RESEARCH ON SETTING OF AT-GRADE PEDESTRIAN CROSSING FACILITIES IN SHENZHEN, CHINA

Keman Wu  
Research Institute of Highway, Ministry of Transportation  
100088 BEIJING China  
E-mail: km.wu@rioh.cn

Chengcheng Tang  
Research Institute of Highway, Ministry of Transportation  
100088 BEIJING China  
E-mail: cc.tang@rioh.cn

Dezao Hou  
Research Institute of Highway, Ministry of Transportation  
100088 BEIJING China  
E-mail: dz.hou@rioh.cn

Ming Jiang  
Research Institute of Highway, Ministry of Transportation  
100088 BEIJING China  
E-mail: m.jiang@rioh.cn

ABSTRACT
Intense research on at-grade pedestrian crossing facilities in Shenzhen is made in this paper. According to the present situation in Shenzhen, the ideas and suggestions to settings of intersections and central refuge islands for twice-crossing pedestrians are given to make contributions to subsequent urban planning in Shenzhen and to provide references for the revision of related standards.

1 OVERSEAS AND DOMESTIC RESEARCH STATUS

1.1 Overseas Research Status
The rapid development of automobile industry and the acceleration of urbanization make the problem of conflict between pedestrians and vehicles in modern cities become more serious. Roger Johansson from Gothenburg Road Department in Sweden has given the setting method of humanized, accessible Pedestrian crossing facilities in the book “Streets for Everybody”. It includes traffic signal lamp, pedestrian crossing facilities without traffic signals, positions of crossing street without zebra crossings etc.. Mohammed S. Bowman, BL and vecellio RL(1994)
analysis the accident of 32894 vehicles and 1012 pedestrians on 3 urban main streets and study the effects of different types of central refuge islands in pedestrian facilities on vehicles and pedestrian safety. King, MR et al. analysis the effects of facilities like central raised islands, traffic signal lights, zebra crossings etc. on the speed of vehicles, danger level of pedestrians’ exposure in traffic through quantitative approach like measuring speed, volume etc and qualitative approach like shooting video, comparing photos etc.. The research result indicates that these pedestrian facilities can make speed of 85% vehicles drop 2mPh, and then make the danger of pedestrians’ exposure in traffic drop 21%. V.P. Sisiopiku(2003) observed the behavior of pedestrians’ crossing street on all kinds of zebra crossings and the situation of using these facilities. The situation of pedestrians’ using crossing facilities is analyzed through video materials. 83% pedestrians cross street prioritizing zebra crossing on road sections without signal control. It is indicated that the setting position and using situation of zebra crossings are effected by pedestrians’ starting and destination points. Walls of trees and concrete barriers can have effect on pedestrians’ choosing zebra crossings. Kay Fitzpatrick, Shawn Turner et al. evaluated pedestrian crossing facilities through the survey of pedestrians’ requirements and experiences on crossing streets. They analyze the safety of pedestrians’ crossing street on zebra crossings without signals. They propose that the safety of pedestrians’ crossing street on the intersections with high volume and high vehicles’ speed without signals can be improved through setting facilities like central refuge island etc.. Baltes establishes in “Pedestrian Level of Service For Midblock Street Crossings” the mathematical method of service level evaluation of pedestrians’ crossing street on road sections and aims at improving safety, convenience and quickness of pedestrians’ crossing street on road sections.

1.2 Domestic Research Status
In China, the research on pedestrian crossing facilities starts relatively late. Since the 1980s the scholar Duan Liren started the research on the aspect and achieved good results on intersections, traffic characteristic of pedestrians on road sections, pedestrian traffic safety and design of signal system for pedestrian crossing. Feng Shumin et al. (2004) investigated 42 zebra crossings on 11 intersections in Ha’erbin and get the overall average speed of pedestrians’ crossing street 1.47m/s and analyzed the effect of age and sex of pedestrians, the length of zebra crossings, the number of pedestrians crossing streets, green time etc. on the speed of pedestrians’ crossing streets. Ministry of construction of the People’s Republic of China has in 1996 promulgated “technical specification on urban pedestrian overpass and pedestrian underpass” (CJJ69-95), which plays a guiding role for the plan and construction of pedestrian overpass and pedestrian underpass. By the end of 2001 Traffic planning institute of Guangzhou planning bureau has established “the implementation plan of pedestrian crossing facilities in Guangzhou”, which puts forward a series of suggestions on the plan, construction, and management etc. of pedestrian crossing facilities in Guangzhou. Lu Jian et al. (2002) has put forward the recommended value of corresponding pedestrian crossing facilities’ reasonable
interval based on the analysis of pedestrian traffic characteristics. Jiao Leizhi (2004) summarized stereo and at-grade pedestrian crossing facilities fully, and studied in-depth the approach of adding central refuge islands and setting pedestrian crossing signal lamps on the most common pedestrian crossing facilities, zebra crossings, and expounded the roles, characteristics, applicable conditions and effects on the safety of pedestrians and vehicles. By the end of 2007, Shanghai municipal project administration combining with the real situation of pedestrian crossing facilities on main streets in Shanghai has promulgated “planning guidelines of pedestrian crossing facilities on main streets in Shanghai” (SZ-C-B03-2007), in which layout, design of crossing facilities on intersection on main roads, design of at-grade crossing facilities on main road sections, design of at-grade crossing signal facilities on main roads etc. are normalized.

2 ANALYSIS OF CURRENT SITUATION
Traffic planning data in every major city indicates that 40% of trips in China are made by pedestrians, but in medium-sized cities 50%, small cities up to more than 60%. The high volume of pedestrians will be bound to escalate the conflict between vehicles and bicycles and pedestrians. By October 2012, there are 4227 road traffic accidents involving casualties because of running a red light in China, which lead to 798 deaths. So you can see that at a national level rational planning and improvement of pedestrian crossing facilities is looming ahead.

With the development of traffic safety in Shenzhen, the safety of pedestrians as disadvantaged groups is cared by more and more people. Meanwhile the economic development promotes the growth of population and vehicles. Traffic in Shenzhen faces huge challenges. How to solve the conflict between vehicles and bicycles and pedestrians on broad roads becomes one of the biggest research topics. Pedestrian crossing facilities as an organic part of traffic safety facilities play a crucial role on solving above conflict reasonably and are one of the facilities to be improved urgently in Shenzhen. In the following left picture, a crossing tunnel is used by vehicles, pedestrians and the vendor illegally together, which makes a great drop of capacity of the crossing tunnel, and pedestrians have to give way to vehicles, which does not accord with the rule of protecting disadvantaged groups, and also damages city scene; similarly, in the following right picture, in bustling city lots with high pedestrian density the at-grade crossing facility is disadvantaged to traffic safety, and also makes the vehicles’ capacity of the road drop greatly.
3 SETTING OF PEDESTRIAN CROSSING FACILITIES

It is learned through discussions and investigations that vehicle phases and pedestrian phases at most intersections in Shenzhen are separated, and all-red phases for vehicles are set at parts of intersections in Shenzhen, which embody the humanized concept. However, two problems are to be solved for at-grade crossing facilities: the first is the conflict between pedestrians and right-turning traffic at a small number of intersections, the second is the setting of central refuge islands for pedestrians’ twice crossings.

3.1 Setting of at-grade intersections

(1) The setting example of at-grade intersections (intersections with signal control) in Shenzhen is shown in figure 2. At the Pedestrian crossing point, level differences between roadway and footway should be set through curb ramps, which makes the crossing streets easy for pedestrians using wheel chairs, pushing a pram, and carrying a big luggage. And curb ramps should not be set at curves of intersections, but at straight sections, because ramps on curve sections go against the orientation for blind persons’ crossing streets.
(2) Intersections without signal control and intersections with conflict between right turning vehicles and pedestrians should be set with smaller turning circle to increase the difficulty of vehicles turning, and to reduce their turning speed, which benefits pedestrians’ prior crossing streets. The setting of turning circles should satisfy the request of large vehicles’ turning.

3.2 Setting of Central Refuge Islands for At-grade Twice-Crossings
For road sections with signal control the basic principle for setting twice-crossing facilities is that pedestrians cannot finish crossing in one time or have difficulties in finishing crossing in one time in the green time. The reasons of pedestrians’ twice-crossing contain green time for pedestrians’ crossing, width of roads, number of lanes, and speed of pedestrians.

For road sections without signal control the basic principle for setting twice-crossing facilities is that pedestrians cannot or hardly to find gaps of vehicles to finish crossing in one time. The reasons of pedestrians’ twice-crossing contain number of lanes, width of roads, speed of pedestrians, and volume of vehicles.

Central refuge islands should be set for at-grade twice-crossings. The setting of central refuge islands should satisfy:

(1) it is shown in the questionnaires of pedestrians in Shenzhen that more than 60% of pedestrians think the width of central refuge islands more than 2m, which is
shown in figure 3. So combined with the questionnaires, discussion, and related
references the width of central refuge islands for pedestrians’ crossing at new
intersections in Shenzhen should be more than 3m, and at least 2m; the width of
central refuge islands for pedestrians’ crossing at reconstructed and managed
intersections should be at least 1.5m; the length of central refuge islands
depends on the number of pedestrians standing on it.

Figure 3: the minimal width of central refuge islands

The area of central refuge islands is decided by formula 1:

\[ S = \frac{P \times s \times C}{3600} \]  

(Formula 1)

Among them, \( S \) is the area of central refuge islands \( (m^2) \), \( P \) is predicted or actual pedestrians
traffic at peak hours \( \text{person times/h} \), \( C \) is the period of signal of the green light for pedestrians
\( (s) \), and \( s \) is the area occupied by a pedestrian \( (m^2/\text{person}) \), chosen from table 1 below, based on
the level of service,

<table>
<thead>
<tr>
<th>Service level</th>
<th>Area occupied by pedestrian ( (m^2/\text{person}) )</th>
<th>Explain</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>( \geq 1.21 )</td>
<td>can stand on or freely pass through queue area without bothering other queuing people</td>
</tr>
<tr>
<td>B</td>
<td>0.93~1.21</td>
<td>can stand on or do limited activities without bothering other queuing people</td>
</tr>
<tr>
<td>Service level</td>
<td>Area occupied by pedestrian (m²/person)</td>
<td>Explain</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>C</td>
<td>0.65~0.93</td>
<td>Can stand on and do limited activity of passing through queue area, which will bother other queuing people. The density is still in the range of comfort.</td>
</tr>
<tr>
<td>D</td>
<td>0.28~0.65</td>
<td>It is possible to stand without touching others. Moving in queue area will be very limited. Only moving ahead with the crowd is possible. Waiting for a long time in the density is very uncomfortable.</td>
</tr>
<tr>
<td>E</td>
<td>0.19~0.28</td>
<td>It is unavoidable while standing and impossible to move in queue area. Queuing in the density can only last for very short time, otherwise people will feel very uncomfortable.</td>
</tr>
<tr>
<td>F</td>
<td>≤0.19</td>
<td>It is unavoidable while standing and impossible to move in queue area. Pedestrians feel rather uncomfortable in the density. There will be potential panic among the crowds.</td>
</tr>
</tbody>
</table>

It is suitable for the service level to be designed at Level C or Level D. Table 2 lists the values of S corresponding to different values of C and P when the service level is between C and D (s=0.65m²/person).

Table 2: proposed areas for central refuge islands

<table>
<thead>
<tr>
<th>P (person/h)</th>
<th>3000</th>
<th>4000</th>
<th>5000</th>
<th>3000</th>
<th>4000</th>
<th>5000</th>
<th>3000</th>
<th>4000</th>
<th>5000</th>
</tr>
</thead>
<tbody>
<tr>
<td>s (m²/person)</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
</tr>
<tr>
<td>C (s)</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>S (m²)</td>
<td>20</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>50</td>
<td>70</td>
<td>80</td>
</tr>
</tbody>
</table>

(2) for road having a medial divider, the medial divider can be used for setting central refuge islands, and the width of the central refuge islands equals to the width of the medial divider.

(3) for road without medial divider, when being reconstructed and managed, the central refuge islands can be set by following the steps below:

① it is known from the discussion with traffic polices in Shenzhen that when the vehicles going straight and turning left at intersections are separately in different lanes, the central refuge islands can be reconstructed using the space, through which the vehicles going straight don’t pass. Above is a relatively common method of reconstructing central refuge islands in Shenzhen, which is shown in figure 4.
Considering the rich groundwater resources in Shenzhen, it is inconvenient to move the underground pipelines. If the direction of the underground pipelines at intersections is unknown and it is inconvenient to change route of them, one of the approaches can be used to reconstruct the central refuge islands, and the line markings should be delimited, when necessary, isolation lairages should be set, which is shown in figure 5. The results of this method have been accepted by traffic management department of ministry of public security in Shenzhen. The method adjusts measures to local conditions with characteristics of special economic zones.
After reconstruction

Figure 5: before and after comparison diagram of the reconstruction of central refuge islands by occupying the space of one of the approaches

(4) In the range of central refuge island for pedestrians’ crossing, the ground elevation for pedestrians’ passing through and standing on should be the same with grade elevation. The end range of central refuge islands should be designed as island structure, which is at least 15cm higher than road surface. The width of the end range of central refuge island should be 1m, and anti-collision barrels should be set on them. Reflective or luminous facilities should be set on their end ranges. If drivers are in the situations of bad visual field or overspeed at bends of road sections, they will probably rush on the central refuge islands. So, the traffic safety facilities like line markings, crash bearers, warning stakes etc. should be set rationally to guide vehicles to avoid the central refuge islands smoothly. The setting of the central refuge islands has no effect on the normal running track of vehicles through rational design of road alignment and traffic operation and management. On the range of central refuge islands, where pedestrians pass through, safety warning posts with the radius of 10-15cm should be set. One of the reasons to set safety warning posts is to prevent vehicles
stray into the central refuge islands. So, their interval should not more than a vehicle’s width and be 1.6m. The other reason is that pedestrians can lean on them with elbow for their convenience while standing and waiting. So, their height should be the height of people’s elbows and be 1-1.2m. It is shown in figure 6.

\textbf{Figure 6: an example for setting of central refuge islands}

(5) The misalignment setting of zebra crossings is common abroad, which can be seen in road sections without signal control. Pedestrians’ crossing streets often happen in China. The method letting pedestrians go a few steps against traffic and then cross the street for the second time will amount to one more line of defense, which are more conducive to pedestrians’ crossing streets, and should be used widely. The misalignment setting of zebra crossings should guarantee pedestrians’ twice-crossing streets in the central refuge islands against traffic to find vehicles in the opposite direction in time. The misalignment setting of central refuge islands at road sections and intersections without traffic control is shown in figure 7. At huge intersections with signal control the misalignment setting of central refuge islands will reduce the volume of the intersections, and then have effect on their capacity. To make the area of central refuge islands optimal, the design of signal system for pedestrian crossing should always be used. So, at intersections with signal control the misalignment setting of zebra crossings should try to be avoided.
(6) When the conflict between pedestrians and right-turning vehicles at intersections with huge volume of right-turning vehicles becomes serious, channelizing islands should be set to separate the going-straight and right-turning vehicles. At intersections with channelizing islands the zebra crossings should be set through the channelizing islands, and the channelizing islands are set as central refuge islands for pedestrians’ crossings, which is shown in figure 8.

Figure 8: example for channelizing islands as central refuge islands

The design example of channelizing islands is shown in Figure 9.
Figure 9: design example of channelizing islands

4 SUMMARY AND FORECASTING

The in-depth research on at-grade pedestrian crossing facilities in Shenzhen is conducted in the paper according to the traffic characteristics of the economic special zone. Solutions for existing problems are raised, and contribution to city planning in Shenzhen is expected. Meanwhile, the setting of central refuge islands for pedestrians’ at-grade twice-crossing is elaborated in the paper. The proposed values of service levels and areas of central refuge islands for pedestrians’ at-grade twice-crossing are given. Concrete measures for adding central refuge islands aimed at Shenzhen’s characteristic are raised. Providing references for the revision of national, industry and regional standards is expected.

REFERENCES


Planning guidelines of pedestrian crossing facilities on main streets in Shanghai (SZ-C-B03-2007). Shanghai municipal project administration.