MARKED CROSSWALKS & ENHANCEMENTS
Problem and Background

- High pedestrian crash rate due to wide, fast roadways
- Six- to eight-lane roads
- 45 mph speed limits
- Among the highest pedestrian fatalities in the nation
- Wanted to improve pedestrian infrastructure and provide a safer environment for vulnerable road users

Source: Pedro Venda, panoramio.com
Solution

- City worked with the FHWA to identify, install & evaluate various safety countermeasures
- 18 sites identified
  - 14 received countermeasures
  - 4 served as control locations
- Multiple countermeasures deployed at each site:
  - warning signs, advance yield markings, lighted pedestrian pushbuttons, high-visibility crosswalks, median refuges, automated pedestrian detection, speed trailers
CASE STUDY: CROSSWALKS & ENHANCEMENTS (LAS VEGAS, NV)

Results

- Motorist yielding rates & pedestrian safety improved
- At one site, 11% of vehicles blocked the crosswalk before turning
  - After a "TURNING VEHICLES YIELD TO PEDESTRIANS" sign installed, no motorists blocked the crosswalk
- Number of pedestrians who looked for turning vehicles during the WALK increased with the sign
- Combining pedestrian safety countermeasures led to major increases in pedestrian safety
- City encouraged by results and hopes to further implement improvements
1-118 – Crosswalk

- (a) That part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs, or in the absence of curbs, from the edges of the traversable roadway; and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the existing sidewalk at right angles to the centerline.

- (b) Any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface.

UVC – CROSSWALK DEFINITION
Sec. 541.302. TRAFFIC AREAS. In this subtitle:

(2) "Crosswalk" means:

(A) the portion of a roadway, including an intersection, designated as a pedestrian crossing by surface markings, including lines; or

(B) the portion of a roadway at an intersection that is within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or, in the absence of curbs, from the edges of the traversable roadway.

(14) "School crosswalk" means a crosswalk designated on a street by a local authority to facilitate safe crossing of the street by children going to or leaving a public or private elementary or secondary school.
HOW MANY CROSSWALKS DO YOU SEE?

Intersection 1

Intersection 2
WHY ARE MARKED CROSSWALKS PROVIDED?

- To indicate to pedestrians where to cross
- To indicate to drivers where to expect pedestrians
- At mid-block locations, crosswalk markings legally establish the crosswalk.
WHEN ARE MARKED CROSSWALKS PROVIDED?

MUTCD Section 3B.18 Crosswalk Markings

Guidance:

- At locations controlled by traffic control signals or on approaches controlled by STOP or YIELD signs, crosswalk lines should be installed where engineering judgment indicates they are needed to direct pedestrians to the proper crossing path(s).
Guidance

- Crosswalk lines should not be used indiscriminately.
- An engineering study should be performed before a marked crosswalk is installed at a location away from a traffic control signal or an approach controlled by a STOP or YIELD sign.

The engineering study should consider:

- Number of lanes
- Presence of a median
- Distance from adjacent signalized intersections
- Pedestrian volumes & delays
- Average daily traffic (ADT)
- Posted speed limit or 85th-percentile speed
- Geometry
- Possible consolidation of multiple crossing points
- Street lighting
- Other appropriate factors
WHERE SHOULD MARKED CROSSWALKS BE PROVIDED?

- Uncontrolled locations?
- Stop controlled locations?
- Signalized locations?
## CROSSWALK INSTALLATION RECOMMENDATIONS

### Table 11. Recommendations for installing marked crosswalks and other needed pedestrian improvements at uncontrolled locations.*

<table>
<thead>
<tr>
<th>Roadway Type (Number of Travel Lanes and Median Type)</th>
<th>Vehicle ADT ≤ 9,000</th>
<th>Vehicle ADT &gt; 9,000 to 12,000</th>
<th>Vehicle ADT &gt; 12,000–15,000</th>
<th>Vehicle ADT &gt; 15,000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤ 48.3 km/h (30 mi/h)</td>
<td>56.4 km/h (35 mi/h)</td>
<td>64.4 km/h (40 mi/h)</td>
<td>64.4 km/h (40 mi/h)</td>
</tr>
<tr>
<td>Two lanes</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Three lanes</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>C</td>
</tr>
<tr>
<td>Multilane (four or more lanes) with raised median**</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Multilane (four or more lanes) without raised median</td>
<td>C</td>
<td>P</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

*C = Compliant  
P = Possibly compliant  
N = Not compliant. Markings should not be installed without additional safety treatments
Guidance

- New marked crosswalks without other measures designed to reduce traffic speeds, shorten crossing distances, enhance driver awareness of the crossing, and/or provide active warning of pedestrian presence, should not be installed across uncontrolled roadways where the speed limit exceeds 40 mph and either:
  - The roadway has four or more lanes of travel without a raised median or pedestrian refuge island and an ADT of 12,000 vehicles per day or greater; or
  - The roadway has four or more lanes of travel with a raised median or pedestrian refuge island and an ADT of 15,000 vehicles per day or greater.
### Table 1 - Proposed DC Uncontrolled Crosswalk Engineering Treatments

<table>
<thead>
<tr>
<th>Roadway Configuration</th>
<th>1,500 - 9,000 vpd</th>
<th>9,000 - 12,000 vpd</th>
<th>12,000 - 15,000 vpd</th>
<th>&gt; 15,000 vpd</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Lanes</td>
<td>A</td>
<td>A</td>
<td>A or B</td>
<td>B or C</td>
</tr>
<tr>
<td>2 Lanes with CTL</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B or C</td>
</tr>
<tr>
<td>2 Lanes One Way</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>4 Lanes w/raised Median</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>3 Lanes No Median</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>5 Lanes w/raised Median</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>6 Lanes w/raised Median</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>4 Lanes No Median</td>
<td>B</td>
<td>B or C</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>5 Lanes No Median</td>
<td>B</td>
<td>B or C</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>6 Lanes No Median</td>
<td>B</td>
<td>B or C</td>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>

**Volumes Below 1500 vpd**
- Treatment A: Parallel Crosswalk and/or W11-2 assembly
- Treatment B: High Visibility Crosswalk and Side of Street Ped Law Sign
- Treatment C: In-Street Stop For Peds Sign and/or Traffic Calming
- Treatment D: Activated Pedestrian Device (RRFB, In-road LEDs, etc.)
- Something with a red signal (Ped Hybrid, Full Signal)
Do a crosswalk Inventory based on set criteria
  - Improves defense during lawsuits
  - Consistency
  - Seattle, WA did evaluation of all crosswalks after Zegeer study published

District of Columbia crosswalk reviews
  - Resurfacing projects
  - System wide evaluations
  - Corridor Analysis
  - Individual requests
What factors are taken into consideration for installation of marked crosswalks in your agency/region?
High-visibility crosswalks have been associated with a 40% decrease in pedestrian crashes (Signal and Non-signal in NYC).\(^{(1)}\)

In school zones, a decrease of 37% observed in San Francisco.\(^{(2)}\)

**RESEARCH**


Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations
Final Report and Recommended Guidelines


TECHBRIEF
Crosswalk Marking Field Visibility Study

ANY ISSUES WITH THESE CROSSWALKS?
**SECTION 3B.18**
CROSSWALK MARKINGS

- **Standard:**
  When crosswalk lines are used, they shall consist of solid white lines that mark the crosswalk. They shall not be less than 6 inches or greater than 24 inches in width.
Guidance

- If transverse lines are used to mark a crosswalk, the gap between the lines should not be less than 6 feet.
Guidance

- Transverse lines, if used on both sides of the crosswalk, should extend across the full width of pavement or to the edge of the intersecting crosswalk to discourage diagonal walking between crosswalks (see Figures 3B-17 and 3B-19).
Option:

- For added visibility diagonal or longitudinal lines may be used to mark the crosswalk
- When diagonal or longitudinal lines are used, transverse lines may be omitted
**SECTION 3B.18**

**CROSSWALK MARKINGS**

**Guidance:**

- *If used, the diagonal or longitudinal lines should be 12 to 24 inches wide and separated by gaps of 12 to 60 inches*
Guidance:
- The design of the lines and gaps should avoid the wheel paths if possible, and the gap between the lines should not exceed 2.5 times the width of the diagonal or longitudinal lines.

Benefits
- Less maintenance
- Longer service life
- Ultimately lower cost
Although the MUTCD provides for design options, research and observation indicate that the continental and ladder designs are the most visible to drivers.

These “longitudinal” markings also improve guidance for pedestrians with low vision and cognitive impairments.
California
- 4’x4’x4’

Benefits
- Higher friction than some markings materials
- Wheelchairs, walkers don’t have the slight bump
NATIONAL MUTCD COMPLIANT?
NATIONAL MUTCD COMPLIANT?
NATIONAL MUTCD COMPLIANT?
Guidance:

- Crosswalk markings should be located so that the curb ramps are within the extension of the crosswalk markings.
Detectable warning surfaces are required by 49 CFR, Part 37 and by the Americans with Disabilities Act (ADA) where curb ramps are constructed at the junction of sidewalks and the roadway, for marked and unmarked crosswalks.

Detectable warning surfaces contrast visually with adjacent walking surfaces, either light-on-dark, or dark-on-light.
Two Ramps in line with pedestrian zone ideal

- PROWAG
  - 1 Ramp should be design exception

- Level landings:
  - Top - 4’x4’
  - Bottom - if single ramp making turn 4’x4’
RAMP GRADE

- Recommended maximum grade to allow for construction tolerance – 7.1%
- Maximum grade – 8.3%
- Least slope possible is preferred
- When “chasing grade,” ramp length need not exceed 15’, but slope must be uniform (PROWAG)
Abrupt changes of grade are difficult to use and can cause wheelchairs to flip over backward or forward.
- Ramp alignment is important to the stability of the wheelchair.
- Important grade changes take place at right angles
  - If not, a wheelchair becomes unstable and may tip
R302.6 Cross Slope. Exception as provided in R302.6.1 and R302.6.2, the cross slope of pedestrian access routes shall be 2 percent maximum.

- **R302.6.1 Pedestrian Street Crossings Without Yield or Stop Control.** Where pedestrian access routes are contained within pedestrian street crossings without yield or stop control, the cross slope of the pedestrian access route shall be 5 percent maximum.

- **R302.6.2 Midblock Pedestrian Street Crossings.** Where pedestrian access routes are contained within midblock pedestrian street crossings, the cross slope of the pedestrian access route shall be permitted to equal the street or highway grade.
GUTTER SLOPE
(PARALLEL TO THE CURB AND THE ROADWAY)

- Slope should not exceed 2% at the curb ramp*
  - But some slope is needed for drainage
For other crosswalk types, costs tend to vary by a large amount. For instance, for crosswalks using other materials such as brick or pavement scoring, costs range from $7.25 to $15 per square foot, or approximately $2,500 to $5,000 each. Ladder crosswalks cost range from $350 to $1,000 each and patterned concrete crosswalks cost $3,470 each or $9.68 per square foot on average.
ENHANCEMENTS: VIEW ADDITIONAL MODULES IN WORKSHOP
ADVANCE MARKINGS

- Advance PED XING or SCHOOL pavement stencils
- Advance solid lane lines
ADVANCE, OVERHEAD & CROSSWALK SIGNS
ADVANCE STOP AND YIELD LINES

- Optional for uncontrolled crosswalks
- 20 to 50 ft in advance of crosswalk
- YIELD vs. STOP – must match State law
- Stop line for “Stop Here For Pedestrians”, Yield line for “Yield Here for Pedestrians”
TWO-STAGE CROSSING ISLAND
RAISED CROSSWALKS

- FHWA Study “The Effects of Traffic Calming Measures on Pedestrian and Motorist Behavior” - 2001
- Increase pedestrian visibility & more effective when combined with an overhead flashing light
- For low speed local streets
- Should not be used on emergency routes, bus routes, or high speed streets
- Storm water runoff and snow plowing considerations

Figure 6. Raised crosswalk and overhead flasher, Towerview Drive, Durham, North Carolina.
## Table 8. Comparison of Vehicle Speeds at the Treatment and Control Sites.

<table>
<thead>
<tr>
<th>CITY AND TREATMENT</th>
<th>50TH PERCENTILE SPEED TREATMENT SITE</th>
<th>50TH PERCENTILE SPEED CONTROL SITE</th>
<th>DIFFERENCE IN SPEEDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durham, NC – Research Drive Raised crosswalk</td>
<td>33.3 km/h (20.7 mi/h)</td>
<td>39.8 km/h (24.7 mi/h)</td>
<td>6.5 km/h (4.0 mi/h) *lower at treatment site SIGNIFICANT¹</td>
</tr>
<tr>
<td>Durham, NC – Towerview Drive Raised crosswalk &amp; overhead flasher</td>
<td>18.5 km/h (11.5 mi/h)</td>
<td>38.4 km/h (23.9 mi/h)</td>
<td>19.9 km/h (12.4 mi/h) *lower at treatment site SIGNIFICANT</td>
</tr>
<tr>
<td>Montgomery County, MD² Raised Crosswalk</td>
<td>34.6 km/h (21.5 mi/h)</td>
<td>38.6 km/h (24.0 mi/h)</td>
<td>4.0 km/h (2.5 mi/h) NOT SIGNIFICANT</td>
</tr>
</tbody>
</table>

¹ Significant at the 0.05 level or better, using a two-tailed test.
² Vehicle speeds in Montgomery County were measured only when the staged pedestrian was present.

## Table 9. Pedestrians for Whom Motorists Stopped to Let Them Cross.

<table>
<thead>
<tr>
<th>SITE AND TREATMENT</th>
<th>TREATMENT SITE</th>
<th>CONTROL SITE</th>
<th>SIGNIFICANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durham, NC — Towerview Dr Raised crosswalk and overhead flasher</td>
<td>79.2% (159)*</td>
<td>31.4% (35)</td>
<td>• (0.000)</td>
</tr>
<tr>
<td>Montgomery County, MD Raised crosswalk</td>
<td>1.2% (169)</td>
<td>1.0% (198)</td>
<td>N</td>
</tr>
</tbody>
</table>
LIGHTING

- Coordinate streetlights with crosswalk markings
- Lights on both sides of street provide better uniformity
- Street lights should be installed on approaches to crosswalks for best results
DESIGN AND OPERATION ISSUES
LIGHTING BOTH SIDES OF CROSSING

Informational Report on Lighting Design for Midblock Crosswalks FHWA-HRT-08-053 April 2008

Fig 11. Traditional midblock crosswalk lighting layout
Fig 12. New design for midblock crosswalk lighting layout

Recommended lighting level: 20 lux at 5’ above pavement

Interpretation Letter 2-563(I)
Pedestrian Flags for Crosswalks
April 27, 2005  Refer to: HOTO-1
Dear Ms. Varney:
Thank you for your February 15 request to experiment with the pedestrian flag education and awareness campaign to improve the safety of pedestrians at crosswalks. We have reviewed your request and determined that the pedestrian flag is not a traffic control device. Therefore, you do not need to request approval from the Federal Highway Administration (FHWA) to experiment with the flag. The flag concept described in your letter is similar to the concept of placing retroreflective material on clothing. Although it is not a traffic control device, it is a way to increase the visibility of pedestrians.

http://mutcd.fhwa.dot.gov/resources/interpretations/2_563.htm
NCHRP Report 562 Page 20

- Moderately effective Salt Lake City UT and Kirkland WA
- Yielding rates from 46% to 79%
- Speed limits of 30 mph or less

Things to consider

- Flags get stolen
- Redistribution at corners
  - Neighborhood or business volunteers
- Some flag holder designs are used as garbage cans

How many are involved with material specs, inspecting or installing?
CROSSWALK MARKING MATERIALS

Less Durable

- Paint
  - Water borne
  - Oil-based

More Durable

- Epoxy
- Polyurea
- Thermoplastic
- Pre-formed marking tape

Guide for Maintaining Pedestrian Facilities for Enhanced Safety
FACTORS FOR CHOOSING MATERIAL

- Cost to install and maintain
- Durability
- Retroreflectivity (6 lbs. of glass beads per gallon of paint)
- Friction coefficient (avoiding slippery surface)
- Applied using existing agency labor and equipment or contractor
- Ability to remove markings if changes occur
Most communities use thermoplastic, which is recommended for its longevity.

Many frequently use paint on existing roads or when there is an immediate need.

Epoxy was also mentioned by a number of communities.

Thermoplastic and epoxy markings are used most often on repaving projects.

Those communities that paint markings typically use city crews and equipment.

Communities commonly use contractors to install thermoplastic markings.
COMMON ISSUES WITH NON-DURABLE MARKINGS

- **Maintenance**
  - Re-striped several times a year based on the volume of traffic and the severity of weather.
  - To promote longer lifespan when using paint, a “high build grade” is recommended with glass beads for retroreflectivity.
  - “High build” uses an acrylic cross-linking emulsion that allows for applications of up to 20 mils.
Less durable in cold weather climates
- Where the roads are salted and sanded
- Abrasiveness of these materials will cause more rapid deterioration of markings
- Snow Plow Damage

Some thermoplastic markings and some pre-formed marking tapes can become more slippery with wear
- Manufacturers have significantly improved the friction factor of their materials
- Slippery markings make it necessary to replace the markings sooner.
Large percentage of pedestrian fatalities occur in the evening when conspicuity is reduced.

Crosswalk markings must retain their retroreflectivity, usually accomplished by adding beads or other retroreflective material to marking material.

When the markings wear, the retroreflective quality of the material is often lost first.

Recommend methods established in the MUTCD and described on this website to check for the proper retroreflectivity of crosswalks: [http://safety.fhwa.dot.gov/roadway_dept/night_visib/pavementreg.cfm](http://safety.fhwa.dot.gov/roadway_dept/night_visib/pavementreg.cfm)
- Involves two-part system using a simple mixture of two bonding components
- Most significant downside is its application requires specialized equipment
  - Some states, only a handful of vendors have the specialized equipment
- Sandblasting of pavement is normally required to remove existing materials
- Some epoxies have a relatively long cure time (up to 45 minutes depending on ambient conditions)
Durable and good color stability
- 3 to 5 years service life
Good abrasion resistance
Cures in 2 minutes or less
Requires special striping apparatus
Experimental application by some agencies
- Epoxy truck
Durability

- Snowplows often damage thermoplastic markings
- Can recess markings to decrease the likelihood of snowplow damage, but this is very expensive

Successful use of pre-formed thermoplastic relies on applying the material to a dry, clean surface nearly completely devoid of existing crosswalk material.
- This can complicate applications on existing pavement.

- More cost-effective in the long run
- Better option on rougher pavement surfaces
- More visible and less slippery than paint when wet
PRE-FORMED MARKING TAPE

- Most durable
- Highly retroreflective
- Long-lasting
- Slip-resistant
- Little to no maintenance
- Although initially more costly than paint more cost-effective in the long run
- Recommended for new and resurfaced pavement
- More visible and less slippery than paint when wet
BRICK OR PAVERS

- Not a crosswalk marking, but may be used for decorative purposes
- Must have reflectorized white lines on borders to qualify as marked crosswalk
- Expensive to replace if road or utility work cuts pavement
- Not comfortable for those in wheelchairs/strollers (bricks/pavers)
- Expensive to install and maintain
  - Pavers
  - Bowmanite materials
  - Stamped asphalt
  - Inlaid markings

In general, thermoplastics provide a life of two to three times that of paint for long lines,
- Costs averaged almost five times that of paint

Epoxy markings had a life of two to three times that of paint
- Cost four times that of paint

For life-cycle costs, paint was half the cost of thermoplastic
- Costs and durability ranged significantly in this study.
NEW PAVEMENT OR RESURFACING

Include the cost of long-lasting pavement marking materials in the contract.

- Installed by contractors
- Provides longest service life
- Added cost will be minimal to project
- Benefits maintenance budgets
### Figure 31: Relative comparison of crosswalk marking materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Relative Cost</th>
<th>Lifespan (months)</th>
<th>Retroreflectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint</td>
<td>$</td>
<td>3–24</td>
<td>*</td>
</tr>
<tr>
<td>Epoxy Paint</td>
<td>$$</td>
<td>24–48</td>
<td>**</td>
</tr>
<tr>
<td>Thermoplastic (sprayed)</td>
<td>$$</td>
<td>48–72*</td>
<td>**</td>
</tr>
<tr>
<td>Pre-formed Tape</td>
<td>$$$</td>
<td>36–96*</td>
<td>***</td>
</tr>
</tbody>
</table>

Note: Estimates based on minimum standard crosswalk treatment and updated to reflect 2013 comparative costs.\(^{16,17}\)

Thermoplastic and tape have shortened lifespans in snowy areas where they are often damaged by snowplows. Inlaid thermoplastic or pre-formed tape may last significantly longer than standard surface applications.
CASE STUDY
Problem and Background
- Aurora Ave lacked continuous sidewalks, signals & crosswalks
- Major north-south arterial
- 3 mile corridor
- High pedestrian traffic
- Crossing and travelling along roadway difficult and dangerous
Problem and Background

- Average ADT 45,000
- Major transit route
- Crash statistics among highest in the state
  - Percentage of fatal/disabling incidents twice the statewide average
  - Multiple spots along the corridor identified as high ped crash locations by state DOT
Solution

- Corridor improved in segments
  - Continuous curbs, 7-foot sidewalks, & better lighting added
  - Two pedestrian bridges built
- Two-way left-turn lane replaced by a center median with left-turn and U-turn pockets
- Pedestrian crossing islands, crosswalks and signals installed
- Business access/transit lane added to improve transit times, reduce conflicts
CASE STUDY: CROSSWALKS & ENHANCEMENTS (SHORELINE, WA)

Results

- Widely considered a success
- Businesses/citizens initially skeptical were satisfied with results
- In studies of first mile of improvements, officials found a more than 60 percent reduction in collisions for all roadway users
- Transit ridership increased dramatically

Source: FHWA, “Context Sensitive Solutions,”
Marked vs. Unmarked Crosswalks at Uncontrolled locations

Crosswalk Marking Field Visibility Study

MUTCD Section 3B.18

NCHRP Report 562 Page 20
  - Crossing flags

The Effects of Traffic Calming Measures on Pedestrian and Motorist Behavior – 2001
  - Raised Crosswalks

Informational Report on Lighting Design for Midblock Crosswalks
  - FHWA-HRT-08-053 April 2008

PedSafe
  - Case Studies
    - http://www.pedbikesafe.org/PEDSAFE/casestudies.cfm