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Webinar: Exploring Pedestrian Responsive Traffic Signal Timing Strategies in Urban Areas

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Exploring Pedestrian Responsive Signal Timing Strategies in Urban Areas

IBPI Webinar
January 29, 2015

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Research Associate
Civil and Environmental Engineering
Portland State University
Presentation Roadmap

1. Introduction
2. Pedestrian Crossing Behavior
3. Pedestrian Delay Measurement
4. Simulation Modeling
5. Wrap-Up
   1. Conclusions
   2. Implications and Recommendations
   3. Future Work
Introduction

- Growing emphasis on active transportation
- Walking ➔ healthy, livable communities
- Increase in walking trips

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Delay</th>
<th>Simulation</th>
<th>Conclusion</th>
</tr>
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</table>

Source: Data from Pucher et al., (2011)

National Walking Trends

Source: Data from Pucher et al., (2011)

Local Commute Shares - Walk 4%

Source: City of Portland, Climate Action Plan
Introduction

- Pedestrian fatalities:
  - 6% increase in 2012
  - 73% - urban areas
  - 20% - intersections

- Poor crossings:
  - Deter people from walking
  - Unsafe crossing behavior

“On average, a pedestrian was killed every 2 hours and injured every 7 minutes in traffic crashes”

Source: NHTSA, Traffic Safety Facts 2012
Motivation

- Delays affect pedestrians disproportionately
- “Everyone is a pedestrian”

How do we translate “pedestrian first” policies into specific operational strategies at intersections?
Research Questions

- What factors influence crossing decisions? Perceptions of delay?
  - Demographics
  - Trip characteristics
  - Perceptions of safety
- Signal controller pedestrian MOE’s?
  - Actuations
  - Delay
- Impacts of control strategies on different modes? Traffic Regimes?
  - Change in operation
Signal Timing 101

- Signal operation
  - Coordination

- Pedestrian detection
  - Recall
  - Actuated

Free
Research Questions

- What factors influence crossing decisions? Perceptions of delay?
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  - Trip characteristics
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- Signal controller pedestrian MOE’s?
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Pedestrian Crossing Behavior - Review

Demographic Characteristics
- Age
- Gender
- Group status

Crossing Characteristics
- Delay
- Traffic volumes
- Crossing speed

Infrastructure
- Pushbutton feedback
- Countdown timer
- Automated detection

Demographics
MacGregor et al. (1999); Diaz (2002); Yanfeng et al. (2010); Wang et al. (2011); Bradbury et al. (2012)

Crossing
Dunn et al. (1985); Knoblauch et al. (1996); Hamed (2001); Diaz (2002) HCM (2010); Wang et al. (2011);

Infrastructure
Hughes et al. (2000); Keegan et al. (2003); Eccles et al. (2004); Van Houten et al. (2006)
Gaps

- Role of perceived safety and compliance in crossing decisions?
- Perception of delay
  - Demographics
  - Trip characteristics
  - Infrastructure
Methodology

- Intercept survey of crossing pedestrians
- Survey administered using a tablet
- 11 questions, < 5 minutes to complete
Survey Locations

Recall
N = 140
RR = 70%

Actuated
N = 81
RR = 66%

Recall
N = 53
RR = 77%

Actuated
N = 93
RR = 68%
Descriptive Statistics

**Age**
- 76+: 1.1%
- 66-75: 6.3%
- 40-65: 48.6%
- 26-39: 34.9%
- 18-25: 9.1%

**Gender**
- Female: 48.5%
- Male: 51.5%

**Presence of children**
- No: 97.5%
- Yes: 2.5%

**Group status**
- No: 86.6%
- Yes: 13.4%
Trip Characteristics

**Use of public transit**
- Neither: 62.9%
- From public transportation: 18.3%
- To public transportation: 18.8%

**Trip length**
- >15 mins: 16.6%
- 10-15 mins: 10.9%
- 5-10 mins: 27.8%
- <5mins: 44.7%

**Intersection usage**
- 4+days/ wk: 47.4%
- 1-3 days/ wk: 24%
- 1-3 days/ mo: 14.2%
- < 1day/ mo: 8.4%
- First time: 6%

**Trip purpose**
- Other: 0.8%
- Exercise: 3.3%
- Recreation: 3.8%
- Eating out/coffee: 15.8%
- Shopping, errands: 31.1%
- Home: 14.4%
- Accompany minor: 0.3%
- School/college: 1.6%
- Work: 28.9%

Introduction | Behavior | Delay | Simulation | Conclusion
Perceptions

How satisfied are you with the amount of time the signal gives you to cross at this intersection?

How satisfied are you with the amount of time you have to wait before crossing at this intersection?
Perceptions of Safety

In general, how safe do you feel crossing at this intersection?
Attitudes

Please indicate your level of agreement with the following statement: My crossing decisions are influenced by concerns about safety.

Please indicate your level of agreement with the following statement: My crossing decisions are influenced by concerns about whether I am violating traffic code.

100%
80%
60%
40%
20%
0%

Safety

Compliance

Strongly Agree
Agree
Disagree
Strongly Disagree

Introduction | Behavior | Delay | Simulation | Conclusion
Model Results – Crossing Decisions

Please indicate your level of agreement with the following statement: My crossing decisions are influenced by concerns about safety.

CD – Compliance
Perception of Safety
Length (>15 mins)
Rec trip
Home trip
Work trip
Groups
Age 76+

Base Case
Length < 5 mins
Shopping Trips
Age (40-65)
Freq 4+days/wk

N= 362, -2LL = 242.53, Model $\chi^2 = 55.42$, df = 17, $R^2 = 0.25$
How satisfied are you with the amount of time you have to wait before crossing at this intersection?

<table>
<thead>
<tr>
<th>Safety</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recall Int</td>
<td>5.19</td>
</tr>
<tr>
<td>Age (18-25)</td>
<td>-0.31</td>
</tr>
</tbody>
</table>

N= 217, -2LL = 155.08, Model $\chi^2 = 33.33$, df = 14, $R^2 = 0.25$
Findings

- Crossing decisions
  - Safety
  - Trip Purpose
  - Groups

- Delay
  - Perception of safety
  - Time constraints
  - Age
  - Infrastructure

Limitations

- Representative sample
  - Older adults
  - Children
  - Disabled

- Other languages
  - Spanish

- More locations
Research Questions

- What factors influence crossing decisions? Perceptions of delay?
  - Demographics
  - Trip Characteristics
  - Perceptions of safety
- Signal controller pedestrian MOE’s?
  - Actuations
  - Delay
- Impacts of control strategies on different modes? Traffic Regimes?
  - Change in operation
Pedestrian Delay Estimation - Review

- Performance measures to characterize pedestrian service
- Estimated delay is not accurate (Hubbard, 2007)
- Why estimate delay when we can measure it?

\[ d_p = \frac{0.5 (C-g)^2}{C} \]

- \( d_p \) = average pedestrian delay (s/p)
- \( C \) = cycle length (s)
- \( g \) = effective walk time (s)
Pedestrian Actuations and Delay

- Record pushbutton actuations
  - Type 2070 signal controllers
  - Voyage software
- Two novel validated methods
  - Transit priority logs
  - Volume logs
Pedestrian Actuations and Delay

Source: demo.portal.its.pdx.edu/pedbike
Research Questions

- What factors influence crossing decisions?
  - Perceptions of delay?
    - Demographics
    - Trip Characteristics
    - Perceptions of safety
- Signal controller pedestrian MOE’s?
  - Actuations
  - Delay
- Impacts of control strategies on different modes?
  - Traffic Regimes?
    - Change in operation
Delay Optimization - Review

- Early efforts focused on reducing vehicle delay
  - Webster (1958), Little (1975)
- Few studies on optimizing signal timing for pedestrians

Analytical

- Ped delay costs (Noland, (2005))
- Split phasing (Tian et al. (2001))
- Two stage crossing (Wang (2010))

Simulation

- Offsets (Bhattacharya et al. (2005))
- Cycle lengths (Ishaque et al. (2006))
- Type of ped crossing (Ishaque et al. (2007))
- Phasing (Vallyon et al. (2011))
- Green splits (Roshandeh et al. ((2013))

Gap: No studies on impacts resulting from change in mode of operation
Simulation Model

Inputs:
- Volumes
- Speeds
- Geometry
- Signal Timing

VISSIM

Outputs:
- Queue Length
- Travel time
- Delay
- Volumes
- Speeds
- Signal Timing
Site Selection

- Multnomah and 11th
- Multnomah and 13th
- Multnomah and 15th
Time of Day Models

Network volume

Overall average delays per person are higher during mid-day

Ped delay is greater compared to auto delay for all time periods

Auto and ped volumes are greater during mid-day and PM peak

Ped volume greater during mid-day

Average delay per person
Hypothetical Network

- Based on the calibrated Multnomah network
  - All Multnomah ped movements on recall and rest-in-walk
  - All side street vehicle and ped movements are actuated
  - Flows varied in three ranges – High, Med, Low

<table>
<thead>
<tr>
<th>Scenario</th>
<th>V/C Ratio Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>Medium</td>
<td>0.3 – 0.7</td>
</tr>
<tr>
<td>High</td>
<td>&gt; 0.7</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Scenario</th>
<th>Ped Phase Freq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt; 30%</td>
</tr>
<tr>
<td>Medium</td>
<td>30% – 70%</td>
</tr>
<tr>
<td>High</td>
<td>&gt; 70%</td>
</tr>
</tbody>
</table>

Auto V/C Ratios

Pedestrian Phase Frequency
A total of 18 scenarios were constructed, 9 per mode of operation
Comparison – Existing Timing

Low – Low = Low Auto Low Ped

% Change in Average Delay per Person

% Change in Delay = \frac{(\text{Free Delay} - \text{Coordinated Delay}) \times 100}{\text{Coordinated Delay}}

Introduction | Behavior | Delay | Simulation | Conclusion
Optimized Timing

- Optimized splits and offsets, while cycle length constant (80s)
- Optimized cycle lengths, splits and offsets

Introduction | Behavior | Delay | Simulation | Conclusion
Higher Cycle Lengths

**Low Auto-Low Ped**

- **Average Delay per Person(s)**
- **All**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free
- **Auto**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free
- **HV**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free
- **Bike**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free
- **Ped**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free

- **Actuated ped delay**
  - ~47-53s (120s CL)
  - ~35-38s (80s CL)
  - ~13-18s (Free)

**High Auto-High Ped**

- **Average Delay per Person(s)**
- **All**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free
- **Auto**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free
- **HV**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free
- **Bike**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free
- **Ped**: 12 Coordinated (CL=80s), 16 Coordinated (CL=120s), 2 Free

- **Actuated ped delay**
  - ~52-53s (120s CL)
  - ~34-35s (80s CL)
  - ~17-33s (Free)
Division Street Case Study - I

Existing volume corresponds to medium auto – low ped scenario
Expected finding: Free delay < Coordinated delay
Division Street Case Study -II

Similar trends as seen on Multnomah St network

Delay for all modes is lower during free operation

**Existing Volumes (Med Auto - Low Ped)**

- **All**: Delay is lower during free operation
- **Auto**: Delay is lower during free operation
- **HV**: Delay is lower during free operation
- **Ped**: Delay is lower during free operation

**% Change in Average Delay**

- **Low-Low**: -47.6%
- **Low-Med**: -24.5%
- **Low-High**: -24.5%
- **Med-Low**: -24.5%
- **Med-Med**: 16.1%
- **Med-High**: -24.5%
- **High-Low**: -24.5%
- **High-Med**: -24.5%
- **High-High**: 16.1%
Strategies

- **COORDINATED Short Cycle Lengths**
- **FREE**
- **COORDINATED Manage Ped Service Response**
- **PED RECALL**

**Ped Act. Frequency (side st.)**

- **Low** <30%
- **Medium** 30%-70%
- **High** >70%

- **V/C (major st.)**
  - ≤ 0.5
  - 0.5 – 0.8
  - ≥ 0.8

Introduction | Behavior | Delay | Simulation | Conclusion
Pedestrian Responsive Strategies

- Inputs
  - Traffic volumes
  - Pedestrian actuations and delay

- Infrastructure
  - Detection
  - 2070 Controllers

- Locations
  - High pedestrian traffic generators
  - Intersections with high pedestrian delay
  - Intersections with low compliance
Scenario 2 (highest PL) – statistically significant reductions in pedestrian delay
Conclusions

- Safety plays a larger role than compliance in crossing decisions
- Trip purpose and group status influence crossing decisions
- Time constraints and type of pedestrian detection infrastructure influence a pedestrian’s satisfaction with delay
Conclusions

- Free operation is generally beneficial for pedestrians
- Coordination primarily benefits major street through movements
- Treating all users equally, these strategies are recommended:
  - Free operation at V/C < 0.5
  - Coordination with managed response for 0.5 < V/C < 0.8
  - Coordination with short cycle lengths for V/C > 0.8
Implications and Recommendations

- Use existing resources for performance measurement
- Consider all users while developing signal timing
  - Trade offs
    - Safety vs. Efficiency
    - Pedestrian delay vs. Auto delay
- 3 E’s for promoting pedestrian compliance and safety
Areas for Future Research

- Continuing investigation into control strategies to benefit pedestrians
- Impacts of increased permissive length on other modes
- Development of priority pedestrian service
  - Current NITC funded project titled “Improving Walkability Through Control Strategies at Signalized Intersections”
Thank you!

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- TREC/NITC
- ITS lab members, PhT colleagues
References


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