Extended Abstract: TRB No. 18-05721

QUANTIFYING PLATOON CHARACTERISTICS ON FOUR-LANE LEVEL FREEWAY SEGMENTS

Jianan Zhou, Corresponding Author
Ph.D. Student, Graduate Research Assistant, Department of Civil Engineering
Nebraska Transportation Center, University of Nebraska-Lincoln
2200 Vine Street, Prem S. Paul Research Center at Whittier School, Lincoln, NE 68503
Tel: 402-580-8928
Email: jianan.zhou@huskers.unl.edu

Laurence Rilett, Ph.D., P.E.
Distinguished Professor and Keith W. Klaasmeyer Chair in Engineering and Technology
Director, Nebraska Transportation Center, University of Nebraska-Lincoln
2200 Vine Street, Prem S. Paul Research Center at Whittier School, Lincoln, NE 68503
Tel: 402-472-1992
Email: lrilett2@unl.edu

Elizabeth Jones, Ph.D.
Associate Professor, Department of Civil Engineering
Nebraska Transportation Center, University of Nebraska-Lincoln
Lincoln, NE 68503
Tel: 402-544-3869
Email: libby.jones@unl.edu

Yifeng Chen, Ph.D.
Traffic Engineer, AECOM
27777 Franklin Road, Suite 2000, Southfield, MI 48034
Tel: 402-570-8771
Email: chaserchen98@hotmail.com

Li Zhao
Ph.D. Candidate, Department of Civil Engineering
Nebraska Transportation Center, University of Nebraska-Lincoln
2200 Vine Street, Prem S. Paul Research Center at Whittier School, Lincoln, NE 68503
Phone: 402-440-9154
Email: li@huskers.unl.edu

November 15, 2017

INTRODUCTION

The Highway Capacity Manual (HCM) 2010 was developed to provide capacity and Level of Service (LOS) analyses for roadway facilities, including freeways. However, in the past ten years rural freeways in the western U.S. have experienced conditions that lie outside the standard HCM 2010 conditions. For example, many freeways experience truck percentages that are much greater than the assumed 25 percent maximum listed in the HCM. In addition, many heavy trucks have speed limiters installed, at the behest of their fleet owners, in order to improve fuel efficiency. The combination of these two factors results in the formation of platoons, and these platoons may adversely affect traffic flow and capacity in a manner that is not included in standard HCM 2010 techniques. If standard HCM 2010 techniques were used, which are based on average density conditions, and with the assumption that all vehicles travel at the same average speed, the freeways would be found to be operating under LOS A or B. However, it is unlikely that most passenger car drivers, who are continually caught behind slower moving vehicles, would feel that traffic is moving smoothly. This paper examines the phenomena described above.

The platoon definition used in this paper are based on previous research (*1-2*). Vehicles that do not impede other vehicles, and are not influenced by the vehicles traveling ahead of them, are defined as free vehicles (*3-4*). The platoon is usually identified by headways between the leading and following vehicles. If the headway is less than the critical headway, the vehicle is classified as belonging to a platoon (*5*). The value of the critical headway used to identify platoons by various researchers varies across road types and by traffic conditions, from 2s to 8s (*4-9*). Most of the platoon identification methods focus on platoons occurring on two-lane highways, and often a single value is used for critical headway for vehicle pairs composed of different vehicle types (*10*). There have been a wide variety of platoon characteristic metrics developed, including the percent of time spent following (PTSF), percentage of free-flow speed (PFFS), average travel speed of passenger cars (ATSPC), the percentage of free-flow speed of passenger cars (PFFSPC), and the percent of followers (*11-12*), etc. Most platoon metrics are based on observations obtained from platoons that pass a specific location and do not capture dynamic characteristics such as platoon formation and dispersion.

The test bed in this research is a 222 mile stretch of Interstate 80 in western Nebraska. The focus is on four-lane level freeway segments and is based on empirical data that was collected expressly for analyzing platoons. The concept of a platoon on a divided four lane (two lanes in each direction) freeway was defined, and a literature review was conducted. A methodology for identifying platoons is provided. An analysis comparing the metrics of vehicles that are impeded in different platoon types and those that are not impeded is conducted. The metrics examined include impeded vehicle speed, difference in speed of impeded and free-flow vehicles, ratio in speed of impeded to free-flow vehicles, number of impeded vehicles, impeded vehicle density, platoon existence time and distance, and platoon-caused-delay.

METHODOLOGY

Data were collected at 13 sites along a 222-mile freeway segment of I-80 in Nebraska between Lincoln and North Platte from June 1 to December 22, 2015. In total, 60 hours of uni-directional traffic flow at each site were recorded. Data were collected using the Nebraska Transportation Center (NTC)'s mobile data collection equipment and the NTC ITS van. Traffic flow data were obtained from the video using Autoscope Rackvision (*14*). The vehicles were categorized into five types according to FHWA guidance (*15*): car (class 2, 3), bus, single-unit truck (class 5-7), heavy truck (class 8-13), and recreational vehicles. In total, 48,903 vehicles were observed.

In this research, the critical leading and lagging headway are used to categorize whether a vehicle is in a platoon or not. Vehicles on all lanes in one direction with leading headways less than or equal to critical leading headways, or with lagging headways less than or equal to critical lagging headways, are considered to belong to the same platoon. There are three vehicle groups according to whether: (1) the vehicle was impeding other vehicles (e.g., it is a platoon leader); (2) the vehicle was impeded by other

vehicles (e.g., it is a platoon follower); or (3) they are free flow vehicles. This paper assumes that there is not a single value, but rather the critical headway is a function of the vehicle types and their relative position. The critical headway for each scenario is determined based on two observations (*5*):

1. The speed of the vehicles with headways no greater than the critical headway is lower than the speed of the vehicles with headways greater than the critical headway; and
2. The vehicles with headways no greater than the critical headway show a high linear relationship between the speed and headway while vehicles with headways greater than the critical headway show a low linear relationship between the speed and headway.

Then, there are analyses for: a) the speed distributions for impeded and non-impeded passenger cars, single-unit trucks, and heavy trucks; and b) the relationships between the number/percentage of impeded vehicles and the traffic volume.

The platoons are divided into groups based on how many lanes the platoon occupies as well as the vehicle type of leader. The analyzed metrics of the platoon characteristics include:

1. impeded vehicle speed (IVS);
2. difference in speed of impeded and free-flow vehicles (IVS-FFS);
3. ratio of impeded vehicle speed to free flow speed (IVS/FFS);
4. number of impeded vehicles (NIV) in platoon;
5. density of impeded vehicles (DIV);
6. platoon existence time (t);
7. platoon existence distance (s);
8. platoon-caused-delay (pd).

FINDINGS

The results of this paper indicate that the critical headways range from 3.0 s to 8.0 s, and are a function of whether a leading or lagging headway was required.

Using the new platoon identification methodology and empirical data from western Nebraska, an analysis of the platoon formation was conducted. The analysis showed that: (1) 51 percent of vehicles are impeded; (2) the average speed of trucks was approximately 9.5 percent lower than passenger cars; and (3) the number and percentage of vehicles that impeded in platoons increased with traffic volume.

The platoons that were identified were classified into eight groups (four groups for two-lane platoons and four groups for one-lane platoons). A number of platoon characteristic metrics were identified, and it was shown that:

1. The two-lane platoons have lower impeded vehicle speed (IVS), difference in speed of impeded and free-flow vehicles (IVS-FFS), and ratios of impeded vehicle speed to free-flow speed (IVS/FFS) than one-lane platoons; on the other hand, the two-lane platoons experience a higher number and density of impeded vehicles than one-lane platoons.
2. In all the platoon types, on average, vehicles impeded by two-truck-leading platoons experience: 1) the lowest average speed (64 mph), the lowest difference in speed of impeded and free-flow vehicles (-11 mph), and the lowest ratio of impeded vehicle speed to free flow speed density (0.86); 2) the highest number of impeded vehicles (7.2), density (30veh/mi/ln), and platoon-caused-delay (140 s/platoon); and 3) the longest existence time (1104 sec.) and existence distance (16.93 mi).

Overall, this study demonstrates that vehicles impeded in two-truck-leading platoons at a high volume and truck percentage condition are most severely affected by platoons.

CONCLUSION

This research proposed a new platoon identification methodology for four-lane freeways. It is based on critical headways that vary according to vehicle type. It was found that the critical headway used to identify platoons varies with vehicle type and ranges from 3 to 8 seconds. It was also found that 51 percent of the vehicles in the test bed may be classified as impeded vehicles, 36 percent may be classified as impeders, and approximately 13 percent may be classified as free-flow vehicles. The calculated metrics demonstrate that platoons do have an adverse effect on vehicles in the corridor.

The increase in heavy truck volumes, combined with the widespread use of truck speed limiters, has resulted in a new paradigm. This research has provided a new methodology for identifying platoons and measuring their effects on impeded vehicles. Given current predictions that truck traffic will double by 2010 (*16*), and the fact that heavy trucks will continue to have speed limiters installed, the issues examined in the research presented here will only grow in importance in the coming years.

ACKNOWLEDGEMENTS

This research is supported by the Nebraska Department of Transportation's Research Project (NTRC No. TSPT1-02) *Assessing Passenger Car Equivalency Factors for High Truck Percentage*, and is gratefully acknowledged. The contents of this extended abstract reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein, and are not necessarily representative of the Nebraska Department of Transportation.

REFERENCES

1. Highway Capacity Manual, 2010. TRB, National Research Council, Washington, D.C., 2010.
2. Van Aerde, M., and S. Yagar. Capacity, Speed and Platooning Vehicle Equivalents for Two-lane Rural Highways. In Transportation Research Record 971, TRB, National Research Council, Washington, D.C., 1984, pp. 58-67.
3. Vogel, Katja. What Characterizes a "Free Vehicle" in an Urban Area? Transportation Research Part F: Traffic Psychology and Behavior, Vol. 5, No. 1, 2002, pp. 15-29.
4. Al-Kaisy, Ahmed, and Sarah Karjala. Car-Following Interaction and the Definition of Free-Moving Vehicles on Two-Lane Rural Highways. Journal of Transportation Engineering, Vol. 136, No. 10, 2010, pp. 925-931.
5. Ali, Asma Tayyab, Aimee Flannery, and Mohan M. Venigalla. Prediction Models for Free Flow Speed on Urban Streets. In Proceedings of the 86th Annual Meeting of the Transportation Research Board, Washington D.C., 2007.
6. Miller, Alan J. A Queueing Model for Road Traffic Flow. Journal of the Royal Statistical Society: Series B (Methodological), 1961, pp. 64-90.
7. Edie, L. C., et al. Analysis of Single Lane Traffic Flow. Traffic Engineering, Vol. 21, 1963, pp. 27.
8. Keller, H. Effects of a General Speed Limit on Platoons of Vehicles. Traffic Engineering & Control, Vol. 17 (Analytic), 1976.
9. Fitzpatrick, K., Miaou, S.P., Brewer, M., Carlson, P. and Wooldridge, M.D. Exploration of the Relationships between Operating Speed and Roadway Features on Tangent Sections. Journal of Transportation Engineering, Vol. 131, No. 4, 2005, pp.261-269.
10. Krammes, R.A. Effect of Trucks on the Capacity of Level, Basic Freeway Segments. A thesis in civil engineering, 1985.
11. Romana, M. and Pérez, I. Measures of Effectiveness for Level-Of-Service Assessment of Two-Lane Roads: An Alternative Proposal Using a Threshold Speed. In Transportation Research Record: Journal of the Transportation Research Board, No. 1988, TRB, National Research Council, Washington, D.C., 2006, pp.56-62.

12. Al-Kaisy, A. and Karjala, S. Indicators of Performance on Two-Lane Rural Highways: Empirical Investigation. In Transportation Research Record: Journal of the Transportation Research Board, No. 2071, TRB, National Research Council, Washington, D.C., 2008, pp.87-97.
13. Brilon, W. and Weiser, F. Two-lane Rural Highways: the German Experience. In Transportation Research Record: Journal of the Transportation Research Board, No. 1988, TRB, National Research Council, Washington, D.C., 2006, pp.38-47.
14. Yu, X., Prevedouros, P. and Sulijoadikusumo, G. Evaluation of Autoscope, SmartSensor HD, and infra-red traffic logger for vehicle classification. In Transportation Research Record: Journal of the Transportation Research Board, No. 2160, TRB, National Research Council, Washington, D.C., 2010, pp.77-86.
15. James, L. and Randall, P.E. Traffic Recorder Instruction Manual. Texas Department of Transportation, 2012.
16. Rosekind, M.R. and Darling III, T.S. Notice of Proposed Rulemaking; Federal Motor Vehicle Safety Standards; Federal Motor Carrier Safety Regulations; Parts and Accessories Necessary for Safe Operation; Speed Limiting Devices; Docket No. NHTSA-2016-0087, Docket No. FMCSA-2014-0083, 2016.