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ScienceDirect

Transportation Research Procedia 10 (2015) 145 – 154

Transportation Research Procedia

www.elsevier.com/locate/procedia

18th Euro Working Group on Transportation, EWGT 2015, 14-16 July 2015, Delft, The Netherlands

Discharge headway model for heterogeneous traffic conditions

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Abstract

Discharge headway is the headway between successive vehicles negotiating an intersection during the green time of signal operation. It is an important parameter in signal operations and analysis since estimation of parameters such as saturation flow and capacity of an intersection depend on it. Although there have been several studies on discharge headway in homogeneous traffic conditions, there are only a few studies on discharge headways in heterogeneous traffic. This study examines the factors affecting discharge headway under heterogeneous traffic conditions which is characterized by mixed vehicle composition and lack of lane discipline. A novel method to measure headways in such cases is proposed here.

To get individual vehicle headways, each lane is divided into multiple strips. The width of a strip is approximately equal to the width occupied by a motorcycle. The headways of vehicles in each strip are measured separately and used for analysis. Data collection for the study was carried out at signalized intersections in Chennai, India. Data was collected for one approach at all intersections. From the data collected, headways of individual vehicles were measured. Linear mixed effect regression was used to model discharge headway. The effect of vehicle type, lateral position on roadway, and green time on discharge headway were modeled. From the regression analysis, it was found that all these factors had significant impact on discharge headway. The discharge headway model proposed in this study could be used for obtaining saturation flow rates and capacity at signalized intersections under heterogeneous traffic conditions.

Peer-review under responsibility of Delft University of Technology

Keywords: Discharge headway;Heterogeneous Traffic; Signalized intersections, Linear mixed regression

1. Introduction

Intersections are a vital part in an urban transportation network. The main traffic parameters at a signalized intersection include discharge headway, saturation flow, and capacity. Among these, discharge headway is an important one since it is used to determine other parameters such as saturation flow and start-up lost times at intersections. These two parameters have in turn been used in determining optimal signal timings. Inaccuracies in discharge headway values would lead to non-optimal signal operations. Several studies have been carried out on discharge headway - on factors affecting it, on distribution followed by headway, and on determination of other traffic parameters from discharge headway. Most of these studies were done for homogeneous traffic which is characterized by lane disciplined

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Peer-review under responsibility of Delft University of Technology
doi:10.1016/j.trpro.2015.09.064

movement and cars were the predominant vehicle type present. Several Asian countries including India have heterogeneous traffic lacking in lane discipline. This study focuses on understanding discharge headway of heterogeneous traffic.

While discharge headway has been studied for over seven decades, even recently studies have examined fundamental questions such as the existence of a saturation headway (Radhakrishnan and Mathew (2011); Remias et al. (2013)). Heterogeneous traffic conditions and the absence of lane following provide significant challenges to the study of discharge headways. For example, consider a single lane with two motorized two-wheelers travelling side-by-side which is followed by a car. How would the headway for the car be defined? The traditional definition of headway as the time gap between successive vehicles in a lane cannot be applied here.

In this paper a novel method of headway definition is proposed. The roadway width is divided into multiple strips. A strip is narrower than a lane just wide enough to accommodate no more than one two wheeler at a time. Headway is measured in each strip separately. Data is collected from three different intersections. At one of the intersections data is collected for morning and evening peak periods. Headway data shows significant variability. Regression models are developed for discharge headway with vehicle type, lateral position along the road width, and the green time period as explanatory variables. To better capture the variability of headway a mixed-effects model is also developed. The use of strips to more accurately and meaningfully measure headway is a fundamental contribution of the present work. This is also the first attempt, to the best of our knowledge, of developing a mixed-effects model for discharge headways.

The rest of the paper is organized thus: the next section provides an overview of literature in the area. While the research is over seven decades old, the emphasis here is on relevant and recent work only. Data collection and extraction process are described next. The analysis of data including the estimated models are presented in the fifth section followed by a concluding section.

2. Literature Review

Discharge headway at a signalized intersection can be defined as the time interval between two successive vehicles on a lane crossing the stop line at an intersection during the green time. Greenshields et al. (1947) was one of the first studies on discharge headway in which he reported average headways for the first five vehicles of the queue . Carstens (1971) reported the average starting delay for vehicles in queue as 0.75 s and average headway spacing for straight moving cars as 2.29 s per vehicle. Moussavi and Tarawneh (1990) conducted studies on departure headways at signalized intersections in Nebraska and concluded that departure headways show high variability for different intersections possibly because of the different traffic and geometric conditions prevailing there. They also came up with a set of values for departure headway of first seven queue positions. Bonneson (1992) developed a model for discharge headway at signalized intersections based on driver reaction time, driver acceleration, and vehicle speed. His model showed that a minimum discharge (saturation) headway is reached only after eighth or ninth queue position. Al-Ghamdi (1999) conducted a study on discharge headway at intersections in Riyadh, Saudi Arabia. He observed that it is not reliable to use discharge headway values from other countries in Saudi Arabia due to changes in factors such as driver behaviour and intersection geometry, and came up with average headway values for different queue positions.

Several other studies have come up with distributions for discharge headways. Jin et al. (2009) studied the departure headways at signalized intersections. They found that distributions of departure headways at each position in queue follow a log-normal distribution except the first one. A car-following model was also proposed to explain this behavior which can be used for intersection capacity analysis and traffic control. Liu et al. (2011) introduced a hazard based model to analyze the first discharge headway of queuing vehicles. The model has been developed on the basis of data collected from Beijing and it was found that the first discharge headway is dependent on vehicle type and complexity of intersection and any other disturbance to the vehicle movement will further increase the discharge headway. Wu et al. (2010) studied departure headway distributions. Their study revealed that for modeling headway data, log-laplace distribution model is suitable at free flow conditions and log-logistic model during peak hours. Yin et al. (2009) also arrived at similar conclusion about fitting headway distributions to headway data for free-flow state and congested state. Their findings include that headway data follows log-normal distribution when traffic is in free-flow state and