Background

- Need for a more sustainable transportation system and higher demands for more active travel modes.
  - Need to increase cycling and walking.
- To encourage more walking trips, the provision of comfortable pedestrian facilities is paramount.
- In highway design, the pedestrian comfort level is normally indicated by the pedestrian level of service (PLOS) for a given roadway or facility.
  - PLOS determined by Highway Capacity Manual (HCM)
    - Originally developed for analyzing vehicle flow.
- The relationship between vehicle flow and vehicle level of service is quite different from the relationship between pedestrian flow and pedestrian level of service.

Objective of Study

- To develop a behavioral theory based procedure that incorporates the concept of personal space and evasive movements to determine the pedestrians' comfort and perceived levels of service for pedestrian facilities in commercial, residential and leisure areas.

Concept of Personal Space

Hall (1990)


**Concept of Personal Space**

If I can punch you in the throat without moving my feet, you’re in my personal space.

We assume that when a pedestrian feels that his or her personal space is encroached on, he or she will take evasive movements to protect that space. Therefore, the number of evasive movements will be used to capture pedestrian conflicts and level of discomfort.

If a pedestrian facility has a high average number of evasive movements undertaken by its users, we will assume that this facility will provide pedestrians with a low level of comfort and hence, should have a low level of service.

**Theoretical Model**

- We assume that when a pedestrian feels that his or her personal space is encroached on, he or she will take evasive movements to protect that space.
- Therefore, the number of evasive movements will be used to capture pedestrian conflicts and level of discomfort.
- If a pedestrian facility has a high average number of evasive movements undertaken by its users, we will assume that this facility will provide pedestrians with a low level of comfort and hence, should have a low level of service.
Methodology

- This research used two types of data:
  - Subjective data collected from a pedestrian questionnaire survey.
  - Objective data collected from video recordings.
- It collected these data twice:
  - Calibration sample (569 interviews and video recording at 28 sites)
  - Validation sample (216 interviews and video recording at 12 sites)

Measurement from Video Recording

- 468 samples of five minutes each.
- Both peak and off-peak periods.
- Sites: 8 residential, 15 commercial, 5 recreational
- Sidewalk widths: 3.1-10.0m.
- Flow: 3,400 - 9,025 ped/hour

Pedestrian Survey

- The pedestrians were asked to list the top two factors they considered as most important when rating the pedestrian facilities, including:
  - walking speed
  - number of pedestrian conflicts
  - continuity of pedestrian facilities
  - aesthetics
  - influence of surrounding vehicles
  - maintenance of sidewalk pavements
- Participants were also asked to state their best judgment on the levels of service of the facilities at their locations and these were coded from A (excellent) to F (unfavorable).

Results – KHCM vs Pedestrian Ratings of Service

- KHCM over-estimate the level of service significantly
Results – Important Attributes

- The two most important contributing factors reported were walking speed and number of conflicts.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Most Important</th>
<th>Second Most Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking Speed</td>
<td>40.1%</td>
<td>24.1%</td>
</tr>
<tr>
<td>Number of Conflict</td>
<td>23.7%</td>
<td>25.5%</td>
</tr>
</tbody>
</table>

Results – Personal Space

\[ \bar{x} = 0.65; \bar{y} = 0.49 \]

\[ Y = -49.249 \ln(X_1) + 52.530 \ln(X_2) - 137.519 \]

- Description Variable Min Max Mean Std. Dev Evasive Movements (#)
  - Evasive Movements (#) \( Y \)
  - Sidewalk Width (m) \( X_1 \)
  - Volume (ped/min) \( X_2 \)
  - Residential (0,1) \( X_3 \)
  - Commercial (0,1) \( X_4 \)
  - Leisure (0,1) \( X_5 \)

- R-square value of 0.77
**Results – Revised Table for PLOS**

<table>
<thead>
<tr>
<th>LOS</th>
<th>Evasive Movements (Number/min/m)</th>
<th>Space (m²/ped)</th>
<th>Flow Rate (ped/min/m)</th>
<th>Average Speed (m/sec)</th>
<th>Density (ped/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≤3.58</td>
<td>≥ 3.30</td>
<td>≤ 20</td>
<td>≥ 1.25</td>
<td>≤ 0.30</td>
</tr>
<tr>
<td>B</td>
<td>≤6.32</td>
<td>≥ 2.00</td>
<td>≤ 32</td>
<td>≥ 1.20</td>
<td>≤ 0.50</td>
</tr>
<tr>
<td>C</td>
<td>≤10.13</td>
<td>≥ 1.40</td>
<td>≤ 46</td>
<td>≥ 1.15</td>
<td>≤ 0.70</td>
</tr>
<tr>
<td>D</td>
<td>≤13.06</td>
<td>≥ 0.90</td>
<td>≤ 70</td>
<td>≥ 1.03</td>
<td>≤ 1.10</td>
</tr>
<tr>
<td>E</td>
<td>≤19.00</td>
<td>≥ 0.38</td>
<td>≤ 106</td>
<td>≥ 0.67</td>
<td>≤ 2.60</td>
</tr>
<tr>
<td>F</td>
<td>Over 19.00</td>
<td>&lt; 0.38</td>
<td>&gt; 106</td>
<td>&lt; 0.67</td>
<td>&gt; 2.60</td>
</tr>
</tbody>
</table>

**Results - Validation**

<table>
<thead>
<tr>
<th>Sidewalk Width (m)</th>
<th>LOS A Perceived</th>
<th>Revised Perceived</th>
<th>LOS B Perceived</th>
<th>Revised Perceived</th>
<th>LOS C Perceived</th>
<th>Revised Perceived</th>
<th>LOS D Perceived</th>
<th>Revised Perceived</th>
<th>LOS E Perceived</th>
<th>Revised Perceived</th>
<th>LOS F Perceived</th>
<th>Revised Perceived</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>13</td>
<td>11</td>
<td>7</td>
<td>31</td>
<td>9</td>
<td>21</td>
<td>15</td>
<td>5</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>3.8</td>
<td>6</td>
<td>6</td>
<td>11</td>
<td>6</td>
<td>8</td>
<td>20</td>
<td>8</td>
<td>14</td>
<td>8</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>4.5</td>
<td>3</td>
<td>4</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>10</td>
<td>4</td>
<td>7</td>
<td>12</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>6.5</td>
<td>4</td>
<td>3</td>
<td>10</td>
<td>4</td>
<td>8</td>
<td>11</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

**Conclusion**

- To encourage more walking trips, the provision of comfortable pedestrian facilities is paramount.
- The PLOS prescribed by the HCM over-estimate the PLOS.
- A new PLOS index is developed that is based on the concept of personal and evasive movements.
- Higher number of evasive movement => lower PLOS
- The new PLOS index is much more accurate in predicting pedestrian perceived level of service.
- The findings from this research provided some useful guidance to engineers to assist them in designing more comfortable pedestrian facilities.

**Acknowledgement**

Thank You!

Questions?