International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

RESEARCHERID
THOMSON REUTERS

[Guo *et al.*, 9(5): May, 2020]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

VELOCITY ANALYSIS OF LEFT TURN VEHICLES DURING GREEN COUNTDOWN SIGNALS AT SIGNALIZED INTERSECTIONS

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DOI: 10.5281/zenodo.3865893

ABSTRACT

In urban transportation network, signalized intersections are the crucial bottlenecks with complex traffic conditions, easily appearing the phenomenon of traffic congestion. It is important to identify vehicle operation characteristics for improving the efficiency and safety of signalized intersections. This study focuses on examining the velocity changes of left turn vehicles during green countdown signals. The results show that when approaching the stopline during the countdown signals, left turn vehicles are more likely to experience operation fluctuation of abrupt acceleration and deceleration in peak hours, and maintain a stable acceleration in off-peak hours. The differences of speed feature between peak and off-peak periods might be due to traffic flow characteristics and drivers' emotional states. The findings of this study can provide supporting evidence for improving road safety and traffic efficiency at signalized intersections.

KEYWORDS: Velocity characteristics; signalized intersection; left turn vehicle.

1. INTRODUCTION

With an increase in the number of privately owned vehicle, urban road traffic volumes continue to increase. This results in intensifying contradiction between traffic supply and demand, as well as an increase in traffic jams and car crashes, especially in signalized intersections. Studies have shown that left-turning flow is an important factor affecting the efficiency of urban traffic. Therefore, determining the speed characteristics and the driving behavior of left-turning vehicles can help improve the safety and capacity of signalized intersections.

Zhu et al. [1] used descriptive statistics and hypothesis testing to analyze the effects of countdown signals on vehicle speed. The results showed that the use of countdown signals and violation detection combined can greatly decrease the percentage of over speed. Zhang et al. [2] found that after installing countdown signals, there is no significant difference in traffic flow, but the number of red-light violation greatly reduces. Wu et al. [3] and Dong [4] used the Logistic model to establish drivers' behavioral decision models at signalized intersections to show the effects of the countdown time display on driving behavior.

Wang et al. [5] used the cumulative curve and traffic flow theory to build a queuing model for left turn vehicles, and obtained the minimum green time and the longest red time for left-turn phase with left-turn waiting area. Ni et al. [6] and Jiang [7] analyzed the driving characteristics of left-turning vehicles, and explored the effect of left-turn waiting zone on traffic capacity at signalized intersections. Ma et al. [8] proposed a series of design patterns for left-turn waiting areas, in order to increase the capacity of left-turn traffic.

In summary, the traffic characteristics of left turn vehicles during countdown signals is still sufficiently explored. This study will analyze the velocity changing characteristics of left turn vehicles upstream of the stopline.

2. RESEARCH METHOD

In this study, the intersection of Nanjing Rd and Gongqingtuan West Rd. in Zibo city (see Figure 1) was selected for analysis. A school gate is located in the west side of the intersection, so the intersection is with very unbalanced traffic flows. An unmanned aircraft system was used to gather vehicle information at the signalized

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

intersection. The software Kinovea was used to extract traffic parameters such as velocity, position, and stopping distance.

Figure 1 The selected signalized intersection (Nanjing Rd. & Gongqingtuanxi Rd.)

3. RESULTS AND DISCUSSION

This study analyzed the velocities of left turn vehicles at the stopline and 20m upstream of the stopline during green countdown signals in peak and off-peak hours. Figure 2 shows the velocities of left turn vehicles during peak hours. In general, vehicles' speeds are greater at the stopline than 20m upstream of the stopline. As countdown signals begin, left turn vehicles usually accelerate in order to pass through the intersection in this cycle. There is no remarkable difference in speed between the two positions, which means that these vehicles increase their speeds at a small rate. It was observed that there are several vehicles decelerate within 20m upstream of the stopline, such as vehicle No.s 3, 9 and 21. This could be that following too closely to the vehicle in front, the vehicle has to slow down to keep a safe distance.

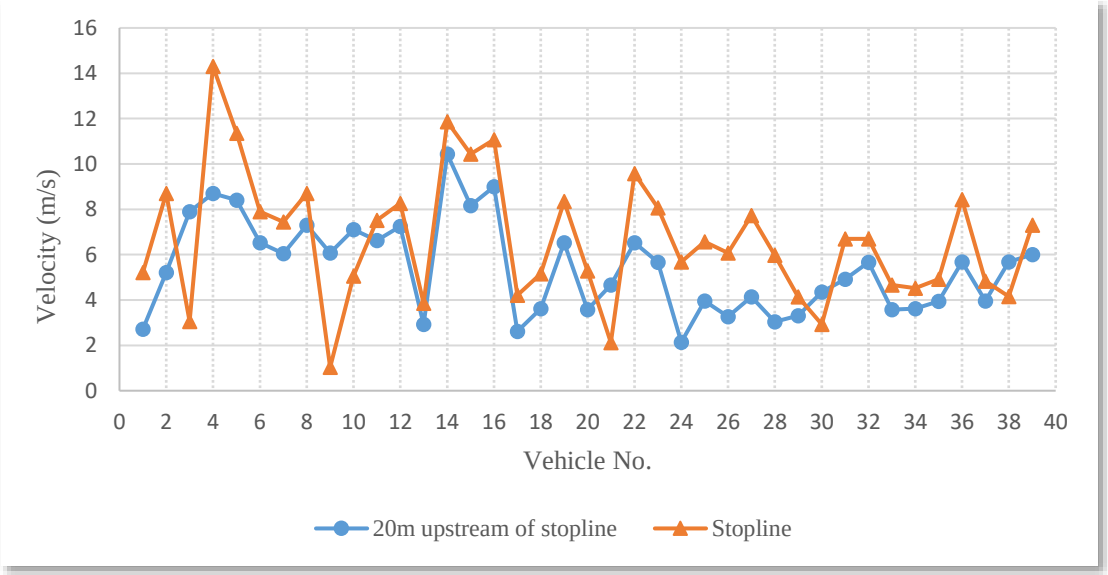

Figure 2 Velocities of left turn vehicles during peak hours

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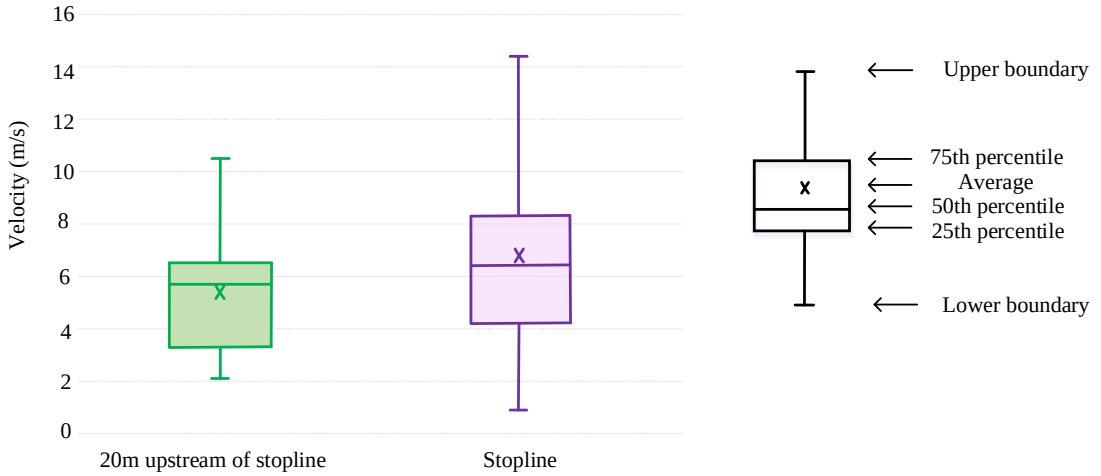

Figure 3 Box plots of speed distribution for left turn vehicles during peak hours

Figure 3 shows the speed distribution for left turn vehicles during peak hours, including mean, 25%, 75%, maximum and minimum values. It was noticed that in the position of 20m behind the stopline, the speeds are distributed between 2.1m/s-10.4m/s, and the average is about 5.4m/s. While, the speeds are distributed between 1.0m/s-14.3m/s, and the average is about 6.4m/s at the stopline. The results indicate that during the green countdown signals, left turn vehicles are more likely to appear speed fluctuation at the stopline. As mentioned above, left turn vehicles are more likely to appear deceleration (after acceleration state) near the stopline, to maintain a safe following distance.

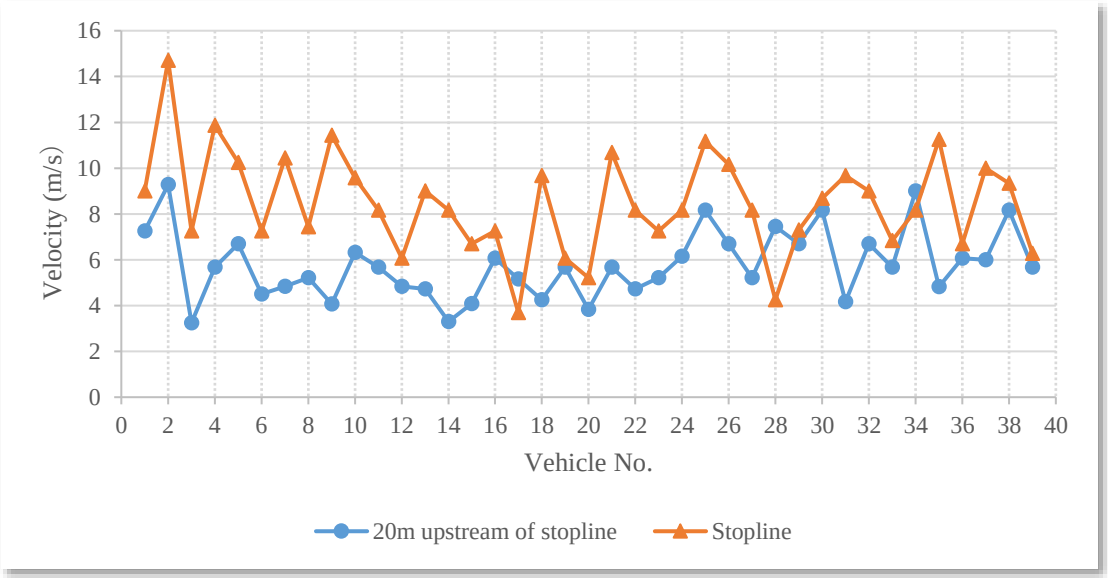

Figure 4 Velocities of left turn vehicles during off-peak hours

Figure 4 shows the velocities of left turn vehicles during off-peak hours. In general, vehicles' speeds are greater at the stopline than 20m upstream of the stopline. Compared to peak hours, the speed differences in the two positions are smaller in off-peak hours. It means that left turn vehicles could increase their speeds at a relatively stable rate in off-peak hours. Moreover, the results in Figure 4 also show that in off-peak hours, left turn vehicles can run smoothly. That is, these vehicles can always speed up, and the deceleration cases appear to be less frequently.

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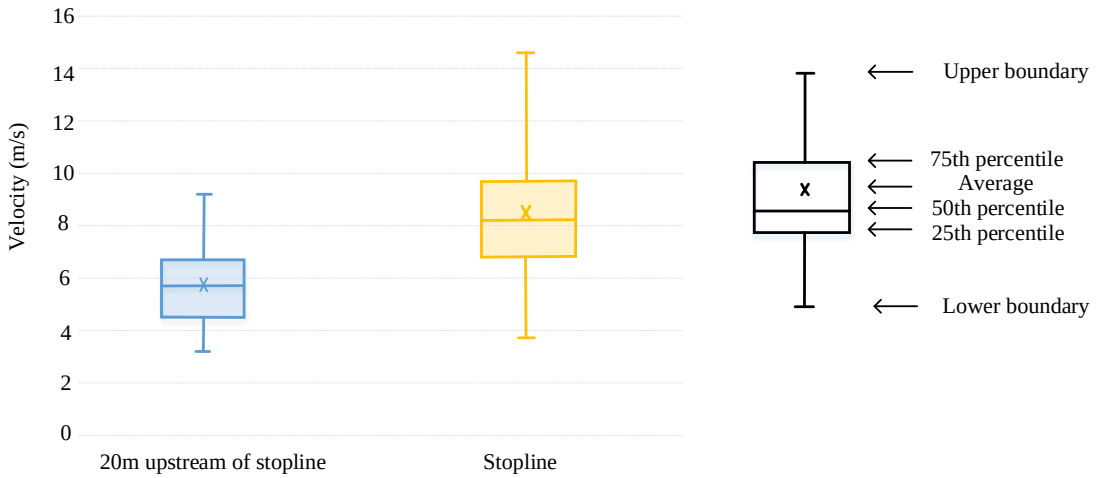

Figure 5 Box plots of speed distribution for left turn vehicles during off-peak hours

Figure 5 shows the speed distribution for left turn vehicles during off-peak hours. In the position of 20m behind the stopline, the speeds are distributed between 3.25m/s-9.275m/s, and the average is about 5.8m/s. While, the speeds are distributed between 3.7m/s-14.7m/s, and the average is about 8.5m/s at the stopline. The results indicate that during the green countdown signals, left turn vehicles can accelerate at a high rate.

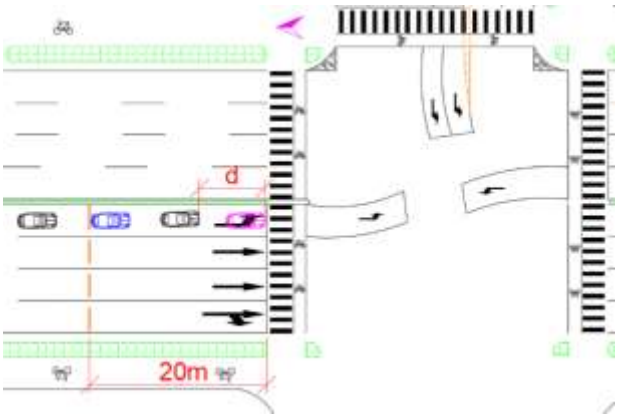

Figure 6. The distance headway of left turn vehicles during peak period

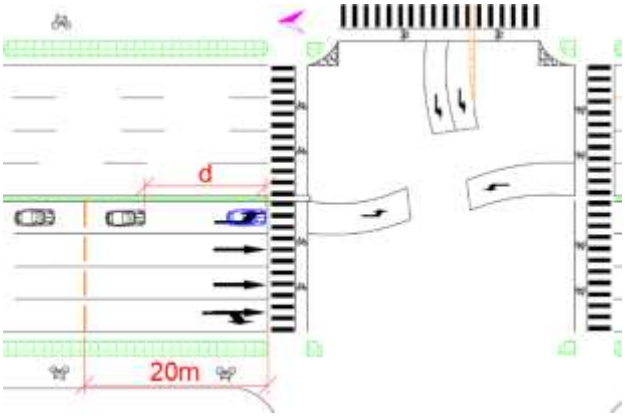

Figure 7. The distance headway of left turn vehicles during off-peak period

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There are differences in speed feature between peak and off-peak periods, mainly due to traffic flow characteristics. During rush hours, a large number of vehicles are moving with small space headway. The vehicle speed is highly restricted to the speed of the vehicle ahead in one left turn lane (see Figure 6). Thanks to limited vehicle headway (see Figure 7) with accelerating velocity, vehicles are prone to occur moving fluctuation of abrupt acceleration and deceleration. In off-peak hours, this could be considered as a relatively homogeneous stream of traffic flow. With large space headway, most left turn vehicles can accelerate quickly to get out of the intersection during the countdown signals.

Moreover, drivers' emotional states might also contribute to the differences of speed feature between peak and off-peak periods. Drivers are more likely to be involved in anxiety and stress states, in high traffic flow during peak hours. The anxiety and stress states easily lead to risky driving behavior, such as abrupt acceleration and deceleration. Instead, drivers are more likely to experience calm states, resulting in driving smoothly.

4. CONCLUSION

This study analyzed the speed characteristics of left turn vehicles within 20m upstream of the stopline during the countdown signals at signalized intersections. The results show that within 20m upstream of the stopline, left turn vehicles are more likely to appear moving fluctuation of abrupt acceleration and deceleration in peak hours, and keep acceleration quickly to pass through the intersection in off-peak hours, during the green countdown signals. The differences of speed feature between peak and off-peak periods might be due to traffic flow characteristics and drivers' emotional states. The findings of this study can provide supporting evidence for improving road safety and traffic efficiency at signalized intersections.

5. ACKNOWLEDGEMENTS

This study was supported by Graduate Study Project of Shandong University of Technology (No. 219082).

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