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Analysis of Vehicle Speed Change at Non-signalized Crosswalks Based on Driving Behavior

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Abstract

The probability of accidents at crosswalks in the city depends more on vehicles’ speed. Drivers’ behavior, therefore, is of great significance. The study aims to reveal the interrelationship between vehicle speed and the onset of yielding when encountering a crossing pedestrian, and analyzes how the pedestrian behavior influences the speed of the approaching vehicle. A two-lane branch road (Southern College Road) in Beijing is chosen as place for traffic conflict observation and video collection. Video recordings were made in order to obtain a more detailed description of the speed and positional condition and the interaction between vehicles and pedestrians, and the behavioral characteristics of vehicles were analyzed. The result has demonstrated the onset of deceleration that drivers are more likely to decelerate 30m-37m ahead of crosswalk at a speed of 40-50km/h, and decelerate 23m-30m ahead of crosswalk at a speed of 30-40km/h. An average distance is about 25m away from the crosswalk. Upon the result, recommendations have been given for improving traffic efficiency and lower accident rate at crosswalks.

Keywords: speed, conflict driving behavior

1. Introduction

Traffic accident data indicates that 37% of the pedestrian injury accident happened at the crosswalk. The safety of pedestrian is affected to a great extent by the velocity of vehicles. At a collision speed of 50km/h, the risk of pedestrian fatally injured is almost eight times of 30km/h [1]. Drivers are always the critical one who is universally
condemned for causing plenty of accidents, nevertheless, they may often fail to realize the lateral pedestrian, or they misunderstand the intention of pedestrians. In other words, both pedestrians and drivers are interacting behaviors of each other under their encounter.

Driving is quite a complicated work, which needs agile mind thinking activity and flexible body movements to ensure correct safety measures in emergency situations and lowest damage rate. The interrelationship between vehicles, road environment and other road users (pedestrians and non-motor vehicles) is in dynamic change at any time. The process of responding to an emergency can be concluded into the following four steps (see Fig.1):

- Situation comprehension
- Projection
- Decision making
- Execution

![Fig.1. speed behavior process](image)

Situation comprehension is drivers’ perception to the whole driving condition and environment, which brings them a situation categorization and a quick judgment about whether there would be a danger or not. Projection often comes from drivers’ accumulated experience before. Decision making is the determining factor affecting the severity of accidents if there is a collision. It directly influences the execution embodied by speed, and the can be regarded as hierarchy. The execution manages the vehicle commands (steering-wheel).

Andras Varhelyi [2] revealed speed adaptation problems at crosswalks and identify a so-called ‘ideal’ situation in which the vehicle brakes on the driver’s own initiative in order to give priority to a pedestrian. He also found that on the basis of pedestrians crossing frequency and vehicle driving status change, the speed is obviously affected by crossing pedestrians about 40 to 50 meters ahead before crosswalks in Sweden. Ashton [3] thought that the distribution of the collision speed between pedestrians and vehicles can be used to evaluate the serious degree of conflicts, and he built a model to evaluate speed influence on the accident possibility of deaths when a random pedestrian occurs in uncertain place and uncertain traffic speed conditions. Karkee [4] in his doctoral thesis focused on pedestrian safety and comparison of various kinds of pedestrian protection facilities, and considered avoiding distance as one of the most important evaluation index. FENG Shu-min and PEI Yu-long [5] focused on vehicle delay and gave a specific calculating method.

Speed behavior (deceleration especially) before crosswalk is analyzed based on the four steps of driving behavior process in this study, which will promote to improve traffic efficiency and lower accident rate at crosswalks.
2. Methodology

Clues of driver's behavior can only get reflected through the vehicle's path and speed change. For the research of driving behavior at non-signalized mid-block crosswalks when facing potential conflicts with passing pedestrians, a video camera is used at the traffic scene to collect video data. It has also been saved for playback analysis later again to get the vehicle's speed changes.

Speed and position connection between vehicles and pedestrians at the crosswalk can be found through specimens. Based on the actual measurement data, we find out, discuss and give an expression to some regular patterns of this connection. According to previous data, there's a big difference among different countries and organizations on the arrangement of the traffic conflict research time. Considering the arrangement of the observation time and reference to the urban traffic conflict characteristics of road traffic accident, observation time for up to three days or more is indispensable at the same place, and of course, the same observation environment. Holidays and peak hours are all unacceptable. Pedestrian crossing behavior can be classified into two types: single pedestrian crossing and pedestrian group crossing. For studying speed and position connection between single vehicles and single pedestrians, here we only regard single pedestrian crossing as valid specimen.

To avoid the research vehicle driving conditions being influenced by adjacent lanes, branch road with fewer lanes is a better choice, so that we can get ideal data. A two-lane branch road (Southern College Road) in Beijing is chosen this time as place for traffic conflict observation, and video collection as well. It is in the circle of the third ring road, in Haidian district, in the northwest city zone. The average vehicle speed is about 38km/h, and the average pedestrian speed is about 1.25m/s. Relationship between pedestrian speed and headway can be illustrated as Fig.2. Pedestrian speed presents an escalating trend with the headway decreasing.

![Fig.2. relationship between pedestrian speed and headway](image)

The basic speed and position relations between pedestrian and vehicle are divided into the following four categories in this study.

- There is a big time gap for pedestrians and drivers to pass the potential collision point respectively. After the judgment that there is enough time to avoid an accident and no potential risk, there is no change of speed for both sides. This kind of circumstance is seen as safe situation, which is not collected as conflict specimens, and signed as case 1.
- There is a critical time gap for pedestrians and drivers to pass the potential collision point respectively. Pedestrians need to cross the road with a small acceleration so that they can pass before vehicle. This kind of circumstance is seen as one of typical situation, which is collected as conflict specimens, and signed as case 2.
There is a critical time gap for pedestrians and drivers to pass the potential collision point respectively. Pedestrians need to stop and wait, and vehicles pass first. This kind of circumstance is seen as one of typical situation, which is collected as conflict specimens, and signed as case 3.

There is hardly a time gap for pedestrians and drivers to pass the potential collision point respectively. Both drivers and pedestrians’ behavior has been changed to a large extent, for both sides refuse to yield to each other, but compromise at last. This is one kind of serious traffic conflict and is more likely to cause an accident. It is signed as case 4.

3. Data analysis and results

3.1. Behavioral analysis between speed and crossing pedestrian

After observation, the speed behavior change of vehicle for the duration of approaching crosswalk can be illustrated as Fig.3, Fig.4, and Fig.5 (The conflict point is “0,0” point on the horizontal coordinate axis, and the pedestrian start point is “-4,0”). Specific data analysis is as follows.

In case 2 (see Fig.3), after the judgment that there will be a collision without deceleration, vehicles first slow down and give the priority to pedestrians, then pedestrians cross the road with a uniform speed or an acceleration. Under this circumstance, vehicle speed has been changed to a small extent. Despite a higher cost of energy caused by braking, compared with case 3 correspondingly, the safety of pedestrians can be guaranteed, and traffic efficiency as well.

In case 3 (see Fig.4), after the judgment that there will be a collision without deceleration, drivers trample the brake pedal gently, then pedestrians hesitate and stop right beside the lane. Then drivers accept this surrender and pass the crosswalk with a uniform speed or acceleration. Under this circumstance, there is hardly no speed change for vehicle. In terms of pedestrians, their entitlement at the crosswalk is deprived by vehicles, which means a reduction of crossing efficiency.
In case 4 (see Fig.5), both drivers and pedestrians realize each other but don’t slow down until a later time. Under this circumstance, both drivers and pedestrians’ behavior has been changed to a large extent. Communication and comprehension between them is not enough. This is one kind of serious traffic conflict and is more likely to cause an accident.

3.2. Behavioral analysis between speed and distance

Motor vehicle deceleration behavior can be seen as drivers are forced to have changed their original driving behavior by passing pedestrians. There is a direct relation between the vehicle speed and distance from vehicle to crosswalk at the onset of deceleration. According to the statistics, drivers are more likely to decelerate 30m before crosswalk at an initial speed of 50km/h, and correspondingly, decelerate 25m before crosswalk at an initial speed of 40km/h. They usually don’t decelerate when the speed is under 30km/h (see Fig.6). That is to say, the higher the speed is, the further drivers decelerate, which of course, is in accordance with previous data and reality. When speed...
is up to 45km/h, there is an obvious increase of change rate, which means drivers are aware of potential danger brought from high speed.

Fig. 6 Relationship between onset deceleration distance and vehicle speed

Fig. 7 shows the relationship between average speed and distance for the duration of approaching crosswalk. (The conflict point is “0,0” point on the horizontal coordinate axis). An average distance of deceleration is about 25m before the crosswalk.

Compared to foreign data, the result of the average decelerating distance 25m is a little bit shorter. Reasons may be concluded into three points:

- There is a reaction time for situation comprehension, projection and decision making.
- Consciousness of drivers in China to yield is not as same as foreign counties. Some time it is not with their own will but “have to”.
- Specimens consist of radical drivers more than conservative drivers.
4. Conclusion and discussion

The results show that there are two types of driving characteristics: conservative drivers and radical drivers. The former ones keep on driving at a low speed fluctuating between 60% to 70% of preceding speed, and pedestrians pick up their pace since they realize having been given the priority to cross the road. However, the latter ones show no hesitation, radical drivers will accelerate passing the crosswalk. This subjective judging probability which has potential security threats to pedestrians is usually affected by drivers experience to some extent. In other words, a lot of drivers will find an interesting pattern through driving in the “confrontation” with a crossing pedestrian once after another. Though sometimes pedestrians have the ability to cross before the vehicle arrive, they will still assign priority to vehicles because of the potential danger if drivers have no deceleration intention or even speed up instead. In the process of the game drivers get a “reward” as a victory; on the contrary, they may get a “penalty” for the loss of time and inconvenience brought by deceleration.

According to the study, recommendations can be given for both drivers and pedestrians: Make sure that your following intention is clear enough to other ones, so that they can make projection and decision correctly and effectively.

5. References