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Information point and saturation flow at signalized intersections

Lijun Gao [a,*], *Bhuiyan M. Alam* [b], *Brian W. Randolph* [c], *Douglas K. Nims* [a], *Richard S. Martinko* [d]

[a] *Department of Civil Engineering, University of Toledo, Toledo, OH 43606, USA*
[b] *Department of Geography and Planning, University of Toledo, Toledo, OH 43606, USA*
[c] *College of Engineering, University of Toledo, Toledo, OH 43606, USA*
[d] *Richard Martinko Consulting, Maumee, OH 43537, USA*

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ABSTRACT

This paper introduces an information point factor and attempts to identify how it affects saturation flow and their relationship at signalized intersections. An information point is defined as any object, structure, or activity located outside of a traveling vehicle that can potentially attract the visual attention of the driver. Saturation flow rates are studied at three pairs of signalized intersections in Toledo, Ohio, USA. Each pair of intersections consists of one intersection with a high number of information points and one intersection with a low number of information points. Study results reveal that, for each pair of intersections, the one with high information points has a lower saturation flow rate than the one with low information points. A statistical analysis shows that the differences are significant. Based on the saturation flow data of the paired intersections, information point effect models are developed and presented in this paper.

1. Background

Geometric, traffic, and environmental conditions can all affect the saturation flow rate. HCM 2010 (TRB, 2010) states that the following factors affect the saturation flow rate: lane width, heavy vehicle, approach grade, parking lane and parking activity, bus stop, lane utilization, turning traffic in a traffic lane group, crossing pedestrian to turning traffic group and area type.

HCM 2010 (TRB, 2010) also provides an adjustment factor of 0.9 to account for larger discharging headways for intersections located in central business areas. Past researches (Agent and Crabtree, 1982; Niittymaeki and Pursula, 1997; Zegeer, 1986) conducted in the past confirms this type of area effect, with varying adjustment factor values from 0.93 to 0.99. Le et al.

* *Corresponding author*. Tel.: +1 352 895 0403.
E-mail address: gaotraffic@gmail.com (L. Gao).
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(2000) studied the effects of recreational, business, residential, and shopping area types on discharging headway, finding only the recreational area type is significantly different from other area types. Thus, they suggested a new area type adjustment factor of 0.92 for recreational areas, with no adjustment factor for other area types.

A Kentucky study (Agent and Crabtree, 1982) and Indiana study (Perez-Cartagena and Tarko, 2004, 2005) found that small- and medium-size communities have significantly higher discharging headways than large communities. A research report completed by the Texas Transportation Institute (Bonneson et al., 2005) analyzed and provided additional adjustment factors such as the number of lanes, area population, traffic pressure, and speed limit. Severe weather, unusual traffic composition, and special local conditions can also greatly affect discharging headway (Mukwaya and Mwesige, 2012). Turner and Harahap (1993) mention that roadside land uses that generate parking and non-transport activities can affect headways.

2. Introduction

This study introduces a new saturation flow adjustment factor, known as "information point" or "distraction point" to more quantitatively account for the effects of roadside characteristics on saturation flow. In this paper an information point or distraction point was defined as any object, structure, or activity located outside of a traveling vehicle that can potentially attract the visual attention of the driver. For example, a roadside business can be considered an information point. Crossing streets, overhead or roadside signals and signs, bicyclists, roadside pedestrians, and certain events can all be considered information points, as they can potentially attract a portion of driver attention and affect discharging headways. Certain information points can be located away from the discharging vehicles, such as pedestrians on sidewalks, or a music concert on a plaza near the study intersection.

Information points, such as high rise buildings, shops, pedestrians, signs and crossing streets are densely distributed in the downtown area. These information points can distract driver attention away from driving, which results in higher headways. Naturally, some intersections have more information points than others, even if both are located in the same central business area. The information point adjustment factor is used to account for this difference. This paper studies the information point factor were attempted to trace by examining past the literature, and then conducting an empirical study to isolate and identify the factor's effect.

According to a recent study by Klauer et al. (2014) of novice drivers, looking at a roadside object while they are driving has the same risk of crash or near-crash as sending or receiving text messages, and a higher risk than eating. The study shows how much impact these information points can have on drivers. Studies show that when one lane of a three-lane facility was blocked by an incident, the capacity reductions were approximately 50%, rather than the 33% because of the 33% loss in physical capacity (Cambridge Systematics Inc, 1990; Lari et al., 1982; Reiss and Dunn, 1991). The rubbernecking impact of accidents on freeway traffic in the opposite direction was evaluated in a University of Virginia research report (Masinick and Teng, 2004). The term rubbernecking refers to the driver's tendency to slow down as he/she pass an incident to see what is happening. The results show that the impact of the rubbernecking on the capacity and delay in the opposite direction is significant.

When people drive without full engagement, consciously or unconsciously, they may prolong their headways from preceding vehicles. The more information points there are, the more judgment or observations some drivers will potentially make and process while driving, which can result in larger headways. The first few queued drivers can see and process most of the information while waiting for a green signal. Drivers queued further behind may not be able to see all the information points, such as street name signs, until they drive closer to the intersection.

Advance street name signs that identify the next upcoming intersections help drivers drive better and reduce headways, resulting in a higher saturation flow [US Department of Transportation (USDOT), 2009b]. A nationwide research study by USDOT (2009b) shows that advance street name signs reduce certain types of crashes related to way finding (e.g., sideswipes due to last minute lane changes) at a statistically significant level. Many near-miss incidents could have happened before a real accident, and the last minute lane changes certainly would disrupt the saturation flow and prolong the headways. From this research result, it can be inferred that the advance street name signs can reduce discharging headways as well.

According to a United States Sign Council report of 'Sign Legibility Rules of Thumb' (United States Sign Council, 2006), the time that it takes a driver to detect, read, and react to roadside signs increases as his/her traveling speed increases. When the speed is low, the effect of information points is low, and when the speed is high, the effect of information points is also high. So logically, the more information points there are, the lower optimum discharging speed that produces minimum headway would be (Gao and Alam, 2015).

Recreational traffic can also be affected more by surrounding information points. Commuters traveling to work and back home may not be affected by most of the information points. In the discussion of how driver populations influence capacities, HCM 2010 stated that the capacity of a freeway segment traveled by recreational traffic is 10%–15% lower than if the segment is traveled by commuter traffic (TRB, 2010).

Commuters consist of a higher proportion of the traffic during peak hours, which results in a lower average headway. A previous study shows lower discharging headways occur more during peak time periods than off-peak periods (Branston, 1979). Since longer queues are typically associated with peak traffic periods, other studies found that higher traffic pressure (longer queue) can reduce discharging headways (Bonneson et al., 2005, 2006). Also, drivers who pay attention to information points tend to drive on the outer lanes so that they can better observe and prepare to make turning maneuvers. Some studies imply that vehicles traveling on the outer through lanes have higher headways (Bonneson et al., 2005; McMahon et al., 1997). Large cities and tourist towns consist of a higher percentage of drivers