, the distance of interest is the lateral distance from the vehicle being overtaken. The methodological framework uses both statistical and neural network techniques in order to provide answers to the following research questions:

- Are filtering and overtaking similar patterns?
- What affects a PTW driver decision to accept critical virtual lane widths when filtering and critical lateral distances when overtaking?
- How the performance of classical statistical models compare to those of neural networks in predicting the probability of a PTW driver to accept critical spaces during filtering or overtaking?

For the first, an attempt to evaluate the similarity of filtering and overtaking patterns with respect to the kinematic characteristics of the PTW and those of the rest of the traffic will be conducted. Emphasis will be given to the characteristics of the width of the virtual lane utilized by the PTW driver during filtering, as well as to the lateral distance the PTW driver positions itself from the vehicle he/she overtakes. This will enable the detection of those values of virtual lane width and lateral distance that are critical (lower than a certain threshold). The second question will be addressed by investigating the relationship between the kinematic characteristics and the probability of PTW driver engaging in extreme filtering and overtaking conditions using binary logistic regression models. The analysis aims at revealing which variables may be influential to the decision of a PTW driver to accept critical lane widths during filtering and critical lateral distances during overtaking. Finally, the third question will provide evidence on the performance of the models developed and their adequacy in terms of discrimination power when compared to neural networks. Neural networks are used as a typical example of computational intelligent techniques that are frequently met in transportation modeling.