Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2022, 9(7):84-91**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Research on the Accident and Prevention Measures for the Right Turn Blind Spot of Trucks at the Intersection

Ai M Sun, Qian Cao

School of transportation and vehicle engineering, Shandong University of Technology, China

Abstract With the rapid development of the transportation industry, the number of trucks has continued to increase. In recent years, trucks turning right at intersections have caused huge traffic accidents, causing huge losses to life and property. Road managers have proposed many management methods for trucks turning right blind spots. to reduce the occurrence of accidents. Starting from the causes of right-turn blind spots of trucks, this paper analyzes the reasons for the formation of two right-turn blind spots of trucks, that is, blind spots due to inner wheel differences and blind spots of rearview mirrors. Matlab and CAD are used to calculate the area of the wheel difference blind area, and the blind area is used to evaluate the safety of trucks turning right at the intersection, and then the relationship between the safety factor and the truck's turning angle is obtained. The safety factor decreases with the increase of the truck's right-turn angle. Finally, the prevention measures for the right-turn blind spot of trucks are put forward from two parts: improving the intersection, optimizing the rear-view mirror.

Keywords Truck turning right; inner wheel difference blind spot; rearview mirror blind spot; wheel difference area; prevention measures

Introduction

Trucking plays an important role in our country's economic and social activities. According to the data released by the Ministry of Transport [1], by the end of 2020, there were 11.1028 million trucks, with a tonnage of 157.8417 million tons, an increase of 2.06% and 16.17% respectively over the same period in 2019. In addition, in 2016, there were about 1.8 million truck-related traffic accidents in China [2], accounting for about 21.1% of the total number of traffic accidents. Truck accidents should be extensively studied.

Due to the large size of the truck and the high cab, during the turning process, pedestrians or cyclists are close to the truck, and the driver has a blind spot of vision, resulting in frequent traffic accidents and serious casualties. According to statistics from the Hangzhou Traffic Police Department, in 2019, 65 people died in Hangzhou due to right-turn accidents of heavy-duty trucks, accounting for 28.76% of the fatalities in heavy-duty vehicle traffic accidents. 33.33% of the number. In order to avoid traffic accidents in the process of right-turning of truck drivers, it is very necessary to study the blind spot of right-turn vision of trucks.

Scholars at home and abroad have also carried out a lot of research on the blind spot of trucks turning right. Wang Qingzhou et al. [3] used Matlab software to establish a right-turn model of a truck, accurately estimated the turning process of the truck, and proposed a calculation method for the blind area area. The safety assessment of the right-turn blind spot of trucks shows that the right-turn separation intersection has higher driving safety than ordinary intersections. Huang Xiangyu et al. [4] designed a set of right turn blind spot monitoring device for

large vehicles, which monitors the blind spot in real time through radar ultrasonic waves. When the truck driver turns on the right turn signal, the radar ultrasonic wave starts to work to monitor the surrounding objects of the truck, to assist the driver in the process of turning right. Sun Guojun [5] estimated the wheel gap area of a large truck turning right under ideal conditions, found the influence of the turning radius on the wheel gap area, and evaluated the relationship between the safety of the truck and the wheel gap, which effectively avoided the wheel gap. traffic accidents caused.

Ron Schindler et al. [6] study two scenarios between a truck and a vulnerable road user, one of which is when a truck wants to turn right at an intersection and a cyclist parallels and plans to cross the intersection. Thomas Richter et al. [7] studied the accident severity of right-turning trucks and straight bicycles, and proposed that conflicts and blind spots during green light driving are the main problems of accidents, and put forward suggestions and improvement measures for turning accidents, including intersections. The distance between non-motorized vehicle lanes and motorized vehicle lanes should be as small as possible, additional rear-view mirror systems should be installed on trucks, and traffic knowledge should be popularized among road users. Kun Feng Wu [8] developed a four-step analysis program using the data from the on-board data recorder to better understand the collision process of a right-turn collision of a large bus, and concluded that the crash occurred because the driver was turning right. During the process, the rearview mirror and the speed difference with the passing vehicle were not checked in time.

This paper studies the formation mechanism of the blind area of vision during the right turn of the truck, calculates the inner wheel difference and the wheel difference area of the truck turning right, and finds the factors that affect the wheel difference area. Then, it puts forward effective suggestions and measures to avoid collisions, reduce the collision accidents of trucks, and ensure the safety of life and property of drivers and vulnerable road users.

Method

There are two types of right-turn blind spots for trucks: blind spots for interior wheel differences and blind spots for rearview mirrors [9]. The inner wheel difference is the difference between the turning radius of the front inner wheel and the rear inner wheel during the turning process of the vehicle, and the inner wheel difference blind spot is the blind spot formed when turning. As shown in Figure 1. The blind spot of the rearview mirror is that when the vehicle turns right, the driver's visual area will be reduced, and the scope seen by the rearview mirror of the truck will become smaller, forming a blind spot. Compared with other motor vehicles, large trucks have a high driving viewpoint due to their own characteristics, which leads to more blind spots in the visual field design [10].

Inner wheel difference blind spot

The inner wheel difference will change with the change of the wheel angle. When the wheel angle reaches the maximum value, the inner wheel difference is the largest. At this time, the trajectory of the front wheel of the car is the minimum radius arc [11]. Figure 2 shows the inner wheel difference model of a truck turning right. It can be seen from the figure that the inner wheel difference formula is:

$$R = OD - OC = r_1 - r_2 = \sqrt{\left(\sqrt{r^2 - d^2} - n\right)^2 + d^2} - \sqrt{r^2 - d^2} + n \qquad (1)$$

In the formula: d is the wheelbase of the truck, r is the turning radius, and n is the wheelbase of the truck. The size of the inner wheel difference is jointly determined by d, r, and n. When only a certain variable is considered: the larger the wheelbase or wheelbase, the larger the inner wheel difference; the smaller the turning radius, the larger the inner wheel difference. It can be seen from Table 1 that the larger the model, the larger the maximum inner wheel difference. The inner wheel difference of medium and large trucks is much larger than that of small and medium-sized vehicles.

Figure 1: Right turn blind spot of truck

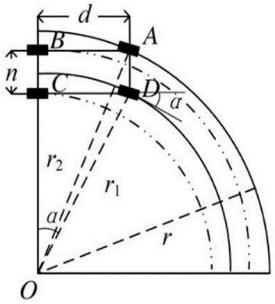


Figure 2: The difference between the inner wheels of the truck turning right

Table 1: Inner wheel difference of typical models

Car model	Wheelbase d (m)	Track width n (m)	Minimum turning radius r (m)	Maximum inner wheel difference R(m)
Chery QQ	2.34	1.42	4.8	0.86
BMW 7 series	3.21	1.65	6.25	1.20
Wuzheng 1800 light truck	3.25	1.42	6.2	1.19
Yellow Sea Bus	6.27	1.81	12	2.08

Rearview mirror blind spot

For some articulated trucks, it is connected to the front and semi-trailer via a tow pin. When the vehicle turns, as the turning angle continues to increase, due to the different turning radii of the front and the semi-trailer, when the front of the vehicle starts to turn, the semi-trailer is still in a straight-ahead state, and gradually the rear of the semi-trailer will begin to disappear in the rear view. within the field of view of the mirror. As shown in Figure 3, the grid line in the figure is the visible range of the truck driver's exterior rearview mirror. When the vehicle is turning, as the turning angle gradually increases, the visible range gradually becomes smaller. If the rearview mirror cannot see the surrounding environment of the truck, the rearview mirror will fail. At this time, it is just within the inner wheel difference range of the vehicle trajectory, so the driver cannot notice pedestrians or non-motor vehicles. According to research, in the process of turning the articulated truck, the angle between the front of the truck and the semi-trailer is about 20° under normal conditions, and the truck driver can only see the semi-trailer within 5 to 10 meters behind the traction pin through the rearview mirror. Trailer length. For those semi-trailers with particularly long lengths, half of the semi-trailers will be out of sight when the vehicle is in the process of turning and looking through the rearview mirror. This situation greatly affects the driver's judgment of the position of the vehicle body, resulting in unnecessary traffic accidents.

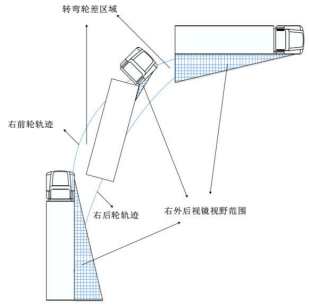


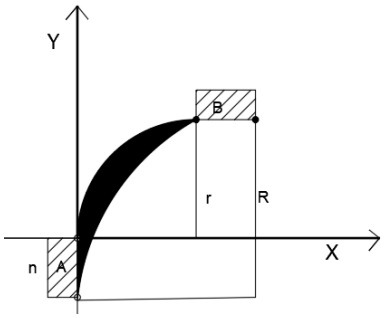
Figure 3: Changes in the field of view of the exterior rearview mirror

Truck wheel differential area and safety assessment

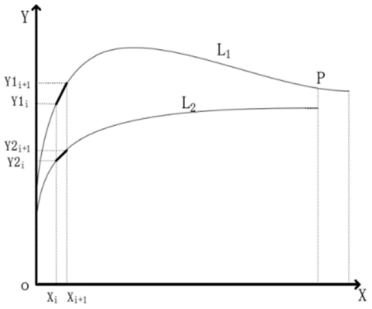
During the turning process of the vehicle, because the front and rear wheel trajectories are different, a semi-circular arc trajectory will be formed, such as the red area in Figure 1. This area is the area generated by the wheel difference, which is the blind spot of the field of view. The size of this area has a great influence on traffic accidents. How to judge the area of this area is an important problem to solve the right-turn accident of trucks.

Calculation of Blind Zone Area in Actual State

In the actual state, the driving trajectory of the truck during the turning process is shown in Figure 4. The ideal state refers to: when the vehicle is preparing to turn at the intersection, when the front wheel reaches the horizontal line of the curve, it starts to turn at a constant speed, and the trajectories of the front and rear wheels of the vehicle are circular motions. As you complete the turn, the wheel traces a quarter circle. A Cartesian coordinate system is established, as shown in Figure 4(a). In the figure, the vehicle starts turning at point A and ends at point B. Compared with the ideal state, it can be seen that the trajectory of the truck turning right in the actual state is an irregular turning model.



a) Trajectory model of trucks turning right under ideal conditions



b) Trajectory model of trucks turning right under actual conditions

Figure 4: Trajectory model of large truck in ideal state and actual state

We solve the real truck right-turn trajectory model. Among them, L_1 is the trajectory of the front wheel of the truck during the turning process, and L_2 is the trajectory of the rear wheel of the truck during the turning process. The front and rear wheels are the wheels of the surveyed truck. The area surrounded by the two curves L_1 and L_2 is the blind area of the truck turning right. Point P is the point where the truck is ready to go straight after turning right. At this time, the front and rear wheels start to move straight. The two curves of L_1 and L_2 are not known functions, so we use the trapezoidal method to calculate the integral to obtain the blind area.

$$S = S_{L1} - S_{L2} - S_T = \sum_{i=0}^{i} \frac{(Y1_{i+1} + Y1_i)(X_{i+1} - X_i)}{2} - \sum_{i=0}^{i} \frac{(Y2_{i+1} + Y2_i)(X_{i+1} - X_i)}{2} - Y1_{ie} \times \mathrm{n}$$
$$= \sum_{i=0}^{i} \frac{(X_{i+1} - X_i)\left[(Y1_{i+1} - Y2_{i+1}) + (Y1_i - Y2_i)\right]}{2} - Y1_{ie} \times \mathrm{n} \quad (2)$$

In the formula: S_{L1} is the area enclosed by the L1 track and the coordinate axis, S_{L2} is the area enclosed by the L_2 and the coordinate axis, ST is the rectangular area in the figure, i is the driving time when the truck turns right, X_i, Y_{1i}, Y_{2i} are respectively for the coordinates of the curves L_1 and L_2 at time i, the rear wheel reaches point P and starts to move straight at time ie.

According to research and analysis, the blind spot area has a great relationship with the length and turning angle of the truck. Taking the length of the truck and the angle of the turning angle as the parameters of the variable, through the analysis of the parameter variables, it is found that the length and angle variables can be independent of each other, and the curve fitting and formula extraction of the angle and length are carried out. Use Taylor's formula to transform the relationship between the dead zone area and the trigonometric function, and use the exponential polynomial to fit the curve. Taking the speed and the length of the truck as a single variable, the area of the blind spot of the truck's right turning sight is calculated by changing the length and turning angle of the truck. The series exponential polynomial is fitted, and the output model is:

$$S = 5 \times 10^8 + 119 \times \left(\varphi^4 - 82.1 \times \varphi^3 + 44.2 \times \varphi^2 - 8.8 \times \varphi + 0.069\right) \times \left(h^2 - 6.48 \times 10^3 \times h + 6.32 \times 10^7\right) \quad (3)$$

In the formula: h is the length of the vehicle, and is the turning angle of the truck.

Road Intersection Safety Assessment

Most right-turn traffic is not controlled by traffic lights, so that large vehicles collide with non-motor vehicles and pedestrians in the slow lane due to the existence of blind spots in the process of right-turning, causing serious traffic accidents. This paper evaluates the safety factor of vehicles turning right at the intersection, which is beneficial to improve the design of the intersection.

Define the area of the wheel gap when the truck turns right, the area other than the overlap area of the pedestrian crossing and the wheel gap area percentage, which is the road safety factor of the intersection, denoted as P, and the formula is:

$$P = \left(1 - \frac{S_1}{S_2}\right) \times 100\% \quad (4)$$

In the formula: S1 is the wheel difference area and the overlapping area of the crosswalk, and S2 is the wheel difference area.

We scale the intersection with a certain proportion and match the front and rear wheels of the vehicle during the turning process. We use CAD to calculate S_1 and S_2 to obtain the safety factor. We study the relationship between the turning angle of the truck and the safety factor. Keeping the rest of the variables the same, the resulting relationship is shown in Figure 5.

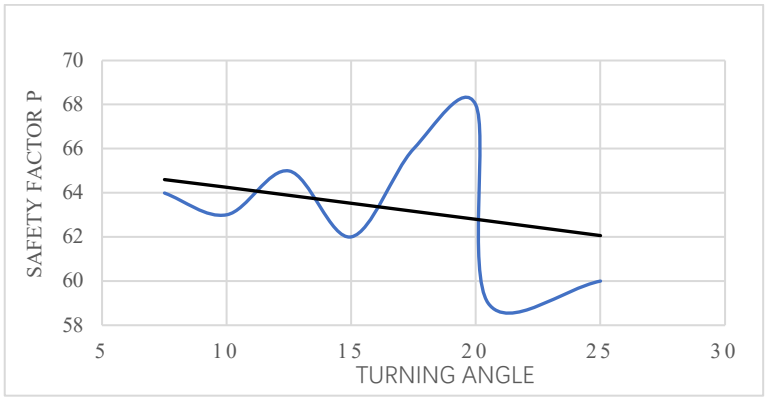
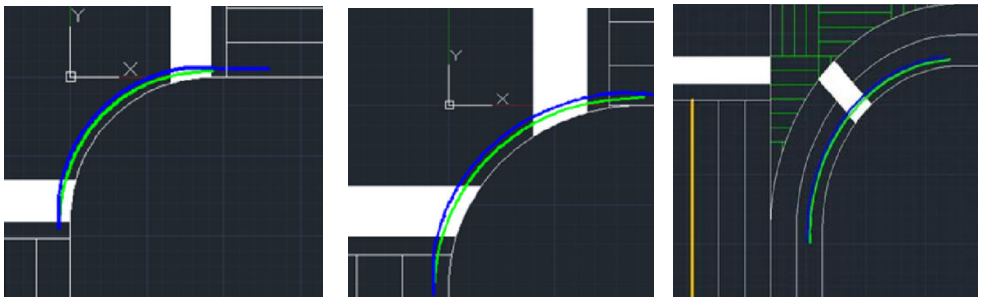


Figure 5: The relationship between the turning angle of the vehicle and the safety factor value

The obtained data is subjected to univariate regression to predict the overall trend. As the turning angle increases, the safety factor decreases. Then the turning angle increases, and the area where the wheel difference area and the crosswalk area overlap will be more. According to the above safety factor, in order to ensure the safety of non-motor vehicles and pedestrians on the road, when designing the intersection, the turning radius can be increased within the allowable range, so that the vehicle adopts a smaller turning angle during the turning process. Reduce wheel gap area. According to the above safety assessment factor, the common intersections with gentle turns, sharp turns and right-turn split intersections are selected to calculate the safety factor.



(a) soft turn (b) sharp turn (c) Right-turn split junction

Figure 6: Schematic diagram of three intersections

Using CAD and matlab to calculate the area in the figure, the safety factor values of these three intersections can be obtained. is 92.01. From the above data, it can be seen that the right-turn split intersection can significantly improve the safety factor of the intersection, and it is also more convenient and safe for driving. The safety factor of a slow turn is lower than that of a right-turn split intersection, and the safety factor of a sharp turn intersection is the lowest. It can be concluded that when designing the intersection, the turning radius should be appropriately increased, and when the vehicle turns, it should be urged to adopt a smaller turning angle to reduce the area of the blind area of the turning wheel difference; for the sharp turning intersection, the pedestrian crossing can be set inside the intersection. The entrance is far away, such as moving to the position where the truck completes a right turn.

Result and Analyze

Eliminate accidental conflicts in right-turn areas at intersections

Plan the turning radius reasonably. When setting the turning radius of an intersection, consider signal control, road channelization, and traffic flow characteristics. If the turning radius is too small, the right turn angle of the truck will become larger, which will reduce the safety factor of the intersection and cause greater conflicts and delays. The turning radius should be reasonably planned according to the actual situation to ensure that most of the passing vehicles can pass through the same curvature change as the aircraft-non-separation.

Make a right turn split. Right-turn separation intersection is to separate right-turning vehicles separately by establishing separation strips, isolation islands or drawing markings on the road, so that non-motor vehicles and pedestrians can distinguish right-turning vehicles and identify each other's driving directions. Traffic island and road markings are set up to effectively control the speed of vehicles turning right. The traffic island can be used as a safety island for avoiding vehicles when pedestrians cross the street.

Set up signs and markings for big truck turns. Set up "Turn Large Vehicles Carefully" signs at pedestrian crossings or non-motorized vehicle lanes at intersections to warn road vulnerable groups to turn carefully at intersections. And set up a right turn blind spot for trucks at the motor vehicle lane, and a sign to drive carefully, warning truck drivers to slow down, stop and drive slowly. According to the local intersection, the maximum wheel gap area of the truck is reasonably calculated, and the red dangerous area is sprayed at the intersection, so that traffic participants can be clearly reminded and avoid it in time.

Properly moving the stop line of the non-motorized vehicle lane forward, so that the driver of the right-turning vehicle can clearly observe the road conditions on the right, can effectively avoid the conflict between the right-turning vehicle and the vulnerable group on the straight road, and reduce the occurrence of traffic accidents.

Optimize the rearview mirror and early warning function of trucks.

At present, there are many studies to improve the rearview mirror. For example, an electronic exterior mirror with a combination of a camera and a display screen can be used to adjust the aperture of the camera and image processing, so that the driver has a good field of vision in the case of poor outside vision. The use of electronic exterior mirrors can enhance the line of sight of the truck and reduce the blind spot of the driver's field of vision.

In order to improve the early warning function of trucks, this paper designs an on-board auxiliary system that integrates the sound and light alarm system, the active fill light system and the rearview mirror that can be automatically driven and adjusted. Millimeter wave radar is installed on the inside of the rear wheel of the truck to monitor the blind spot in real time, and the blind spot information is collected through the radar. When an obstacle is detected around the vehicle, the driver will be reminded by buzzing sounds and flashing lights of different frequencies. Obstacles exist in the turning blind zone, and a buzzer outside the car will alert traffic participants outside of the vehicle to potential hazards around them. When driving at night, the driver cannot accurately judge the situation outside the car. At this time, the active supplementary light system provides lighting support for the driver. The rearview mirror that can be automatically driven and adjusted is used to automatically adjust the angle according to the different positions of the vehicle when the vehicle turns, so that the driver can see the situation in the blind spot to the maximum extent, thereby reducing the occurrence of danger.

Conclusion

In recent years, traffic accidents caused by the blind spot of trucks turning right at the intersection have brought huge casualties and property losses to the society. This paper starts with the blind spot of trucks and finds two main reasons for the blind spot of sight of trucks turning right. Inner wheel difference blind spot and rearview mirror blind spot. Using the driving trajectory of the truck, the calculation model of the blind area of the truck turning right is established, and the safety factor of the intersection is calculated. solution. Finally, according to the research of the full text, starting from optimizing the sight range of the rearview mirror, increasing the safety factor of the intersection, and reducing the turning angle, the prevention measures for the right turn blind spot of the truck are started.

This paper also has some limitations. When analyzing the sight range of the rearview mirror of the truck, some basic characteristics of the driver are not considered, such as the driver's height, the visual field of eye rotation, etc. The change of the angle between the rearview mirror and the body also has a lot of influence on the sight range and these issues will be analyzed in future research.

References

[1]. Ministry of Transport of the People's Republic of China. Statistical bulletin on the development of the transportation industry in 2020 [R]. 2021.

[2]. Traffic Administration of the Ministry of Public Security. 2017 China Road Traffic Accident Statistics Annual Report [R]. 2018.

[3]. Wang Qingzhou, Xu Lingxuan, Fan Xin, Guo Kai. Research on the formation mechanism of trucks turning right blind spot and the safety of intersections [J]. Chinese Journal of Safety Science, 2017, 27(05):99-104.

[4]. Huang Xiangyu, Shi Lu, Chen Guoqiang, Li Weixi. Design of right-turn blind spot monitoring device for large vehicles [J]. Internal combustion engine and accessories, 2021(19):198-199.

[5]. Sun Guojun. Estimation and safety analysis based on the steering wheel difference area of large trucks [J]. Automation and Instrumentation, 2016(03):98-99.

[6]. Ron Schindler, Giulio Bianchi Piccinini. Truck drivers' behavior in encounters with vulnerable road users at intersections: Results from a test-track experiment [J]. Accident Analysis and Prevention, 2021, 159: 106289.

[7]. Thomas Richter, Janina Sachs. Turning accidents between cars and trucks and cyclists driving straight ahead [J]. Transportation Research Procedia, 2017, 25: 1946-1954.

[8]. Kun Feng Wu, P o J u i L i. Using on-board video data for safety analysis–An analysis of right hook crashes involving large buses at signalized intersections[J]. IATSS Research, 2021, 45: 79-86

[9]. Xu Lingxuan. Research on the formation mechanism and prevention measures of right-turn blind spot for large vehicles [D]. Hebei University of Technology, 2017.

[10]. Wang Qingzhou, Wang Nannan, Huang Yuman, Luan Haimin. Failure mechanism of right-turn rearview mirror of semi-trailer train [J]. Journal of Chang'an University (Natural Science Edition), 2020, 40(02): 117-126.

[11]. Jiao Xuan. Innovative management measures to prevent accidents caused by large trucks turning right in the blind spot [J]. Road Traffic Management, 2021(10):14-16.