A Study on the Influencing Factors of Conflicts Between Motor and Non-motor Vehicles in the Turning Lanes of Signalized Intersection

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Abstract. In order to reveal the influencing factors of the conflicts between the right-turning motor vehicles and the straight non-motor vehicles at the signalized intersection, the unmanned aerial vehicle (UAV) was used to collect the field data. And various methods such as manual statistics, video detection, deep learning were employed to analyze the data to obtain the traffic volume and the trajectory of pedestrians and vehicles. Pearson correlation analysis, 2-tailed significance test and other methods were used to examine the influences of traffic volume, speed, traffic control factors on traffic conflicts. The results show that (1) the correlation coefficient between the traffic volume of non-motor vehicles and the conflict frequency is 0.842 (close to 1), which indicates that the traffic flow of non-motor vehicle has a significant impact on the conflict frequency; (2) the speeds of right-turning vehicles at intersections have no significant impact on the conflict frequency (P = 0.071 > 0.05); (3) the setting of traffic markings is a key factor (P = 0.000 > 0.05), which can be seen in the traffic volume at intersections (not controlled by signals), and the improvement of traffic control elements can effectively reduce the frequency of conflict between motor and non-motor vehicles (MNV).

1. Introduction
With the rapid development of China’s national economy, the number of vehicle increases year by year, and the urban traffic safety problem has become more and more serious. In particular, the traffic conflict between motor and non-motor vehicles (MNV) in the turning lane at intersections has attracted the attention of scholars at home and abroad. Based on the MNV conflicts, a series of methods, such as the calculation of the position, speed and acceleration of traffic participants in conflicts, and the judgment of the frequency of traffic conflict at intersections have been studied [1-3].

The methods of distinguishing and predicting the conflicts between motor vehicles and non-motor vehicles in the turning lanes at intersections have been studied in multi-level and multi angle. As to the mixed traffic flow at signalized intersection, the Haar-Adaboost algorithm was employed to analyze between the right-turning motor vehicles and pedestrians. And it was found that there is significant difference between the traffic characteristics with and without conflict [2]. Usually, vision or trajectory was employed to identify and extracted [3].
Traffic conflict is of practical value for traffic safety detection and evaluation. Serious traffic conflicts must be related to the occurrence of traffic accidents [4]. Formosa et al. found that the traffic conflict can provide an effective evaluation for the traffic accidents by analyzing the occurrence and evolution of traffic conflict [5]. The effects of a variety of traffic conflict technologies in the intersection conflict identification were compared by collecting a large number of intersection traffic conflict data, providing an effective means for the intersection safety evaluation [6-7].

In order to reveal the key factors and their effects of such conflicts, the conflicts between MNV at signalized intersections will be examined. The findings can provide theoretical method and technical support for improving the traffic safety of turning lanes at signalized intersections.

2. Collection of conflict data

2.1. Data Acquisition Experiment

Considering that video recording on the ground will be affected by the blind area of vision or the obstruction, the unmanned aerial vehicle (UAV) aerial photography was used to collect high-definition video data during the experiment. Experimental method: hovering shooting, the shooting height is 100m-130m, and the UAV model is Dajiang series (“Wu” Inspire 2 and Chansi ZENMUSE X7).

(1) Selection of experimental area and time

The representative typical signalized intersections were selected for data collection. After the investigation and comparison of the major intersections, the channelized section of the four phase signalized main road intersection and its internal area were selected. The intersection of Xincun West Street and Shiiji Road in Zhangdian District, Zibo City, Shandong Province was taken as an example (Figure 1). The survey time was selected in the early peak period (7:30-8:30) of the working days, when the traffic flow is large and the frequency of traffic conflicts is high.

(2) Sample size

When investigating the traffic conflicts in the turning lane at signalized intersections, it is necessary to ensure that the data samples are sufficient, which can fully reflect the law of traffic conflicts. The formula for determining the minimum sample size is as shown in equation (1).

\[
N = \frac{pqh^2}{D^2}
\]
where, $N$ -- minimum sample size to be observed; $p$ -- the proportion of vehicles needed in case of conflict; $q$-parameter, which is equal to 1- $p$ ; $h$ -- constant; if the confidence is 95%, $h$ is 1.95; $D$ -- allowable error.

There are 12 kinds of traffic flow directions at signalized intersection. If the conflict of the same flow direction is studied, $p = 1/2$, $h = 1.95$, when the confidence degree is 95%, and the allowable error $D$ is 10%, the minimum sample size can be determined as shown in equation (2).

$$N = \frac{pqh^2}{D^2} = 23$$

(2)

If the conflict involves two traffic flows, $p = 2/12$, when the confidence level is 95%, $h = 1.95$, and the allowable error $D$ is 10%, the minimum sample size can be determined as shown in equation (3).

$$N = \frac{pqh^2}{D^2} = 53$$

(3)

The traffic conflict investigation locations should be selected according to the requirements of the required sample size. If the collected data does not meet the sample requirements, the data should be considered separately and the research environment shall be redefined.

### 2.2. Data Description

As shown in Figure 2 and Table 1, when the right-turning motor vehicle at the intersection conflicts with the straight non-motor vehicle, the speed and distance of conflicting vehicles at intersections were extracted and described (number of samples $N=100$).

| Continuous variable                  | Min. | Max. | Mean  | Standard deviation |
|--------------------------------------|------|------|-------|--------------------|
| Vehicle velocity (m/s)               | 0.48 | 6.34 | 2.66  | 1.38               |
| Conflict distance (m)                | 0.85 | 7.31 | 2.22  | 1.76               |
| Conflict time (s)                    | 0.45 | 2.30 | 0.98  | 0.63               |

The video data collected at the signalized intersection are processed, and traffic volume and other data are extracted. The statistical data of an intersection entrance is shown in Table 2.

| Entrance       | Vehicle types | Motor vehicle (pcu/h) | Non-motor vehicle (pcu/h) | Total (pcu/h) |
|----------------|---------------|-----------------------|--------------------------|---------------|
| North entrance | Left turn     | 511                   | 284                      | 795           |
|                | Straight      | 1292                  | 610                      | 1902          |
|                | Right turn    | 517                   | 63                       | 580           |
|                | Total         | 2320                  | 957                      | 3277          |

### 3. Analysis of influencing factors of traffic conflicts

#### 3.1. The Impact of Traffic Volume on the Conflicts Between Motor and Non-motor Vehicles

The occurrence of conflicts between MNV is based on their interaction. The more traffic volume related to the two, the more serious the potential conflict. In the process of analyzing the influencing factors of the traffic conflict, it is necessary to take the traffic volume as the index to explore the quantitative relationship between the traffic volume and the conflict frequency.

1. The influence of direct non-motor vehicle volume on the frequency of conflict between MNV

   The conflict between the non-motor and the right turning motor vehicles is one of the main characteristics of the traffic conflicts at signalized intersections. First, the correlation analysis is carried...
out to determine the correlation coefficient between the number of non-motor vehicle arrivals and the frequency of conflicts between MNV, as shown in Table 3, and obs. means observations.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Dependent variable & Summary & Conflict frequency & Non-motor vehicle volume \\
\hline
Conflict frequency & Pearson correlation & 1 & 0.842 \\
& Sig. (2-tailed) & - & 0.000 \\
& No. of obs. & 17 & 17 \\
\hline
\end{tabular}
\end{table}

According to Table 3, the correlation coefficient of the two is 0.842, which is very close to 1. It means that the correlation is relatively significant. Due to the low speed of right turning vehicles, according to the t-test results, it is found that it cannot be considered as an influencing factor of the frequency of traffic conflict. Thus, the volume of right turning vehicles is not considered. The number of non-motor vehicle arrivals is an important indicator that affects the frequency of traffic conflict. By analyzing the conflict frequency caused by non-motor vehicle, and making a variety of linear fitting and comparison, the impact model of traffic volume on the conflict frequency is developed, which could analyze the impact of traffic volume on the frequency of conflicts, as shown in Table 4, and where \( f1, f2 \) mean degree of freedom; sig. means significance; \( b1, b2, b3 \) are model parameters.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline
Models & \( R^2 \) & \( F \) & \( f1 \) & \( f2 \) & Sig. & Constant & \( b1 \) & \( b2 \) & \( b3 \) \\
\hline
Linear & 0.698 & 32.42 & 1 & 14 & 0.002 & -12.12 & 0.45 & - & - \\
Binomial & 0.830 & 15.94 & 2 & 13 & 0.000 & -1.38 & 0.03 & - & - \\
Trinomial & 0.810 & 15.88 & 2 & 13 & 0.000 & 7.80 & 0.44 & 0.00 & 0 \\
Exponential & 0.700 & 32.68 & 1 & 14 & 0.001 & 0.16 & 0.00 & - & - \\
Logistic & 0.700 & 32.68 & 1 & 14 & 0.002 & 65.35 & 0.86 & - & - \\
\hline
\end{tabular}
\end{table}

As shown in Table 4, the dependent variable is the number of conflicts, and the independent variable is the number of direct non-motor vehicles. The R-square value of binomial fitting is 0.83, with the largest value. Moreover, in the comparison of F value between binomial fitting and trinomial fitting, \( 15.94 > 15.88 \), thus the binomial fitting is the best one. And the prediction model for the conflict frequency of right turning motor vehicles and direct non-motor vehicles is as shown in equation (4).

\[ Y = 0.03x^2 - 1.38x + 18.57 \]  \hspace{1cm} (4)

where, \( Y \) - In an ideal environment, the frequency of traffic conflicts; \( x \) - number of direct non-motor vehicle arrivals.

\subsection*{3.2. The influence of Speed on the Frequency of Traffic Conflicts}
Research shows that when the speed increases, the severity of the conflict will increase, and even lead to traffic accidents [8-9]. According to the right turning vehicle speed, 100 traffic conflict data collected are divided into seven sections: 0-1, 1-2, 2-3, 3-4, 4-5, 5-6, and 6-7, the unit is meters per second. The distribution proportion of traffic conflict data by speed was counted. Then, according to the statistics of the number of conflicts in different speed ranges, independent sample t-test is carried out, and the following is the analysis process.
Table 5. T-test of conflict number under different conflict speed range.

| Speed of right turning vehicles | T value | Sig. (2-tailed) | 95% Confidence limits |
|---------------------------------|---------|-----------------|-----------------------|
|                                 | 2.795   | 0.071           | 1.778                 |

It can be seen from Table 5 that the significance $P = 0.071 > 0.05$, which indicates that the right turn vehicle speed at the intersection has no significant effect on the frequency of conflict. Because the speeds of right turning vehicles at intersections are generally low, the impact of their speed on the conflict is not obvious.

3.3. The influence of Traffic Control Elements on Conflict

Through video analysis, due to the restrictions of traffic safety regulations and road traffic management regulations, motor vehicles are driven according to the road markings. However, non-motor vehicles often pay less attention on the setting of road markings in the process of driving and drive outside the boundary. This has greatly increased the incidence of traffic conflicts. According to the statistics on whether non-motor vehicles drive on the basis of markings in the traffic conflict (once per minute), it is found that 73% follow in the light of the markings and 27% do not drive in the light of the markings. Some statistical results are shown in Figure 3.

![Figure 3. The number of traffic conflicts whether driving according to the markings.](image)

The independent sample t-test is carried out for the traffic conflict data (driving according to the markings or not), and the results are shown in Table 6. As shown in Table 6, the traffic conflict caused by driving according to the markings is relatively stable ($P = 0.000 < 0.05$), and the difference is significant. This indicates that the setting of markings is a key factor affecting the traffic conflict. However, due to the randomness of non-motor vehicle driving and the lack of understanding of non-motor vehicle specific crossing, the setting of markings is ignored and the effect of markings is reduced. Therefore, paying attention to the function of setting road markings can effectively reduce the frequency of conflicts between motor vehicles and non-motor vehicles.

Table 6. T-test on traffic conflict data whether non-motor vehicles drive according to the markings.

| Driving according to markings | No. of obs. | Mean | Standard deviation | Standard error of the mean | T value | Df | Sig. (2-tailed) | Mean deviation | 95% Confidence limits |
|-------------------------------|-------------|------|--------------------|---------------------------|---------|----|-----------------|-----------------|-----------------------|
|                               | 15          | 1.467| 0.743              | 0.192                     | 7.643   | 14 | 0.000           | 1.467           | 1.055                 |

According to the Utah pedestrian crosswalk code, the pedestrian traffic accidents often occur at signalized intersection of right turning vehicles (not controlled by signals). If the corresponding signs are set up to remind the right turning motor vehicles to yield to the pedestrians, the accident rate will be
reduced by 15% - 30%; If the right turning motor vehicles is controlled by signal, the accident rate will be reduced by 60%. Due to the similar crossing behavior of pedestrians and non-motor vehicles, in order to reduce the crossing conflict of non-motor vehicles, it is better to set up corresponding signs and markings to remind. And it is necessary to carry out special signal control for right turning motor vehicles to reduce the incidence of traffic conflicts and improve the safety of traffic operation.

4. Conclusion
As the occurrence of traffic conflict is affected by various factors, this study analyzed the influencing factors of conflicts between MNV in the right-turning lane at signalized intersection: (1) the regression model of conflict frequency was established, which can predict the traffic conflict frequency with the effect under different traffic volumes; (2) the speed influence of right-turning motor vehicles on the frequency of conflicts is not significant; (3) the settings of signs and markings have a significant impact on the frequency of conflicts between the MNV. More attention should be paid to the improvement and optimal design of signs and markings at signalized intersections.

Acknowledgments
The authors appreciate the National Natural Science Foundation of China (No. 51925801, No.51942806, No. 71901134) and Jiangsu Planned Projects for Postdoctoral Research Funds (No. 2018K118C) for support this study. Special thanks go to the Intelligent Transportation Lab of Shandong University of Technology and the Chuangfei Unmanned Aerial Vehicle Community for their efforts in data collection.

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