The Influence of Urban Crossroad Facilities on Pedestrian Safety in Shanghai, China

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Abstract

With the development of economic, the traffic requirement rapidly increases in Shanghai. Besides building more new infrastructures, the administrators put forward to many countermeasures to increase the vehicle traffic capacity previously and to meet the traffic requirement in China. At the same time, the urban traffic facilities are set up by different departments of government during different periods, and the urban traffic facilities designers and administrators do not pay more attentions to the vulnerable road users' safeguard. As a consequence, there are many imperfect urban traffic facilities which put vulnerable road users in a high risk situation. The pedestrian is the most vulnerable among road users. The crossroad is a typical and practical intersection. The crossroad facilities mainly comprise of vehicle lane, crosswalk, safety island, pavement, pedestrian signal light, guardrail, and other facilities nearby crossroad such as bus station and pillar of high elevation in Shanghai. To research the influence of urban facilities on pedestrian safety, the rate of traffic law violation (RTLV) evaluates the behavior character and dangerous situation of pedestrian. Based on investigation of five types of twice-crossing intersection and sixteen pavements in Shanghai, the more number of vehicle lanes there are at crossroad, the more time pedestrian will wait for, and the less RTLV there is. Within 90 seconds the RTLV decreases with the waiting time increasing, while more than 90 seconds the RTLV is irregular. The reasonable time which pedestrian waits for is 90 seconds. The width of pavement has more effective impacts on pedestrian traveling along pavement than length of guardrail. The imperfect installation of bus station nearby crossroad and crosswalk nearby the pillar of high elevation are analyzed in the paper. Considering the blind area between pedestrian and driver due to parking bus, the minimum distance between crosswalk and bus station is given. The integration safety evaluating coefficient (ISEC) comprises of five factors, including pedestrian signal light, guardrail, safety island, number of vehicle lane and whether pedestrian starting from sidewalk. The RTLV of pedestrian decreases when the ISEC of crossroad increases.

Key words: traffic safety; crossroad facilities; pedestrian; crosswalk; traffic law violation; blind area;

Introduction

Road traffic safety is a problem throughout world, special in developing countries. Every day around the world, more than 3000 people die from road traffic injury. Low-income and middle-income countries account for about 85% of the deaths and for 90% of the annual disability adjusted life years (DALYs) lost because of road traffic injury (Peden M. et al. 2004). Road traffic deaths will decline by about 30% in high-income countries but increase substantially in low-income and middle-income countries. Without appropriate action, by 2020, road traffic injuries are predicted to be the third leading contributor to the global burden of disease and injury (Peden M. et al. 2004). There were about 600 peoples die and 45 000 persons injure every day in China. The traffic accident losses are computed at $12~$21 billions each year, that is about 1.5% of GDP of China. In Singapore, injuries from road traffic accidents are the fifth major cause of death. Pedestrians were the second most vulnerable group of road users in 2003. Of the total number of fatalities, pedestrians made up almost 30% compared with 24.6% in 2002. There were 63 pedestrians killed in 2003 compared with 49 in 2002. Among the 63 pedestrians killed, elderly pedestrians were a concern (L.M. Jean, 2004). In Shanghai, there were 27 136 traffic accidents in 2004, compared with declining 49.93 percent in 2003; while there were 1 447 persons lost their lives in 2004, compared with increasing 1.13% in 2003. Among these traffic accidents, there were 120 people die among 557 traffic accidents in the non-mobile drivers, compared with increasing 33.3% in 2003 (Traffic Department, Shanghai Municipality Public Security Bureau, 2004).

The economic development is rapid in China recently, specially in Shanghai. In most cities the governments invest huge expenses on improving urban public traffic infrastructures to meet the continuous increasing demands of traffic requirements. The decision-makers and designers of urban traffic infrastructures focus on solve the problem of jam-packed urban public traffic. They built appropriative lanes for the public bus. They set up more new vehicle lanes and ring roads. There are already three ring roads in Shanghai. There are not non-mobile lanes and pavements in many places of the latest mid-ring road. Many of bicyclists and pedestrians' routes every day have been changed or interrupted by the new traffic infrastructures. High volumes of pedestrians, cyclists and other vulnerable road users have little choice but to travel along roads in close proximity to fast vehicles. As a consequence, many vulnerable road users are put in a high risk situation, which inevitably leads to large numbers of pedestrian and vulnerable road user accidents.

Objective

In towns and cities, there is a tendency for traffic accidents to cluster at specific places, often at intersection (Rune Elvik, 2004). A concentration of accidents at intersection may partly be due to inappropriate road design or inappropriate traffic control at that place. In such case, the clustering of accidents can be avoided or reduced by improving road design or traffic control. There are four types of urban intersection in Shanghai, such as T-junction, crossroad, staggered junction, and roundabout. There are fewer roundabouts in Shanghai now. Intersection with four approaches makes higher demands on road user alertness and behavior than intersection with three approaches. A four-leg intersection has 32 conflict points between the streams of traffic. Now the road is built wider and wider, especially under high elevation. So there is not enough time for pedestrians crossing the crossroad during a green phase of traffic light. To solve that problem, some of crossroads are designed as twice-crossing intersection at different practical traffic environments.

Based on the rule of pavement public traffic installation in Shanghai (SZ-42-2005), the width of pavement is defined as the ratio between the maximum pedestrian flow and the design pedestrian capacity, and it is not less than 3 meters. In fact, due to urban public facilities,

such as booths, telephone boxes, billboards, and bicycles, the effective width of pavement is less than the design width. That causes bottleneck of pavement, and imposes pedestrian on dangerous of non-mobile lane or more dangerous of vehicle lanes. The length of guardrail between pavement and non-mobile lane is not compulsorily regulated by traffic laws.

First different parameters of twice-crossing intersection impact on the pedestrian behaviors. The different parameters of twice-crossing intersection mainly include the number of vehicle lanes, the facilities such as pavement, virescence zone, safety island, guardrail and pedestrian signal light. The rate of traffic law violation (RTLV) of pedestrian evaluates the influence of facilities on pedestrian traffic safety.

Secondly considering the blind area between pedestrian and driver due to parking bus, the imperfect installation of bus station nearby crossroad and crosswalk nearby the pillar of high elevation are analyzed, and the minimum distance between crosswalk and bus station will be given.

Investigation

The investigation in the influence of urban crossroad facilities on pedestrian safety is carried on from February to June in 2006. The pedestrian behaviors of traffic law violations are surveyed by manual work. The surveying period is on the daytime from Monday to Friday, and the weather is no raining.

To research the character of the pedestrian traffic law violations in twice-crossing intersection, there are three assumptions. The assumptions are as following:

1. The non-vehicle lane is figured out the total vehicle lanes because pedestrians should cross the non-mobile and vehicle lanes safely when she/he decides to cross the crossroad from the sidewalk.
2. Based on traffic safety laws, the pedestrian violates the traffic safety laws when pedestrian signal light turns red no matter whether she/he still enters the non-mobile lane or stops the crossroad and interrupts the cycles and vehicles.
3. The time of yellow phase of pedestrian signal light is figured out the total green time.

To survey influence of width of pavement and the length of guardrail on character of pedestrian behavior, 16 pavements are investigated in Xu jiahui district in Shanghai, and the surveying items are concluded as follows.

1. The number of pedestrians traveling along the pavement is sum up two direction ways pedestrian flows. The number of pedestrians is recorded each ten minutes by manual work.
2. The number of pedestrians traveling outside the pavement is counting while counting the number of pedestrians traveling along the pavement.
3. The effective width of pavement is equal to practical width of pavement subtracting from the width of all objects occupying pavement.

Results

The five types of twice-crossing intersection in Shanghai are classified and shown in figure 1.

Based on the figure 1, the important factors impacting the pedestrian traffic law violations are the number of vehicle lanes, the pedestrian waiting time, the width of pavement and length of guardrail between pavement and non vehicle lane.

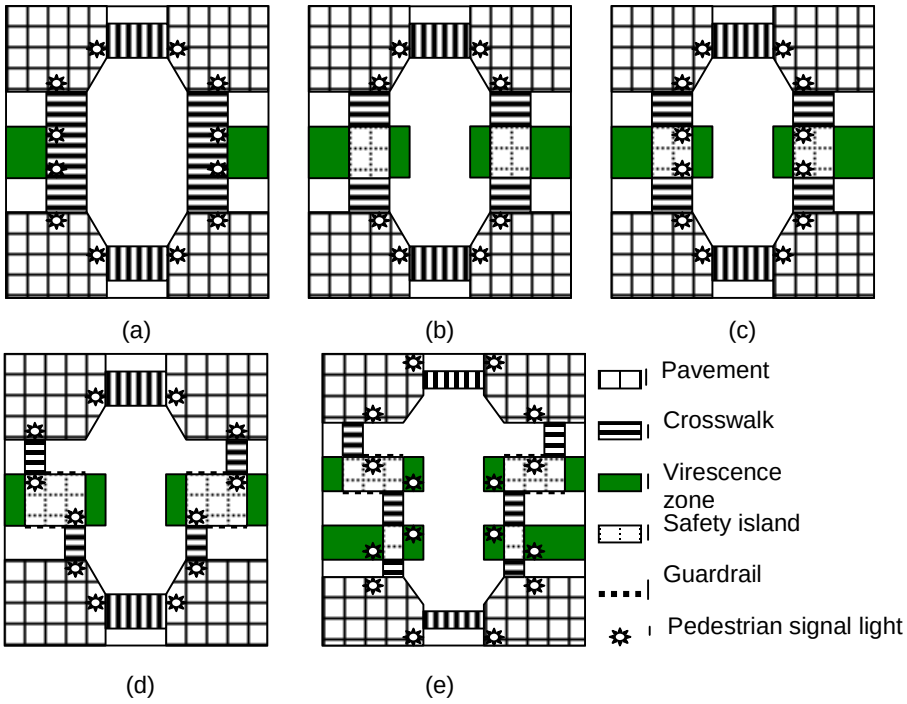

Figure.1 five types of twice-crossing intersection

Number of vehicle lanes

The wider the road becomes, the more number of vehicle lanes pedestrian would cross. The number of vehicle lanes impacts on times of the pedestrian crossing intersection and the vehicle speed. Considering the degree of traffic safety education and the estimation capacity of dangerous situation, the pedestrian will judge whether or not she/he crosses the intersection. The relation between the number of vehicle lanes and the RTLV is shown in figure 2.

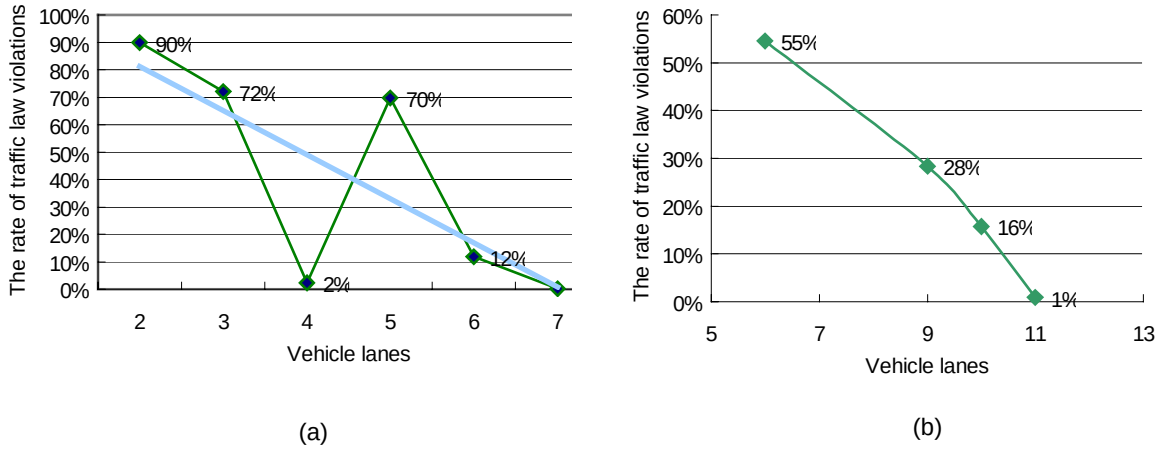

Figure 2 the relation between the number of vehicle lanes and the RTLV

The pedestrian should spend two times on crossing the twice crossing intersection through the safety island or virescence zone. In figure 2(a), the number of vehicle lanes is the number of vehicle lanes crossing the intersection once time separately. In figure 2(b), the number of vehicle lanes is total mount of vehicle lanes twice crossing the intersection. The tendency is the decreasing relation between the amount of vehicle lanes and the RTLV.

Pedestrian waiting time

The relation between waiting time and the RTLV is shown in figure 3.

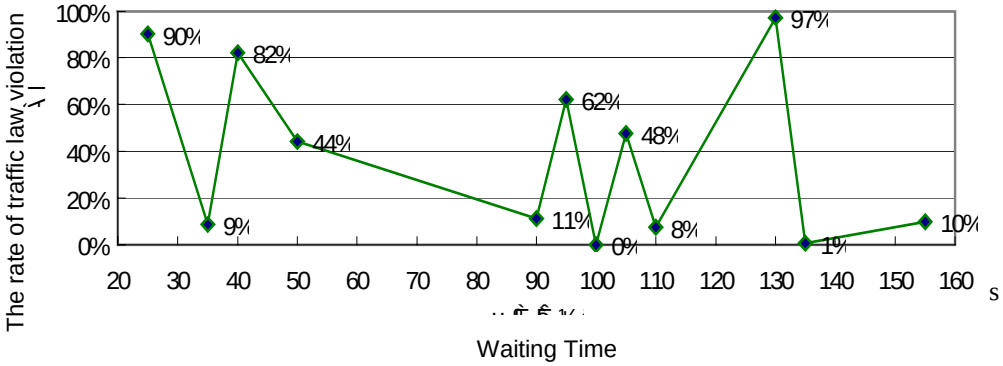

Figure 3 the relation between waiting time and the RTLV

The tendency of the relation is almost decreasing within 90 seconds. But there is not obvious tendency when the waiting time is more than 90 seconds.

Width of pavement and length of guardrail

To eliminate the influence of guardrail between pavement and non-mobile lane on character of pedestrian behavior, the different widths of pavements without guardrail are investigated. There is the using rate of pavement definition.

$$\text{the using rate of pavement} = \frac{a}{a+b} \times 100\%$$

In the above formula, variable 'a' stands for the number of pedestrians traveling along the pavement. Variable 'b' stands for the number of pedestrians traveling outside the pavement. The relation between the using rate and the effective width of pavement is shown in table 1.

Table 1 the relation between the using rate and the width of pavement

Surveying section of pavement	the using rate of pavement	the effective width of pavement (m)
East of Gongcheng Road	73.8	1.4
West of Gongcheng Road	47.4	0.9
East of Huashan Road	97.2	2.4
West of huashan Road	99.4	3.6
North of Puhuitang Road	96.5	2.1
South of Puhuitang Road	80.3	1.2
Wanping Road	98.1	1.9
Guangyuan Road	87.6	1.6

To research the guardrail impacting pedestrian behavior, different length guardrail pavements are surveyed. The relation between the using rate of pavement and the length of guardrail is shown in table 2.

Table 2 the relation between the using rate and the length of guardrail

Surveying section of pavement	the using rate of pavement	the length of guardrail (m)
The North of Caoxi Road	90.8	36
The West of Guangyuan Road	93.6	73
Hengshan Road	99.3	30
Huashan Road	91.1	21
Hongqiao Road	97.2	87
The West of Jianguo Road	91.3	40
The North of Nandan Road	94.7	64
The South of Nandan Road	89.6	52

The correlation coefficient between the using rate of pavement and the width of pavement is 0.74. The correlation coefficient between the using rate of pavement and the length of guardrail is 0.33. That demonstrates improvement the width of pavement have more effective impacts on pedestrian using pavement and to protect pedestrian safety from dangerous bicycle and vehicle flows while there is complex relation between the using rate of pavement and the length of guardrail.

Blind area

The five types of twice-crossing intersection are often designed under the high elevation in Shanghai. Due to the impact of pillar of high elevation shown in figure 4, incorrect crosswalk installation shown in figure 4(a) produces blind area for driver and pedestrian, and imposes the pedestrian on very dangerous traffic situation. In figure 4(b), improving crosswalk installation and adding guardrail eliminate the blind area for driver and pedestrian.

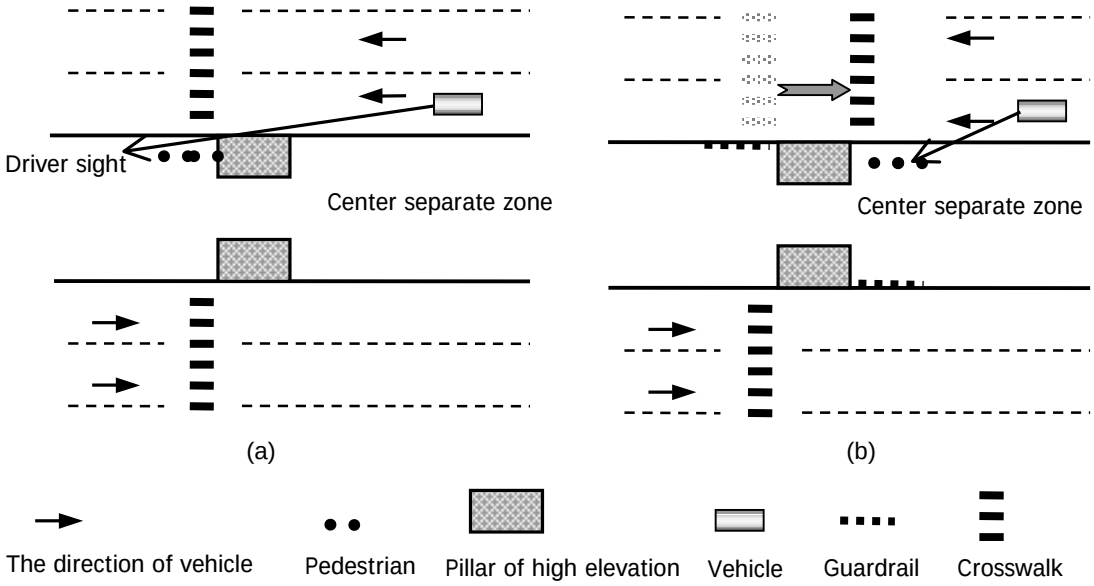

Figure 4 the installation of crosswalk under high elevation

There are three types of bus station installation nearby intersection shown in figure 5. Because of parking bus, there are two blind areas in figure 5(a), while there is a blind area in figure 5(c) when pedestrian crosses the intersection along crosswalk. In figure 5(b), though the blind area is eliminated, how far distance between crosswalk and bus station is more safety to pedestrian?

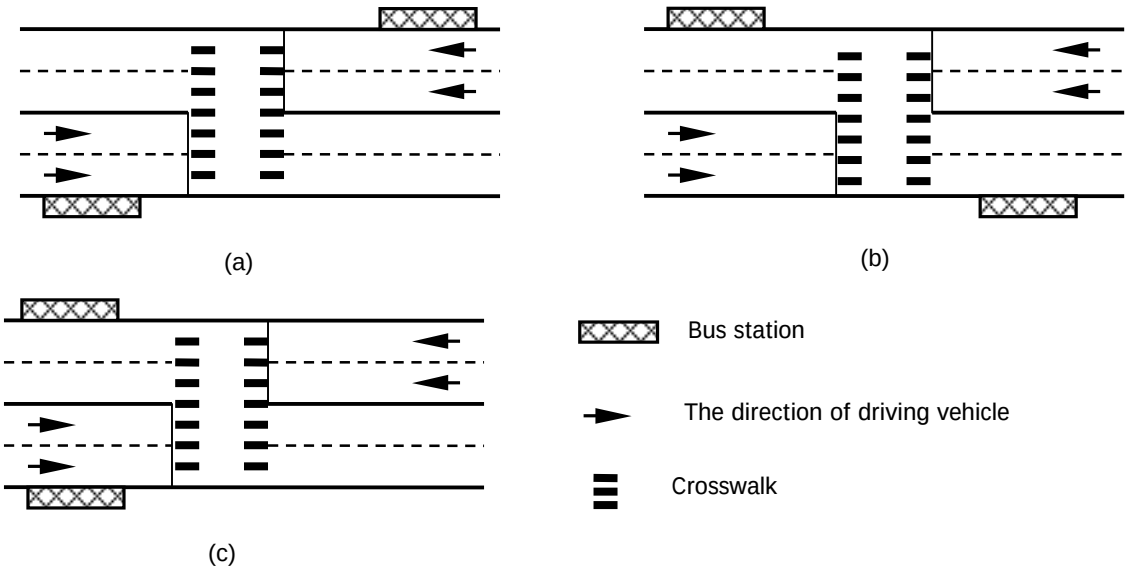

Figure 5 three types of bus station installation nearby intersection

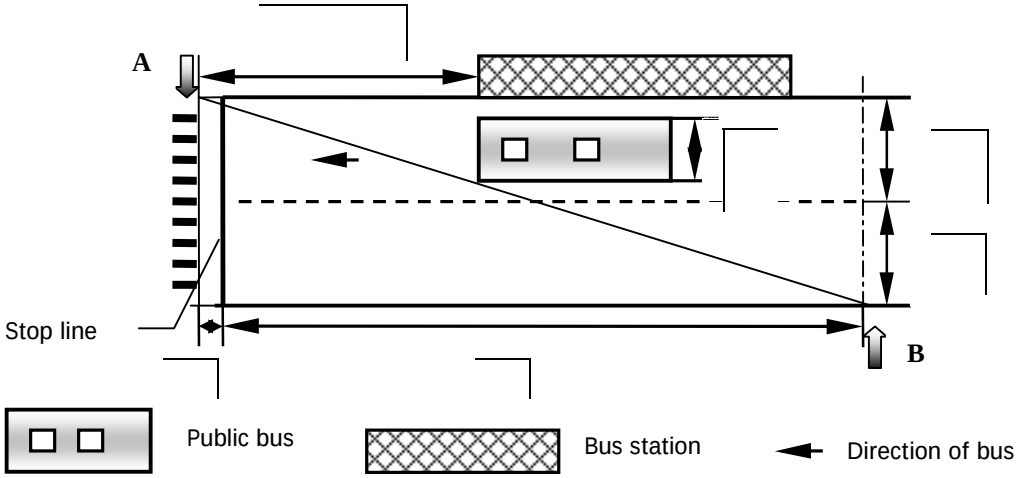

Figure 6 minimum distance between crosswalk and bus station

In figure 6, variable L_1 is stopping distance. Stopping distance is defined as the minimum distance between the place in which driver finds the obstacle objective and the place where vehicle stops just before obstacle objective, such as stop line in figure 6. Constant L_2 is safety distance for pedestrian after vehicle stopping (m) (in common it is 1).Variable $L_{\min}$ is minimum distance between crosswalk and bus station which is safety distance for pedestrian. Constant D_1 is width of vehicle lane (m). Constant D_2 is width of bus (m). Point A and point B are the eye places of pedestrian and driver. The upper area of the line AB is the blind area for pedestrian and driver due to the parking bus.

$$L_1 = \frac{Vt}{3.6} + \frac{V^2}{254(\phi + \psi)}$$

In the formula, Variable V is speed of vehicle (km/h). Constant t is reaction time (s). Reaction time would prolong when driver is fatigue. Constant ϕ is the friction coefficient. Constant ψ is road resistance coefficient.

Based on figure 6,

$$\frac{L_{\min}}{L_1 + L_2} = \frac{\frac{D_1 - D_2}{2} + D_2}{2D_1}$$

$$L_{\min} = \frac{(D_1 + D_2)(L_1 + L_2)}{4D_1} = \frac{(D_1 + D_2)(\frac{Vt}{3.6} + \frac{V^2}{254(\phi + \psi)} + L_2)}{4D_1}$$

To given traffic environment, controlling vehicle speed and prevention driver fatigue are too important factors impacting on the minimum distance between crosswalk and bus station. The two measures are of great benefit to pedestrian traffic safety.

Discussions

With the economic developing rapidly, Shanghai more and more becomes an attractive place for people from whole country, even some place of the world. So more and more people flush into Shanghai to work, travel, and shop. Though the municipality invests huge expense on improving transportation infrastructures, the speed of increasing traffic demands is faster than the speed of traffic supplies. So the government pays more attention to solve the problem of citizens' demands of traffic through taking many measures, such as building subways, broadening the road, setting up the high elevations, scientific traffic control. From the view of solving traffic demands, the government has got some effects. But from the view of priority of safeguard for vulnerable road user, there are some defects in urban traffic facilities. Now there is lack of the process of road safety audit in Shanghai. The twice-crossing intersection is more common intersection in Shanghai. Through investigation the character of pedestrian traffic law violations, more safeguard measures for pedestrian could be concluded.

The higher number of vehicle lanes is, the lower RTLV is. If there is more number of vehicle lanes, the speed of vehicle becomes higher, and the time of pedestrian crossing intersection becomes longer. The high speed vehicle makes pedestrian more careful before her/his decision to cross intersection. But the high speed vehicle threatens the pedestrian safety when crossing intersection, especially for pupils or elders. To existing road, it is impossible to change the number of vehicle lanes to supply more safeguards to pedestrian. In the other hand, there is not enough time to fulfilling crossing intersection for pedestrian. Many vehicle lanes make the phases of traffic light more complicated. The urban road designer should consider deeply the contradiction between traffic capacity and pedestrian safeguard. In high volume pedestrian places, such as shopping center, school and university campus, and hospital, the road should not be wider. In other words, these places should not build nearby the large number of vehicle lanes.

Perfect facilities could bring more effect on pedestrian safeguard. It is very difficult and limited by the practical traffic environment to improve the number of vehicle lanes and the safety island, and improving them should invest huge expense. It is long time to change pedestrian behavior of obeying traffic law through education. So improving pedestrian signal light and guardrail are the best ways to protect pedestrian from traffic law violations and dangerous traffic situations.

The state of pedestrian behavior crossing the intersection on the crosswalk is divided two states. One state is obeying traffic laws. Another state is violating traffic laws. So based on the influence of pedestrian behavior on whether obeying or violating traffic laws, the safety evaluating coefficient (SEC) is given 1 or 0. In common, if there are pedestrian signal light, guardrail and safety island in intersection, the SEC is given 1, or else given 0. Based on

figure 1(a), the rate of traffic law violation (RTLV) is almost negative linear decreasing with the number of vehicle lanes increasing. When the number of vehicle lanes is 7, the RTLV is 0, so in that case the SEC is given 1. The other SEC is defined as the number of vehicle lanes divided by 7. The RTLV is higher when pedestrian cross the twice-crossing intersection starting from the separate zone, such as safety island, while the RTLV is lower when starting from sidewalk. So SEC is given 1 when pedestrian cross the intersection starting from sidewalk, or else given 0.

The ISEC comprises of five factors, including pedestrian signal light, guardrail, safety island, number of vehicle lanes and whether starting from sidewalk. The relation between the RTLV and the ISEC is shown in table 3. The correlation coefficient between RTLV and ISEC is -0.62. So perfecting the urban traffic facilities could improve pedestrian safeguard situation.

Table 3 the relation between RTLV and ISEC

RTLV	0.00%	0.00%	0.14%	0.15%	0.29%	0.66%	1.27%	3.73%	7.27%	10.00%
ISEC	5	4.57	2.71	2.57	4	2.57	3.57	3.86	2.86	3.57
30.65%	31.25%	42.59%	44.05%	62.12%	75.54%	84.78%	85.41%	89.88%	97.22%	100.00%
3.43	2.57	2.71	3.86	2.71	3.43	1.71	2.43	2.29	2.43	1.71

Conclusions

The urban crossroad facilities mainly comprise vehicle lanes, crosswalk, pavement, safety island, pedestrian signal light, and other facilities nearby crossroad such as bus station and pillar of high elevation. Based on investigation of crossroad facilities and analyzing blind area, there are some conclusions following as below.

1. The more number of vehicle lanes there are at crossroad, the more time pedestrian will wait for, and the less RTLV there is. The reasonable time which pedestrian waits for is 90 seconds. The width of pavement has more effective impacts safeguard on pedestrian traveling along pavement than guardrail of pavement.
2. From the view of pedestrian safety safeguard, the blind area is most important fact when the bus station nearby crossroad and crosswalk nearby the pillar of high elevation are designed, and the minimum distance between crosswalk and bus station is given.
3. ISEC evaluates the perfect degree of crossroad facilities, and RTLV evaluates the pedestrian safety situation. The RTLV of pedestrian decreases when the ISEC of crossroad increases.

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