A GUIDELINE FOR PEDESTRIAN TIMING ACCOMMODATION INTO SIGNAL COORDINATION

Ali Gholami
Zong Tian

Center for Advanced Transportation Education and Research (CATER)
Department of Civil & Environmental Engineering
University of Nevada, Reno
Outline

Introduction

Mathematical Model

Model Validation
Introduction

Accommodating pedestrian timing
Introduction

Non-Accommodating pedestrian timing
Research Question

When accommodation (A) of pedestrian timing into coordination is preferable over non-accommodation (NA)?
Factors influencing the decision

- Weight of side street
- Transition factors
- Required pedestrian time
- Pedestrian volume
- Vehicle volume
- Cycle length and other signal parameters
Mathematical model

Non-accommodation

Shortening Transition Method

Lengthening Transition Method

Intersection 1
Intersection 2
Intersection 3
Intersection 4

Time

Distance

Intersection with pedestrian call

Bandwidth before pedestrian call

Distance

Intersection with pedestrian call

Bandwidth before pedestrian call
Mathematical model

- $t_a = t_p - g_s$  
  Additional time needed for green time of the side street for pedestrians to cross main street (sec)

- $\beta_s = \left[ \frac{t_a}{C \times \mu} \right]^+$  
  The number of transition cycles during one transition period

- $\beta_t = \left[ \frac{C - t_a}{C \times \mu} \right]^+$

- $L^i_2 = \begin{cases} t_a + (i - 1)\alpha & \text{if } t_a + (i - 1)\alpha \leq r_t \\ r_t & \text{if } t_a + (i - 1)\alpha > r_t \end{cases}$
  The time distance of the lower bound of delayed green to the beginning of the next green time

- $L^i_3 = \begin{cases} (C - t_a - (i - 1)\alpha) / r & \text{if } C - t_a - (i - 1)\alpha \leq r \\ r & \text{if } C - t_a - (i - 1)\alpha > r \end{cases}$

- $U^i_2 = \begin{cases} t_a + (i - 1)\alpha - g & \text{if } t_a + (i - 1)\alpha > g \\ 0 & \text{if } t_a + (i - 1)\alpha \leq g \end{cases}$
  The time distance of the upper bound of delayed green to the beginning of the next green

- $U^i_3 = \begin{cases} C - t_a - (i - 1)\alpha - g & \text{if } C - t_a - (i - 1)\alpha - g > g_t \\ 0 & \text{if } C - t_a - (i - 1)\alpha - g \leq g_t \end{cases}$

- $g^i_{a.2} = L^i_2 - U^i_2$

- $g^i_{a.3} = L^i_3 - U^i_3$
  Amount of green time that is delayed by transition
Mathematical model

\[ g_b = \begin{cases} 
\frac{r \times v_m}{f_s} & \text{if } \frac{r \times v_m}{f_s} < g \\
g & \text{if } \frac{r \times v_m}{f_s} \geq g 
\end{cases} \]

\[ g_{b,2}^i = \begin{cases} 
g_b & \text{if } U_2^i = 0 \text{ and } g_b < g_{a,2}^i \\
g_{a,2}^i & \text{if } U_2^i = 0 \text{ and } g_b \geq g_{a,2}^i \\
g_b & \text{if } U_2^i > 0 \text{ and } L_2^i - U_2^i = g \\
0 & \text{if } U_2^i > 0 \text{ and } U_2^i < g \text{ and } g_r \geq g_{a,2}^i \\
g_{a,2}^i - g_r & \text{if } U_2^i > 0 \text{ and } U_2^i < g \text{ and } g_r < g_{a,2}^i 
\end{cases} \]

\[ g_{r,2}^i = \begin{cases} 
g_{a,2}^i - g_b & \text{if } U_2^i = 0 \text{ and } g_b < g_{a,2}^i \\
0 & \text{if } U_2^i = 0 \text{ and } g_b \geq g_{a,2}^i \\
g_r & \text{if } U_2^i > 0 \text{ and } L_2^i - U_2^i = g \\
g_{a,2}^i & \text{if } U_2^i > 0 \text{ and } U_2^i < g \text{ and } g_r \geq g_{a,2}^i \\
g_r & \text{if } U_2^i > 0 \text{ and } U_2^i < g \text{ and } g_r < g_{a,2}^i 
\end{cases} \]
Mathematical model

\[ g_{b,3} = \begin{cases} 
  g_b & \text{if } U_3^i = 0 \text{ and } g_b < g_{d,3}^i \\
  g_{d,3}^i & \text{if } U_3^i = 0 \text{ and } g_b \geq g_{d,3}^i \\
  g_b & \text{if } U_3^i > 0 \text{ and } L_3^i - U_3^i = g_t \\
  0 & \text{if } U_3^i > 0 \text{ and } L_3^i - U_3^i < g_t \text{ and } g_r \geq g_{d,3}^i \\
  g_{d,3}^i - g_r & \text{if } U_3^i > 0 \text{ and } L_3^i - U_3^i < g_t \text{ and } g_r < g_{d,3}^i 
\end{cases} \]

\[ g_{r,3} = \begin{cases} 
  g_{d,3}^i - g_b & \text{if } U_3^i = 0 \text{ and } g_b < g_{d,3}^i \\
  0 & \text{if } U_3^i = 0 \text{ and } g_b \geq g_{d,3}^i \\
  g_r & \text{if } U_3^i > 0 \text{ and } L_3^i - U_3^i = g_t \\
  g_{d,3}^i & \text{if } U_3^i > 0 \text{ and } L_3^i - U_3^i < g_t \text{ and } g_r \geq g_{d,3}^i \\
  g_r & \text{if } U_3^i > 0 \text{ and } L_3^i - U_3^i < g_t \text{ and } g_r < g_{d,3}^i 
\end{cases} \]
Mathematical model

\[ Z_{n,2}^i = \left[ g_{b,2}^i \times f_s \left( \frac{u_{2}^i + (u_{2}^i + g_{r,2}^i)}{2} \right) \right] + \left[ g_{r,2}^i \times v_m \left( \frac{(u_{2}^i - g_{b,2}^i) + u_{2}^i}{2} \right) \right] - \left[ v_{s,2} \times \rho \left( \frac{(t_{a})^2}{2} \right) \right] \]

\[ Z_{n,3}^i = \left[ g_{b,3}^i \times f_s \left( \frac{u_{3}^i + (u_{3}^i + g_{r,3}^i)}{2} \right) \right] + \left[ g_{r,3}^i \times v_m \left( \frac{(u_{3}^i - g_{b,3}^i) + u_{3}^i}{2} \right) \right] \]

Delay of cycle \( i \) due to pedestrian call
Mathematical model

\[ \gamma = \begin{cases} 
\frac{1}{P(X \geq 1)} & \text{if} \quad \frac{1}{P(X \geq 1)} \leq \beta \\
\beta & \text{if} \quad \frac{1}{P(X \geq 1)} > \beta
\end{cases} \]

The number of cycles that go into transition before another pedestrian call occurs.

\[ P(X \geq 1) = 1 - P(X = 0) = 1 - e^{-v_p/3600} \]

Probability of having at least one pedestrian call during one cycle.
Mathematical model

\[ Z_{n,2}^i = \sum_{i=1}^\gamma \left[ g_{b,2}^i \times f_s \left( \frac{L_2 + (U_2 + g_{r,2}^i)}{2} \right) \right] + \left[ g_{r,2}^i \times v_m \left( \frac{L_2 - g_{b,2}^i + U_2^i}{2} \right) \right] - v_{s,2} \times \rho \left( \frac{(u_a)^2}{2} \right) \]

\[ Z_{n,3}^i = \sum_{i=1}^\gamma \left[ g_{b,3}^i \times f_s \left( \frac{L_3 + (U_3 + g_{r,3}^i)}{2} \right) \right] + \left[ g_{r,3}^i \times v_m \left( \frac{L_3 - g_{b,3}^i + U_3^i}{2} \right) \right] \]

Delay of one transition period due to not accommodating PT
Mathematical model

\[ N = \begin{cases} \frac{3600}{c \times \gamma} & \text{if } \frac{1}{p(x \geq 1)} \leq \beta \\ \frac{3600}{c} \times P(X \geq 1) & \text{if } \frac{1}{p(x \geq 1)} > \beta \end{cases} \quad \text{Number of transition periods per hour} \]

\[ C_t = C + \alpha \quad \text{The length of cycles after the first cycle in transition period} \]

\[ C_\alpha = \begin{cases} \frac{(C+t_\alpha)+[(\gamma-1)c t_\alpha]}{\gamma} P(X \geq 1) \beta + C [1 - P(X \geq 1)] & \text{if } \frac{1}{p(x \geq 1)} \leq \beta \\ \frac{(C+t_\alpha)+[(\beta-1)c t_\alpha]}{\beta} P(X \geq 1) & \text{if } \frac{1}{p(x \geq 1)} > \beta \end{cases} \quad \text{Average cycle length during one hour (sec)} \]

\[ N = \begin{cases} \frac{3600}{c_\alpha \times \gamma} & \text{if } \frac{1}{p(x \geq 1)} \leq \beta \\ \frac{3600}{c_\alpha} \times P(X \geq 1) & \text{if } \frac{1}{p(x \geq 1)} > \beta \end{cases} \]
Mathematical model

\[ D_{n,2}^h = Z_{n,2}^t \times N \]

\[ D_{n,3}^h = Z_{n,3}^t \times N \]

Hourly delay of non-accommodating PT
Mathematical model

\[ Z_{n,1}^t = \left[ \sum_{i=1}^{\gamma} \left[ g_{d,1}^i \times v_m \left( \frac{v_i^1 - v_i^2}{2} \right) \right] \right] - \left[ v_{s,1} \times \rho \left( \frac{v_{a}}{2} \right) \right] \]

Delay of one transition period due to not accommodating PT at Intersection 1

\[ D_{n,1}^h = Z_{n,1}^t \times N \]

\[ D_{n,2}^h = Z_{n,2}^t \times N \]

Hourly delay of not accommodating PT at Intersection 1 if pedestrian call occurs at Intersection 1
Mathematical model

$$D_{n,t}^h = \sum_{i=p}^{p+1} D_{n,i}^h$$

Total hourly delay caused by transition when PT is not accommodated at Intersection $p$ (intersection with pedestrian call) and its next intersection
Mathematical model

Accommodation
Mathematical model

\[ D_{a,1}^h = \left( \frac{t_a}{2} \left( v_m - v_{s,1} \right) \right) \left( \frac{3600}{c} \right) = \frac{1800 \left( t_a \right)^2 \left( v_m - v_{s,1} \right)}{c} \]

Delay caused by adding \( t_a \) to side street green time at Intersection 1 (veh-sec)

\[ D_{a,i}^h = \begin{cases} \frac{1800 \left( t_a \right)^2 \left( 1 - \rho \times v_{s,i} \right)}{c} & \text{if } g_{req} \leq g_a \\ \frac{1800 \min(t_a, g_{req} - g_a)^2 \left( 1 - \rho \times v_{s,i} \right)}{c} & \text{if } g_{req} > g_a \end{cases} \]

Delay of accommodating \( t_a \) (adding \( t_a \) to side street green time) at Intersection \( i \) (veh-sec)

\[ g_{req} = \frac{v_m \times c}{f_s} \]

Required green based on main street volume and its saturation flow rate

\[ g_a = g - t_a \]

Accommodated green (sec)

\[ D_{a,t}^h = \sum_{i=1}^{n} D_{a,i}^h \]

Hourly delay of accommodating PT
Mathematical model

The effect of semi-actuated coordination

\( t_a^a = t_a \times P(X \geq 1) \)  Modified \( t_a \) for accommodating PT at semi-actuated coordination

\( t_a^n = \begin{cases} t_a \\ t_a - \left[ \min \left( t_a, g_l - \left( \frac{v_{l,c}}{c_{l,c}} g_l + E \right) \right) \right] \\ t_a - (\min (g_l, t_a)) \end{cases} \)  if \( \frac{v_{l,c}}{c_{l,c}} \geq 1 \) or \( \frac{v_{l,c}}{c_{l,c}} g_l + E \geq g_l \)

\( \frac{v_{l,c}}{c_{l,c}} < 1 \) and \( \frac{v_{l,c}}{c_{l,c}} g_l + E < g_l \)

Modified \( t_a \) for not accommodating PT at semi-actuated coordination

\( v_{l,c} = v_l \times C \)  Main street left turn volume per cycle

\( c_{l,c} = f_s \times g_l \)  Capacity of left turn (vehicle per cycle)
Mathematical model

\[ A = \left[ \frac{D_{a,t}^h - D_{n,t}^h}{D_{a,t}^h} \right] \times 100 \]

- \( A \gg 0 \) • non-accommodating of PT is preferable
- \( A \ll 0 \) • accommodating of PT is preferable
- \( A \approx 0 \) • there is not a significant benefit of one method over the other one
PeTASC

- Pedestrian Timing Accommodation into Signal Coordination

https://drive.google.com/open?id=0B4juw5AdxVsYTzN5c3hnVUJm5nc
PeTASC

COMPARISON OF PEDESTRIAN TIMING ACCOMMODATION METHODS

- Shortening
- Lengthening
- Accommodating PT

Delay caused by adding PT (veh-sec)

Volume (vehicle per approach)

Input:
- Cycle Length (sec) 200
- Main Street Green Time Percentage from Cycle Length (0-1) 0.6
- Left Turn Green Time Percentage from Cycle Length (0-1) 0.3
- Additional Time Added to Side Street Green Time to Accommodate Pedestrian Time (ts) (sec) 40
- Pedestrian Volume (pph) 40
- Left Turn Percentage from Main Street Volume (0-1) 0.2
- Side Street Percentage from Main Street Volume (0-1) 0.3
- Maximum Percentage Permitted to Add to/ Subtract from Cycle Length (mu) (0-1) 0.1
- Weight of Side Street Volume (rho) (0-1) 7
- Gap out Extension (E) (sec) 1
- No. of Intersections (n) 2
- Saturation Flow Rate (ts) (vph) 2000
- Analysis of Main Street Volume from intervals (vph) 200 200 2000

Analysis Over Cycle Length and Pedestrian Volume
Analysis Over mu and rho
Analysis Over Volume
## Model Validation

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>FROM</th>
<th>INTERVAL</th>
<th>TO</th>
<th>NO OF CASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>50</td>
<td>50</td>
<td>1200</td>
<td>24</td>
</tr>
<tr>
<td>Pedestrian Volume</td>
<td>5</td>
<td>5</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>$t_{q,1}$</td>
<td>5</td>
<td>5</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Cycle Length</td>
<td>60</td>
<td>20</td>
<td>120</td>
<td>4</td>
</tr>
</tbody>
</table>

3456 scenarios
MODEL VALIDATION

Vissim COM Interface
MODEL VALIDATION

Simulation

Mathematical Model

Average Delay Increment after Accommodating Pedestrian Timing

- $t_d = 15$ (sec)
- Cycle = 60 (sec)

Delay Increase (%) vs. Volume (veh/h)

Delay caused by adding PT vs. Volume (veh/sec)
Cycle length 60 seconds. Left side of each curve shows not accommodation area and right side accommodation area.
Advantages and disadvantages

- Who knows if this model is accurate?!! L
- It can be used for different situation
- It is easy to enter inputs and get the best accommodation method
- It can also give the best transition method J
Thank you

Any comments or questions?

*If we have data, let’s look at data. If all we have are opinions, let’s go with mine!*

Jim Barksdale, former Netscape CEO