Understanding Pedestrian Behaviors and Traffic Controls at Signalized Crosswalks for Safety Improvements in Japan and USA

Presented by

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The University of Tokyo

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Qatar University

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NYCDOT

Moderator: Lee Kim
Purpose:
Examine how crosswalk geometry and signal timing/indication impact pedestrian speed and decision making process.

Review current traffic control policies and discuss ways improve safety at signalized crosswalks.
This webinar will:

**Provide** general introduction about existing design and operational policies for pedestrians at intersections in different countries.

**Examine** pedestrian behavior and traffic controls at crosswalks in US.

**Examine** pedestrian behavior at crosswalks in Japan considering the effect of signal timing.
Concepts of Traffic Signal Control for Pedestrians in Different Countries

Miho IRYO-ASANO, Associate Professor
Institute of Industrial Science
The University of Tokyo, JAPAN
Problem Statement

Pedestrian-vehicle conflicts are common safety problems.

– More than one-third of the total number of fatalities in traffic accidents were pedestrians.

– 29% of pedestrian fatalities (42% of elderly fatalities) can be attributed to illegal crossing behavior.

(National Police Agency in Japan, Accident statistics in 2011)
Problem Statement ......cont.

Intersections at the common locations for ped-veh conflicts
• At signalized intersections pedestrian streams are controlled through three intervals:

- **Walk (Green)**
- **Clearance (Flash green, red or yellow)**
- **Don’t Walk (Red)**

The time required by pedestrians who enter the crosswalk at the end of the green indication to complete crossing before conflicting vehicular traffic movements are released.
Problem Statement ......cont.

- Different practices in defining clearance time
- Different patterns of signal indications for clearance time

These different practices affect pedestrian behavior and lead to different patterns.

What is the most efficient signal design in terms of pedestrian compliance?
Functions of pedestrian green phase

Theoretically, the pedestrian phase consists of:

**Discharge time**: Time required for pedestrians to leave curbs or shoulders

→ Dependent on the reaction time, pedestrian demand and crosswalk width

**Clearance time**: Time required for crossing pedestrians to complete crossing

→ Dependent on walking speed and crosswalk length
Definitions of pedestrian signal indications in US

- **Walk**
  - Pedestrians are able to proceed
  - Discharge time
  - Time for all waiting pedestrians to start crossing (7 s reaction time + queue discharge time)

- **Flashing don’t walk**
  - Pedestrians should not start crossing
  - Clearance time
  - Crosswalk length
  - Walking speed
  - 3 ~ 3.5 ft/s (0.9 ~ 1.1 m/s)

- **Don’t walk**
  - Pedestrians should not start crossing
Definitions of pedestrian signal indications in Japan

By: Order of Enforcement of Road Traffic Act in Japan
Definitions of pedestrian signal indications in Japan

- **Green**: Pedestrians are able to proceed.

- **Flashing Green**: Pedestrians should not start crossing. Pedestrians who are on the crosswalks have to complete crossing or **give up crossing and return** to the origin side immediately.

- **Red**: Pedestrians should not cross roads.

By: Order of Enforcement of Road Traffic Act in Japan
How to set minimum green/flashing green time in Japan

- **Green**
  - Pedestrians are able to proceed
  - Crosswalk length
    - Walking speed $1.0\text{m/s (3.3ft/s)}$

- **Flashing Green**
  - Pedestrians should not start crossing.
  - Pedestrians who are on the crosswalks have to complete crossing or give up crossing and return to the origin side immediately.
  - Crosswalk length/2
    - Walking speed $1-1.5\text{m/s (3.3-4.9ft/s)}$

- **Red**
  - Pedestrians should not cross roads
  - Immediately
Pedestrian signal indications in Germany

**Green**  
Pedestrians can proceed

**Red**  
Pedestrians should not start crossing

Provide following time before the start of green on the crossing road

\[
\frac{\text{Crosswalk length}}{2} \times \text{Walking speed} \\
1\sim1.5 \text{ m/s (3.3\sim4.9 ft/s)}
\]

Walking speed

\[
1\sim1.5 \text{ m/s (3.3\sim4.9 ft/s)}
\]
Pedestrian signal indications in UK (Puffin control, midblock crosswalks)

- **Green**: Pedestrians can proceed
- **Blackout**: Pedestrians should not start crossing
- **Red**: Pedestrians should not start crossing

Crosswalk length \( \frac{1}{2} \)

Walking speed

\[ 1.2 \text{ m/s (3.9 ft/s)} \]

Fixed time + extension time considering the existence of crossing pedestrians

With pedestrian detection system
Locations of signal indicator: Puffin control in UK

Located only at Nearside
“Green” → “Blackout” → “Red”
Clearance time is adjusted by detecting existence of pedestrians on crosswalks
Pedestrian compliance becomes better than indicators located at farside
Difference of definition causes different user behavior

**JP**
- I am not confident to finish crossing
- May have to hurry
- Still crossing though red started...

**US**
- I am confident to complete crossing

**DE**
- I am not sure when vehicle comes
- Should give up crossing

I Have to hurry!
Buffer Intervals BIs in Japan

BIs are the time between the end of the PFG and the succeeding vehicle green indication.

- Ideally provided to increase the capacity of left-turners by avoiding conflicts with pedestrians.
Summary of Pedestrian Clearance Time

Japan
- Short PFG (pedestrian have to return if they did not finish crossing half of the crosswalk)
- Long Buffer Intervals BI (5 -10 sec)

US
- Long Flashing Don’t Walk
- Medium BIs (3 -5 sec)

Germany
- Clearance interval is indicated by red
- Clearance and BIs cannot be distinguished
- Low capacity

Pros and cons will be discussed in the following presentations
Pedestrian Behavior at Signalized Intersections in Japan

Dr. Wael Alhajyaseen / Assistant Professor
Qatar Road Safety Studies Center
Qatar University
Doha, Qatar

Email: wyaseen@qu.edu.qa
22% of total fatalities are pedestrians

Ref.: Global Status Report on Road Safety 2015 & 2013, World Health Organization
Pedestrian Fatalities: Japan

- JAPAN: More than third of the crash fatalities are pedestrians

National records = 35%, Police Department of Tokyo = 48%
Signalized Intersections in Japan

- Severe traffic crashes at intersections
- Too large intersections with long delay

**Layouts**

- Large corner radii
  - Enlarge speed of turning vehicles, which induce pedestrian accidents. Illegal parking at corners.
- Large setback distance
  - Enlarge clearance distance and all red time
- Channelization by zebra marking
  - Left-turning vehicle can run on the marking
  - Encourage high-speed turn
- Wide crosswalk and long setback distance
  - Turning vehicle can enter the crosswalk with high speed

**Signal control**

- Too long cycle time
- Long intergreen time (Yellow + all red)
- “Arrow” is used only for green phase
- 4-phase control is dominant
- Traffic lights are placed at near-side
- No 2-stage crossing for pedestrians
Problem Statement

- Intersection layout (crosswalk length and position)
  - Vehicles enter in high speed
  - High degree of freedom gives variety of movements

- Common Objective of Traffic signal control
  
  Provide sufficient capacity for motorized traffic
  Minimize vehicle delay

- Inappropriate signal setting → too long cycle lengths → Long delays
  - Induces hazardous maneuver, such as red light running and early starts at onset of green

Compared to vehicles, pedestrians violate traffic regulations more frequently
Pedestrian Behavior

- Dynamic interaction with
  - Signal indication and timing
  - Traffic conditions
  - Intersection layout
    - Crosswalk length & width
    - Channelization

![Diagram showing pedestrian behavior and interaction with vehicles]

- Longer crosswalks or high turning vehicle volumes
- Shorter crosswalks or low turning vehicle volumes

Left-hand Traffic

- Observed pedestrian path
- Pedestrian position and speed at the onset of PFG
- Pedestrian decision at the onset of PFG
- Right Turn on Red
- Right Turning Vehicles
- Left Turning Vehicles

- Pedestrian position and speed at the onset of PFG
- The onset of PFG
- Pedestrian Signal Phase
Pedestrian Behavior

1. Stop/go Decision
   Pedestrian location at the onset of PFG

2. Crossing Speed
   Affected by signal indication and timing
# Observation Sites

<table>
<thead>
<tr>
<th>Intersection Layout</th>
<th>Sasashima</th>
<th></th>
<th>Imaike</th>
<th></th>
<th>Yagoto Nisseki</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach</td>
<td>West</td>
<td>East</td>
<td>South</td>
<td>West</td>
<td>East</td>
</tr>
<tr>
<td>Crosswalk Length (m, ft)</td>
<td>32, 105</td>
<td>17, 56</td>
<td>36, 118</td>
<td>21, 69</td>
<td>21, 69</td>
</tr>
<tr>
<td>PFG (Sec)</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Pedestrian volume (ped/hr)</td>
<td>2025</td>
<td>1238</td>
<td>1103</td>
<td>360</td>
<td>327</td>
</tr>
<tr>
<td>Sample Size</td>
<td>249</td>
<td>154</td>
<td>32</td>
<td>28</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>153</td>
<td>51</td>
<td>16</td>
<td>24</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>402</td>
<td>205</td>
<td>48</td>
<td>52</td>
<td>77</td>
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</tbody>
</table>
At long crosswalks, stopping probability is significantly higher. The crossing decision is made based on pedestrians' judgment whether they can complete crossing during the available time.
Stop/Go Decision

- Walking speed and position at the onset of PFG

Sasashima West (32m [105 ft], PFG 6 sec)

Start crossing at the end of PFG (Pedestrian Flashing Green)

Pedestrian judgment whether to stop or go is influenced by:
- Their speed
- Distance to crosswalk
- Available time until the release of conflicting vehicles

Start crossing at the end the all-red interval of the parallel vehicle phase

Go (N=249)

Stop (N=155)
First half travel speed significantly increase as the PFG interval proceeds.

Second half travel speed no significant change.
Speed Change Events

- Sudden Pedestrian Speed Changes
- Unpredicted by drivers
- Safety Hazard
Extraction of Speed Change Events

- Statistically significant speed change before and after the event
- Observed speed profile
- Stepwise speed profile
- Speed change due to observation error
- Speed change events

Conceptual figure of Stepwise Speed Profile and speed change event

0.5 m/s or more speed change
# Observation Sites

<table>
<thead>
<tr>
<th>Intersection Layout</th>
<th>Kanayama</th>
<th>Ueda</th>
<th>Fushimi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach</td>
<td>East</td>
<td>North</td>
<td>East</td>
</tr>
<tr>
<td>Crosswalk Length</td>
<td>16, 52</td>
<td>36, 118</td>
<td>28, 92</td>
</tr>
<tr>
<td>(m, ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFG (Sec)</td>
<td>6</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Pedestrian volume</td>
<td>179</td>
<td>338</td>
<td>90</td>
</tr>
<tr>
<td>(ped/hr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample Size</td>
<td>Total</td>
<td></td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>263</td>
<td>373</td>
<td></td>
</tr>
</tbody>
</table>
### Observation Sites

<table>
<thead>
<tr>
<th>Intersection name</th>
<th>E-W</th>
<th>S-N</th>
<th>Vehicle</th>
<th>Pedestrian (location S and N)</th>
<th>Right-turning vehicle</th>
<th>Pedestrian (location E and W)</th>
<th>Right-turning vehicle</th>
<th>Signal phasing length (sec)</th>
<th>Cycle length (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kanayama</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>160</td>
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<tr>
<td>Ueda</td>
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<td></td>
<td></td>
<td></td>
<td>160</td>
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<tr>
<td>Fushimi</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>160</td>
</tr>
</tbody>
</table>

**Signal phase plan**

- **Green**
- **Right-turning arrow**
- **Pedestrian flashing green**
- **Amber**
- **Red**
Number of speed change events at each site

- **20-50%** pedestrians change their speeds at least once during crossing
- **Long crosswalks** have more frequent speed change events (Kanayama North, Fushimi South)
Location & Distribution of Speed Change Events

**Acceleration** events:
- Occur frequently at the entrance of conflict area

**Decelerations** events:
- Occur at either edge of crosswalks
Summary

Crosswalk Geometry
Crosswalk geometry and layout affects pedestrian behavior
- As crosswalk length increase:
  - Pedestrian stopping probability at the onset of PFG increases
  - Pedestrians tend to cross with higher speeds
  - More sudden speed changes $\rightarrow$ more severe conflicts $\rightarrow$ safety hazards
    - Mostly occur around the conflict area with exiting vehicles

Signal Timing
- Significant noncompliance with signal indication
  - Even after the onset of pedestrian red, pedestrian continue crossing until the onset of conflicting vehicles green
  - Pedestrian crossing speed increases as PG and PFG intervals proceeds.
    - Increasing tendency with time
  - Frequent sudden velocity changes during PFG interval
Quantification of Pedestrian Behavior

- Stop/Go decision
- Speed adjustment

Quantified considering the stochastic nature of pedestrians

Taking in account: (1) traffic control and (2) intersection geometry

- Individual pedestrian attributes (position and velocity of the start of PFG, gender, direction of movement)
- Crosswalk length
- Signal timing (PFG)

Generated Randomly

Stop/Go Decision

Go

Approaching Speed

Crossing Speed

Time start crossing

Time complete crossing

Required crossing time

Stop

End

Fixed Value
Applications

1) Proactive Safety Assessment using microsimulation
   - Realistic representation of pedestrian-vehicle

   Input data
   - Intersection geometries
   - Signal control parameters
   - Vehicle and pedestrian demand (assuming random arrival)

   Corner radius
   Intersection angle
   Pedestrian maneuver
   - Velocity distribution
     (depend on layouts and starting time to cross)
   Vehicle maneuver
   - Path distribution
   - Speed profile
   - Lag/gap choice

   Output: Conflict characteristics
   Safely indices

Comparison between different scenarios

Scenarios with different layouts
Applications: Improvements on the Design and Control

2) Road Structure

- Two-stage crossing
- Road narrowing
- Raised crosswalks
- Overpasses / underpasses
Applications: Improvements on the Design and Control

3) Signal Control
- Pedestrian Signal Setting
  - PFG length
  - Buffer time
- Countdown signals
- Position of the signal lights
- Dilemma zone for pedestrians

More efficient setting of pedestrian signal timing to improve compliance

Germany
USA
Japan
UK
Pedestrian Behavior and Traffic Controls at Crosswalks in New York City (US)

H. Joon Park, Ph. D., AICP, New York City Department of Transportation

“Understanding Pedestrian Behaviors and Traffic Controls at Signalized Crosswalks”
Pedestrian Behaviors

- **Macroscopic approach**
  - Pedestrian flow fundamental diagram
  - Average travel time and speed

- **Microscopic approach**
  - Profile on trajectories and speed of pedestrian and conflicting turning vehicles
  - Pedestrian compliance on control policy
Data Collection and Reduction

- Video Data Collection: pedestrian and traffic
- A combination of manual data reduction and video tracking analysis because of heavy pedestrians and video data quality (i.e., camera angle, object overlapping, and homography issues)
Video Data Examples

- Perpendicular view (Park Ave and 29th St)

- Multiple camera views (89 Ave and Merrick Blvd)
Pedestrian speed is an important factor to influence level of service for pedestrian facility and to determine flashing DON'T Walk time at crosswalks.

- Constant pedestrian crossing speed to determine pedestrian clearance time
- Many crosswalks in NYC with hourly pedestrian volume over 2,000

- 2009 MUTCD: 3.5 ft/s (1.1 m/s)
- HCM 2010: 4.0 ft/s (1.2 m/s), or 3.3 (1.0) if >20% elderly population, and reduction of .3 ft/s (0.1 m/s) with >10% upgrade
- NYC standard: 3.5 ft/s (1.1 m/s), 3.0 (0.9) in senior areas & school zones

Note: 1 ft/s is equal to approximately 0.3 meter/s.
Pedestrian Fundamental Diagram
Based on Recent Studies

   *Journal of Statistical Mechanics: Theory and Experiment* 2012, no. 02
Hourly pedestrian volumes at 14 locations were observed from 655 with low density of 0.020 ped/ft² at the west crosswalk of 3rd Ave and 23rd St to 7,655 with high density of 0.082 ped/ft² at west crosswalk of 7th Ave and 43rd St (Saturday). As the crosswalk densities increased, pedestrian speeds gradually decreased.
According to land use characteristics or trip purpose (i.e., tourist/shopper vs. commuter), pedestrians tend to show different crossing speeds. However, these speeds generally do not drop to below 2 ft/s (0.6m/s).
Examples of Various Pedestrian Density Levels

<table>
<thead>
<tr>
<th>Location</th>
<th>Density (ped/ft²)</th>
<th>Speed (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd Avenue and 23rd Street</td>
<td>0.019</td>
<td>5.0</td>
</tr>
<tr>
<td>5th Avenue and 57th Street</td>
<td>0.031</td>
<td>4.0</td>
</tr>
<tr>
<td>7th Ave and 46th Street (North)</td>
<td>0.039</td>
<td>3.4</td>
</tr>
<tr>
<td>7th Ave and 46th Street (East)</td>
<td>0.050</td>
<td>3.2</td>
</tr>
<tr>
<td>7th Avenue and 46th Street (East)</td>
<td>0.071</td>
<td>2.4</td>
</tr>
<tr>
<td>7th Avenue and 43rd Street</td>
<td>0.082</td>
<td>2.3</td>
</tr>
</tbody>
</table>
Pedestrian simulation model application for urban street facility in vicinity of Grand Central Terminal
Pedestrians walk faster during flashing DW time than during Walk time.
- Video surveys at 17 intersections in the vicinities of seven primary schools in NYC.
- The comparison between morning school hour and after school hour showed children walked faster during the morning.

Design speed for pedestrian interval at school crosswalks
The tables below demonstrate the difference in speed between children alone and children with guardians (i.e., father, mother, parents or grand parents) during school peak periods.

<table>
<thead>
<tr>
<th></th>
<th>Children Alone</th>
<th>Children with Guardians</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Speed</strong></td>
<td>5.6 (1.7)</td>
<td>4.7 (1.4)</td>
<td>19.1%</td>
</tr>
<tr>
<td><strong>15th Percentile Speed</strong></td>
<td>4.0 (1.2)</td>
<td>3.7 (1.1)</td>
<td>8.1%</td>
</tr>
<tr>
<td><strong>Median Speed</strong></td>
<td>5.0 (1.5)</td>
<td>4.5 (1.4)</td>
<td>11.1%</td>
</tr>
<tr>
<td><strong>85th Percentile Speed</strong></td>
<td>6.8 (2.1)</td>
<td>5.6 (1.7)</td>
<td>21.4%</td>
</tr>
</tbody>
</table>

Unit: ft/sec (m/sec)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Count</th>
<th>Average Speed</th>
<th>Variance</th>
<th>p-value</th>
<th>Significant (p-value&lt;=0.15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children Alone</td>
<td>458</td>
<td>5.6 (1.7)</td>
<td>5.26 (1.60)</td>
<td>6.67029E-14</td>
<td>Yes</td>
</tr>
<tr>
<td>Children with Guardians</td>
<td>501</td>
<td>4.7 (1.4)</td>
<td>1.42 (0.43)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Unit: ft/sec (m/sec)
Pedestrian–Vehicle Crashes

- Based on 5-year crash data (2009-2013), 31% and 10% pedestrian crashes involved with left turn and right turn vehicles, respectively, in New York City.

<table>
<thead>
<tr>
<th>Vehicle Direction</th>
<th>Left Turn</th>
<th>Right Turn</th>
<th>Thru/Other</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian Crashes</td>
<td>14,474</td>
<td>4,517</td>
<td>27,874</td>
<td>46,865</td>
</tr>
<tr>
<td>Percentage (%)</td>
<td>31</td>
<td>10</td>
<td>59</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: NYSDOT/NYSDMV Accident Database
Intersection Conflicts

- **Driver Perspective**
  - Conflicts with Opposing Traffic
  - Turning (left and right turn) conflicts with Pedestrians

- **Pedestrian Perspective**
  - Left or Right Turn Conflicts with Pedestrians
  - Pedestrian interactions with opposing flow
Elderly citizens were more vulnerable to fatality crashes with turning vehicles, especially with left turn vehicles, while young age (11-30) groups showed higher fatality crashes with right turn vehicles.

Source: Left-turn study, NYC DOT (2015)
### Video Tracking of Near-side Turning Vehicle Movements

<table>
<thead>
<tr>
<th>Location</th>
<th>Image</th>
<th>Location</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="#" alt="Location 1" /></td>
<td>Flatbush Ave./Fulton St. (North)</td>
<td><img src="#" alt="Location 3" /></td>
</tr>
<tr>
<td>2</td>
<td><img src="#" alt="Location 2" /></td>
<td>Queens Blvd./Van Dam St. (South)</td>
<td><img src="#" alt="Location 4" /></td>
</tr>
<tr>
<td>3</td>
<td><img src="#" alt="Location 3" /></td>
<td>46th St./7th Ave. (South)</td>
<td><img src="#" alt="Location 4" /></td>
</tr>
<tr>
<td>4</td>
<td><img src="#" alt="Location 4" /></td>
<td>49th St./7th Ave. (West)</td>
<td><img src="#" alt="Location 4" /></td>
</tr>
</tbody>
</table>
The average exit speeds at study locations ranged from 11.2 (7 mph) to 14.4 km/hr (9 mph).
The conflicts between illegal pedestrian crossings and high-speed vehicles are most likely to occur in a narrower zone at the upstream stop line, but a wider conflict zone at the exit crosswalks.

<table>
<thead>
<tr>
<th>Turning Vehicle Distance from Curb</th>
<th>Turning Vehicle Speeds</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
</tr>
<tr>
<td><strong>46th St./7th Ave.</strong></td>
<td><strong>Queens Blvd./Van Dam St.</strong></td>
</tr>
</tbody>
</table>

![Graph](image3.png)  ![Graph](image4.png)

**Initial Stop Bar** ➔ **Middle of the corner** ➔ **Crosswalk Edge**
Trajectories of observed turning vehicles showed substantial variations in the pre-peak hour and peak period as well as downstream congestion of turning vehicles.

<table>
<thead>
<tr>
<th>Location 1: Flatbush Ave./Fulton St.</th>
<th>7-8 AM</th>
<th>7-9 AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location 2: Queens Blvd./Van Dam St.</td>
<td>7-8 AM</td>
<td>7-9 AM</td>
</tr>
<tr>
<td>Location 3: 46th St./7th Ave.</td>
<td>7-8 AM</td>
<td>7-9 AM</td>
</tr>
<tr>
<td>Location 4: 49th St./7th Ave.</td>
<td>7-8 AM</td>
<td>7-9 AM</td>
</tr>
</tbody>
</table>
# One-Way ANOVA & Post Hoc Test Summary

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Speed (km/hr)</th>
<th>Standard Deviation</th>
<th>15\textsuperscript{th} Percentile (km/hr)</th>
<th>85\textsuperscript{th} Percentile (km/hr)</th>
<th>F-Statistic</th>
<th>F-Critical</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flatbush Ave./ Fulton St.</td>
<td>13.7</td>
<td>4.2</td>
<td>9.7</td>
<td>16.3</td>
<td></td>
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<tr>
<td>Queens Blvd./ Van Dam St.</td>
<td>13.5</td>
<td>2.8</td>
<td>10.1</td>
<td>15.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49\textsuperscript{th} St./ 7\textsuperscript{th} Ave.</td>
<td>14.4</td>
<td>3.7</td>
<td>11.9</td>
<td>16.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46\textsuperscript{th} St./ 7\textsuperscript{th} Ave.</td>
<td>11.2</td>
<td>2.2</td>
<td>8.9</td>
<td>13.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Locations except 46\textsuperscript{th} St./ 7\textsuperscript{th} Ave.</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>1.19</td>
<td>3.04</td>
<td>0.31</td>
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</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>t value</th>
<th>t Critical two-tail</th>
<th>P(T&lt;=t) two-tail</th>
<th>Bonferroni Correction Significance level</th>
<th>Post Hoc Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flatbush Ave./ Fulton St. vs. Queens Blvd./ Van Dam St.</td>
<td>0.3450</td>
<td>1.9803</td>
<td>0.7307</td>
<td>[0.0125]</td>
<td>False</td>
</tr>
<tr>
<td>Flatbush Ave./ Fulton St. vs. 49\textsuperscript{th} St./ 7\textsuperscript{th} Ave.</td>
<td>-1.1117</td>
<td>1.9766</td>
<td>0.2681</td>
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<td>False</td>
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<tr>
<td>Flatbush Ave./ Fulton St. vs. 46\textsuperscript{th} St./ 7\textsuperscript{th} Ave.</td>
<td>3.3728</td>
<td>1.9826</td>
<td>0.0010</td>
<td>[0.0125]</td>
<td>True</td>
</tr>
<tr>
<td>Queens Blvd./ Van Dam St. vs. 49\textsuperscript{th} St./ 7\textsuperscript{th} Ave.</td>
<td>-1.6611</td>
<td>1.9799</td>
<td>0.0993</td>
<td></td>
<td>False</td>
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<tr>
<td>Queens Blvd./ Van Dam St. vs. 46\textsuperscript{th} St./ 7\textsuperscript{th} Ave.</td>
<td>4.0180</td>
<td>1.9893</td>
<td>0.0001</td>
<td></td>
<td>True</td>
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<tr>
<td>49\textsuperscript{th} St./ 7\textsuperscript{th} Ave. vs. 46\textsuperscript{th} St./ 7\textsuperscript{th} Ave.</td>
<td>5.6125</td>
<td>1.9822</td>
<td>0.0000</td>
<td></td>
<td>True</td>
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</tbody>
</table>
Pedestrians often understood FDW time as an extension of pedestrian Walk time and non-compliance rates on FDW ranged from 14.3% to 26.9% during the PM peak hour.

Noncompliance rates on crosswalk and corner area were from 3.2% to 21.9% and from 5.0% to 46.0%, respectively. Approximately 46.0% stood in the parking lane at northwest corner, Madison Avenue and 42nd Street.
Among the study locations, the lowest pedestrian noncompliance percentages on crosswalk area & FDW and steady DW intervals occurred at longer crosswalk with crossing distance of approximately 70-foot and very long Walk time (Ped Timing 1) of 69 seconds.

Third Avenue and 34th Street with same crosswalk length was identified with high noncompliance rates in those categories because there were vehicles occupying the crosswalk and relatively shorter Walk time (Ped. Timng 2).
Pedestrian noncompliance rates at corner waiting areas were highest far-side crosswalk ("F") in a one-way street approach, when the distance ("D") between the approach stop bar and the opposing crosswalk is longer.

A near-side crosswalk from approaching traffic without a parking lane caused pedestrians to remain in the corner waiting area ("X") but induced higher noncompliance on pedestrian Walk time when pedestrians perceived that Walk time is not enough.
Control Policy Score for Pedestrian Safety and Mobility

- Protecting Signal Timing for Pedestrians
  - Leading Pedestrian Interval (LPI)
  - Split Phase
  - Split LPI
  - Barnes Dance
- Turn Prohibitions
- Curb Extension and Safety Island
- Signal Timing Modification (Walk & Flashing DW)
- Exclusive Turn Lanes
- Others
Case Study: Downtown Flushing

Downtown Flushing

Downtown Flushing is a thriving community with a dense concentration of businesses and residents. The area serves as one of the largest intermodal transportation hubs in New York City with the 7 train, the Long Island Rail Road, 20 bus routes, and commuter vans all converging in the downtown. Sidewalks and roadways are congested. Pedestrian traffic regularly spills into the street in many areas, disrupting traffic and posing safety risks. Of particular concern was the intersection of Union Street and Northern Boulevard, which had the greatest number of crashes with pedestrian injuries in the entire borough.

To ease congestion and improve safety in Downtown Flushing, DOT worked with Community Board 7, local business owners and elected officials to analyze and discuss several options to improve pedestrian and traffic safety and reduce congestion. The MTA and NYCEDC were also important partners in the study.

Reorganizing traffic and buses in downtown Flushing improved safety and reduced congestion for all street users.

- Relocated bus stops and sidewalks to reduce the number of pedestrians entering the street.
- Expanded sidewalks to reduce pedestrian overcrowding.
- Turn prohibitions eliminated vehicle-pedestrian and vehicle-vehicle conflicts and improved traffic operations.

Facing north on Main Street at Roosevelt Avenue

Source: Sustainable Streets Index 2012, NYC DOT

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Changes in Travel Time</th>
<th>% Change</th>
</tr>
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<tbody>
<tr>
<td>Morning Commuter Peak Hour</td>
<td>Before</td>
<td>7%</td>
</tr>
<tr>
<td>Morning Commuter Peak Hour</td>
<td>After</td>
<td>2%</td>
</tr>
<tr>
<td>Midday Weekday Peak Hour</td>
<td>Before</td>
<td>3%</td>
</tr>
<tr>
<td>Midday Weekday Peak Hour</td>
<td>After</td>
<td>0%</td>
</tr>
<tr>
<td>Midday Weekday Weekday</td>
<td>Before</td>
<td>15%</td>
</tr>
<tr>
<td>Midday Weekday Weekday</td>
<td>After</td>
<td>14%</td>
</tr>
</tbody>
</table>

Crashes with Injuries

<table>
<thead>
<tr>
<th>Category</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrians</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Bicycles</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Motorists-Injuries</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>Motorists-Crashes</td>
<td>25</td>
<td>31</td>
</tr>
<tr>
<td>Motorists-Pedestrians</td>
<td>45</td>
<td>42</td>
</tr>
<tr>
<td>Motorists-Bicycles</td>
<td>61.6</td>
<td>62.5</td>
</tr>
</tbody>
</table>

Data is based on the years 2007-2010 and includes crashes where at least one of the involved parties was injured. Data is provided by the New York City Department of Transportation and is subject to change.