Pedestrian crossing patterns preference at a non-signalized crosswalk

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Abstract

At the non-signalized marked crosswalk, pedestrians cross the road with changing directions and speeds that result in curved paths and higher chances of safety issues. Analyzing this behavior is a complex task, which is often further limited by a lack of appropriate and detailed data. In this paper, Pedestrians’ crossing patterns in terms of entry/exit pairs and turning points were explored. And the reasons caused such curved patterns investigated. The analytical results indicated that the most influential factor that resulted curved patterns are: (a) short or fast distance (b) avoiding collision with grouping pedestrian crossing together from the same or opposite direction (c) avoiding traffic running straight on the lanes.

Keywords: Crossing patterns; Speed patterns; Speed transition point; Turning points

1. Introduction

Pedestrian safety is still one of the most important safety concerns nationwide \cite{1}. Pedestrians are particularly in danger when crossing the roads\cite{2}. Over 1.2 million people die each year on the world’s roads. Almost half (46\%) of those who die in road traffic crashes are pedestrian \cite{3}. Thus, the research on pedestrian crossing behaviour is the basic and important part for traffic engineering and safety planning. In literature, the crossing process of the
pedestrians divided into three different levels, namely, strategic level, tactical level and operational level [4]. At the strategic level, the pedestrian elaborates an agenda of activities; this level corresponds to off-road activities, i.e. decisions made before the trip [5]. The social force model [6] [7], and cellular automata are representative models of this category. The tactical level concerns of off-road and on-road decisions. Those decisions include activity scheduling, choice of activity area and route choice [5]. Gap-acceptance models have been applied to this situation [8] [9]. These models interpret whether pedestrians accept or reject the available gaps between vehicles while waiting at the roadside. The operational level shows how pedestrian adjust their direction to achieve the goals set at previous levels [10].This level corresponding to path choicedecisions or path preference. Compared to social force model and Gap-acceptance models, the studies about the preferences of pedestrians crossing are limited. For instance, a study was conducted by Chu et al [11] in the United in States; the data were obtained from pedestrians’ stated crossing preference and explained the stated preference with the street environment. Another study was conducted by Behrens [12] in South Africa; Pedestrian crossing choice on selected arterials and freeways in Cape Town has been investigated. The crossing choices were found strongly associated with the location of crossing facilities in relation to dominant pedestrian movement desire lines. Nassiri and Sajed [13] identified and evaluated the effective parameters in pedestrian’s path preference based upon vehicle speed and headway on multilane streets. In an exhaustive study carried out by Papadimitriou et al. [4], pedestrian path preference and road crossing behaviour had been assessed, it has been suggested that interdependence between path preference and crossing behaviour should be considered.

This paper aims at evaluating pedestrian crossing preference at a non-signalized marked crosswalk. To achieve this objective and to make our topic more focused, a Pedestrian Crossing Pattern concept, which refers to a situation when pedestrian faces multiple paths from a given origin to a given destination in a crosswalk have been introduced. A turning point-based method was applied to generate the preferred crossing patterns. A qualitative observation of 555 pedestrians was carried out at a non-signalized marked crosswalk. And the most influential factors that caused pedestrian curved pattern explored and discussed.

2. Materials and methods

2.1. Study area

In our study we chose a typical non-signalized marked crosswalk area encountering by two-way traffic, which is close to a bus station. In Fig. 1, the size of the marked crosswalk area is about 17.4m×6m, which covers four vehicle traffic lanes and two cyclist lanes. The width of Lane1, Lane2, Lane3 and Lane4 is 4m, 3.4m, 3.4m, and 4m respectively, while both of the cyclist lanes are 1 meter wide. And there is a 0.6m-width area for physical barrier between Lane2 and Lane3. The speed limit for vehicles in this area is 60 km/h.
2.2. Data collection

A camera was set to record the marked crosswalk area for 200 minutes between 10 a.m. and 2 p.m. in a weekday. The camera was placed on the roof (about 30 meters) of a residential building. Thus we can get pedestrians’ positional measurement and speed from the camera. This study decoded the collected videos into frames, and synchronized them manually. Based on the collected videos, this study identified the vehicles and pedestrians of these videos in manual.

In the collected videos, there are 5749 cars (61.38%), 617 buses (6.59%), 1384 motorcycles (14.78%), 186 bicycles (1.99%), 1262 pedestrians (13.46%) and 169 other types (ambulance, police car, gas tanker, etc.) (1.80%), and their locations were recorded by the time tags of video frames. This study selected 555 individual pedestrians who crossed this area in the directions of D3 and D4. D1 and D2 are the main traffic flow while D5 and D6 are the right-turn traffic flow.

2.3. Crossing patterns categorization

In Fig. 2, six zones were marked according to the geometrical features in the study area. Each zone is either entry (where pedestrian first step into the road) or exit (where pedestrian step from the road to opposite side) zone for each crossing pedestrian. A categorization of the pedestrian crossing patterns was conducted based on Entry/ Exit points.
and the shape of the trajectories. We defined “turning points” to determine the start position of the pattern adjustment (start of turning) in each a trajectory. In Fig. 2, the red lines represent one of the crossing patterns and the black dots represent the turning point in each pattern.

3. Results

3.1. Spatial layouts of representative crossing trajectories under different crossing patterns

Crossing patterns refers to a situation when a pedestrian faces multiple paths from entry to exit in a crosswalk. Generally, pedestrians’ lateral positions at crossing sites are not as confined, resulting in very autonomous trajectories. These patterns are shown with a connection line between Entry/Exit zones on the crosswalk. The analysis revealed two types of patterns: curved patterns and incurved patterns. The pedestrians with incurved patterns arrived at a point right straight toward their destination (e.g. B(F) entry, F(B) exit), they could follow shortest and safest pattern. There were 108 pedestrians observed with incurved crossing patterns. These pedestrians used zebra lines from entry to exit and cross in perpendicular pattern. Curved patterns pedestrians were not so lucky to arrive at such points (e.g. A(F) entry, F(A) exit), they ended up suffering higher risks. In that case, they could follow one of nine tortuous long patterns than the straight short patterns. There were 447 pedestrians observed with curved patterns. Since the patterns varied greatly with situations, a categorization of the pedestrian patterns was conducted based on entry point and exit point and turning points as mentioned before. The iteration of classification ended up with nine patterns types.

Fig. 3 exhibits the main nine patterns of curved patterns that recorded during the qualitative observation, where the red curve represents the optimal crossing pattern that should pedestrians follow to reach the destination. The percentages of the pedestrian for crossing patterns detailed in Table 1, where most of the pedestrian preferred BE/EB pattern (25.95%).

![Fig. 3.Illustration of curved crossing patterns and legal sequences.](image-url)
3.2. The distance saved by choosing curved crossing patterns

It has been found that pedestrians prefer to cross first and walk later[11]. For example, if the origin is in zone C and the destination is in zone D, pedestrian wouldn’t cross using the legal zone’s sequences which are C-B-E-D (the green lines in Fig 3) and cross within curved pattern. The result can be explained by the fact that the pedestrian can save distance, and they may miss a proper crossing location if they keep going. The analytical result shows that 88.65% from crossing pedestrian saved distance. Theoretically, the shortest path is a direct line from entry to exit, thus the percentage of saved distances can be calculated us:

\[ D_{\text{real},i} = \sum_{i=2}^{n} \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2} \]  

\[ D_{\text{expected},i} = \min D_{\text{entry} \rightarrow \text{exit}} \max \left( \text{card}(x_i, y_i) \in \text{Zebra} \right) \]  

\[ \text{Percentage} = \frac{D_{\text{real},i}}{D_{\text{expected},i}} \]

\( D_{\text{real},i} \) is the sum of the Euclidian distance between two adjacent point in \( T_i \).

\( D_{\text{expected},i} \) is the minimum distance for pedestrians to cross legally using the zebra in a way most of points in \( T_i \) should be in the zebra.

Table 2 exhibitsthe percentage (calculated by Equation (1)(2)(3)) of distances saved for all curved crossing patterns. The higher percentage of distance saved was found in the pattern CD/DC (19.78%). While the lower percentage was found in the pattern AE/EA (5.32%). However, about 11% from curved pattern pedestrians involve errors of distance perception and walk longer than if they walk in the expected sequence.

Table 2. The percentage of distances saved for crossing patterns.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>AD/DA</th>
<th>AE/EA</th>
<th>AF/FA</th>
<th>BD/DB</th>
<th>BE/EB</th>
<th>BF/FB</th>
<th>CD/DC</th>
<th>CE/EC</th>
<th>CF/FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>3.08%</td>
<td>2.18%</td>
<td>15.35%</td>
<td>15.25%</td>
<td>8.31%</td>
<td>8.75%</td>
<td>19.78%</td>
<td>20.77%</td>
<td>15.13%</td>
</tr>
</tbody>
</table>

3.3. Waiting time and crossing patterns

Table 3 shows the pedestrians total waiting time related to each pattern. Commonly, pedestrian wait before crossing, at the median and may wait between lanes or at any point on the road. Pedestrians with AE/EA pattern had the longest waiting time (5.45 seconds). While pedestrians with pattern AD/DA had the shortest waiting time (5.45 seconds).

Table 3. Total waiting time for each pattern.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>AD/DA</th>
<th>AE/EA</th>
<th>AF/FA</th>
<th>BD/DB</th>
<th>BE/EB</th>
<th>BF/FB</th>
<th>CD/DC</th>
<th>CE/EC</th>
<th>CF/FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting Time (s)</td>
<td>5.45</td>
<td>12.38</td>
<td>8.16</td>
<td>8.86</td>
<td>9.26</td>
<td>11.44</td>
<td>8.26</td>
<td>7.84</td>
<td>11.77</td>
</tr>
</tbody>
</table>
4. Discussion

4.1. Reasons for pedestrians to choose different crossing patterns

Table (3) shows eight potential factors that might incentive the pedestrians to choose the curved crossing pattern. Thus the total number of reason in Table 3 more than the number of the pedestrians as they may change or adjust their crossing pattern more than one time during crossing.

Table 3. List of the Reasons curved crossing patterns.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Direction</th>
<th>D3</th>
<th>D4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forcied by the traffic flow of the same direction</td>
<td>19 (7.31%)</td>
<td>18 (6.72 %)</td>
<td></td>
</tr>
<tr>
<td>Avoiding collision with grouping pedestrian crossing together from the opposite direction</td>
<td>36 (13.85 %)</td>
<td>13 (4.85 %)</td>
<td></td>
</tr>
<tr>
<td>Avoiding collision with pedestrians waiting at the edge of the zebra</td>
<td>2 (0.77 %)</td>
<td>14 (5.22 %)</td>
<td></td>
</tr>
<tr>
<td>Avoiding collision with the right turning vehicles</td>
<td>2 (0.77 %)</td>
<td>11 (4.10 %)</td>
<td></td>
</tr>
<tr>
<td>Avoiding traffic running straight on the lanes</td>
<td>2 (0.77 %)</td>
<td>2 (0.75 %)</td>
<td></td>
</tr>
<tr>
<td>Shorter distance</td>
<td>185 (71.75%)</td>
<td>183 (68.28 %)</td>
<td></td>
</tr>
</tbody>
</table>

Other reasons

1. pedestrian Following | 14 (5.38%) | 27 (10.07 %)
2. avoiding illegal stopped cars on the zebra

Total | 260 | 268

4.1.1. Short or fast pattern

The most important factor was the shortest or fastest distance. Pedestrian would not be willing to walk more than a short distance out of their destination. The need to hurry or the desire to keep moving along the shortcut might be the main subjective reason behind the curved patterns. As shown in Table, the crossing patterns of 71.15% of D3 pedestrians and 68.28% of D4 pedestrians were the shortest distance to the desired destination.

4.1.2. Avoid other pedestrians

Pedestrians avoid each other by anticipating when their paths would collide. The curved pattern of 13.85% and 4.85% of the crossing pedestrian on D3 and D4 respectively were to Avoiding collision with grouping pedestrian crossing together from the opposite direction. Some of pedestrians adjust their crossing patterns to avoid collision with pedestrians waiting at the edge of the zebra or Forcied by the traffic flow (pedestrians or motor cycle) of the same direction.

4.1.3. Vehicle avoidance

Usually, pedestrians at signalized crossing sites just follow the regulation and go toward their destinations. The path choice in the rule-following behaviours is very simple. In contrast, at the non-signalized crosswalk, pedestrians force to swerve to void conflicting objects and update their planed path when necessary. They yield to vehicles by stopping or changing directions, which is evidenced by more tortuous long patterns than the straight short patterns. Accordingly, crossing using the incurved pattern seems to be a short-sighted choice in this situation. Pedestrians do not adopt it as they can make predictions of vehicle positions based on their estimated speed and distance to avoid potential dangers.

4.1.4. Other factors

Pedestrian following is a common behaviour [14]. When pedestrians walk together in groups they must coordinate their walking speed and path preference with their neighbours [15]. Some pedestrian tried to avoid illegal stopped cars on the zebra which results in curved pattern. However, what pedestrians really are concerned with is
how to get to the destinations safely by adjusting their velocity. This means that, once pedestrians planed their destination, they no longer care about the crossing paths issue.

5. Conclusions

In this study, pedestrians crossing patterns at a non-signalized marked crosswalk have been analysed from entry to exit investigated for each crossing pedestrian. Based on our analysis, we can make the following conclusions:

1) Most of the crossing pedestrian (D3 = 71.15% and D4 = 68.28%) prefer short or fast patterns.
2) 88.65% from crossing pedestrian saved distance by using the curved patterns, while 11% of the pedestrian walk longer.
3) Other factors like avoiding collision with pedestrian or grouping pedestrian crossing together from the opposite direction or from the same direction also influenced crossing patterns preference.

Our findings have potential applications in development pedestrian’s model, and may facilitate further research into pedestrian crossing behaviour.

Acknowledgements

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References