PUBLIC WORKS DEPARTMENT
MEMORANDUM #2018 – 33

DATE: June 4, 2018

TO: Honorable Mayor Carol A. Dodge and City Council Members

FROM: James A. Hayes, AICP, City Manager JH
Rob Webber, MBA, Interim Director of Public Works RW

SUBJECT: **Council Study Session**
Street Program Integration

PURPOSE

Staff would like to discuss the benefits of closely integrating the street maintenance and improvement programs to maximize spending capacity within the CIP and CDBG funds and develop a plan for a comprehensive street maintenance program.

BACKGROUND

Effort to Date

- September 18, 2017 – Discussion of the Traffic Calming Policy and if changes need to be made
- November 20, 2017 – School Zone Safety Assessment Selection
- November 20, 2017 – Update on Traffic Calming public meeting process for Claude, Melody, 112th Place and Livingston
- February 5, 2018 – Residential Street Program presentation
- March 5, 2018 – Present findings of Traffic Calming Community Meeting for Claude and Melody
- May 14, 2018 – Resolution for Residential Street Program
- May 21, 2018 - Present findings of Traffic Calming Community Meeting for 112th Place and Livingston

The City has four different programs related to street maintenance and improvements and staff would like to closely integrate these programs to maximize spending benefits. The current CIP programs are:

CDBG - The Community Development Block Grant (CDBG) program is funded by the U.S. Department of Housing and Urban Development (HUD), and was created to improve the physical, economic and social conditions for low to moderate income populations. The main objectives of the program are to benefit low to moderate income persons; prevent or eliminate slum and blight conditions; or address an urgent community need.

Residential Street Program – The main objectives of this program is to improve the condition of residential streets throughout the City, work may include mill and asphalt overlay, chip seal asphalt treatment, and full reconstruction of roadways. In addition, the work includes concrete replacement adjacent to roadway prior to asphalt placement or treatment.

Concrete Program – This program repairs damage concrete within the City's sidewalk network, improve mobility by adding or repairing curb ramps, and replaces damaged cross pans.

School Zone – The purpose of this program is to provide planning and engineering services to better understand how school commuters use the transportation network around school areas and implement modifications to the right-of-way or school property to mitigate risks to users of the transportation network while traveling to and from schools.

Historically staff has tried to divide the work from all programs equally among the wards. When looking at the Residential Street Program, the proposed list presented to council divides the work on all wards based on amount of square yardage of street surface being done in the area or amount of total money spent. The Concrete Program is, for the most part, divided equally between the four wards based on the linear footage of concrete being replaced. For the School Zone Program council selects the schools to do during the budget year. Finally, the CDBG Program is based on the CDBG areas designated by Adams County, this program is the least flexible of the current street programs.

Since developing the traffic calming policy, it has been staffs intention to integrate all the street improvement programs. By combining the programs, staff believes the City will get better pricing during the bid process lowering construction cost and maximizing the spending power of the amount budgeted for each program. This approach will allow for a more comprehensive and robust overall project while at the same time providing cost savings due to a larger project scope within the proposed area. Staff would further develop a 5 -7 year plan that would show programmed work within the City.

BUDGET IMPLICATIONS

Proposed 2019 Budget

Program	CDBG	Residential Street	Concrete	School Zone
Fund	CDBG	ADCOT	ADCOT	General Fund
Budget	$200,000	$750,000	$100,000	$100,000
Objectives	Public facility and infrastructure improvements in target neighborhoods.	Citywide street maintenance and improvement.	Sidewalk maintenance and accessibility improvement.	Improve traffic flow and safety in areas around schools.
Current Work	Concrete replacement in targeted neighborhoods	Mill and Overlay and Chip Seal based on 2016 PCI information	Residential concrete replacement	GVA and Stukey Elementary Assessment
Future Work	Claude Court Striping (Northglenn Connect)	Mill and Overlay and Chip Seal based on 2016 PCI information	Residential concrete replacement	GVA and Stukey Elementary Improvements

In 2019 the City will complete the Pavement Condition Index (PCI), this will be the second time using radar technology. With new data, staff will be able to better determine the current rate of degradation to streets further assisting in developing a 5-7 year CIP plan.

In 2019 staff is proposing to use the 4 Mills to complete a mill and overlay and striping plan for Melody Drive which has a current PCI rating of 53. Estimated cost for the Mill and Overlay from 104th Avenue to Huron based on recent bids for similar work is $600,000.00. The estimated striping for the same section as presented at the community meeting is $300,000.00.

RECOMMENDATION/NEXT STEPS
Staff recommends the approval of this initiative and proposes to bring back a Resolution in July, 2018 for approval.

STAFF REFERENCE
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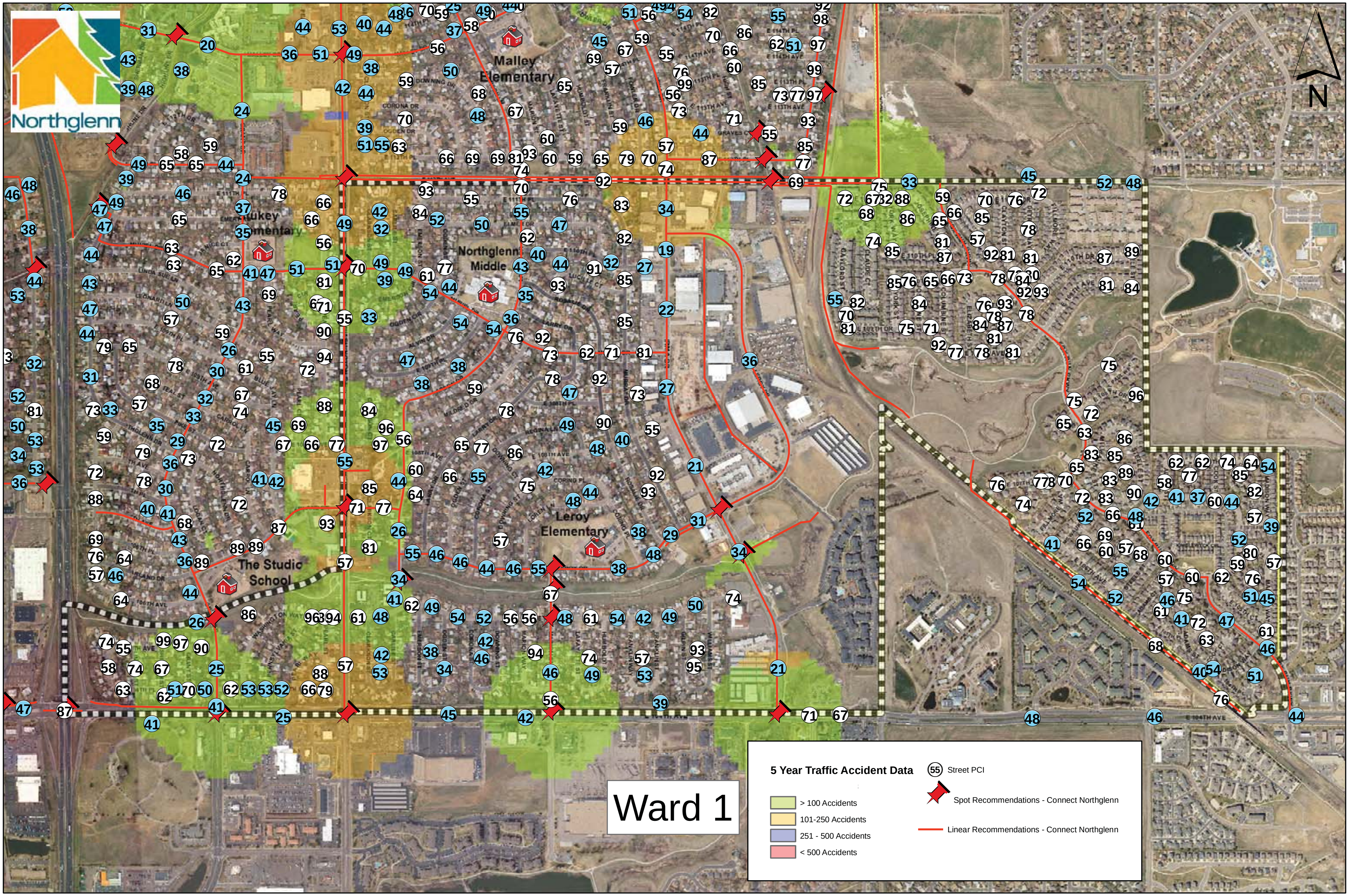
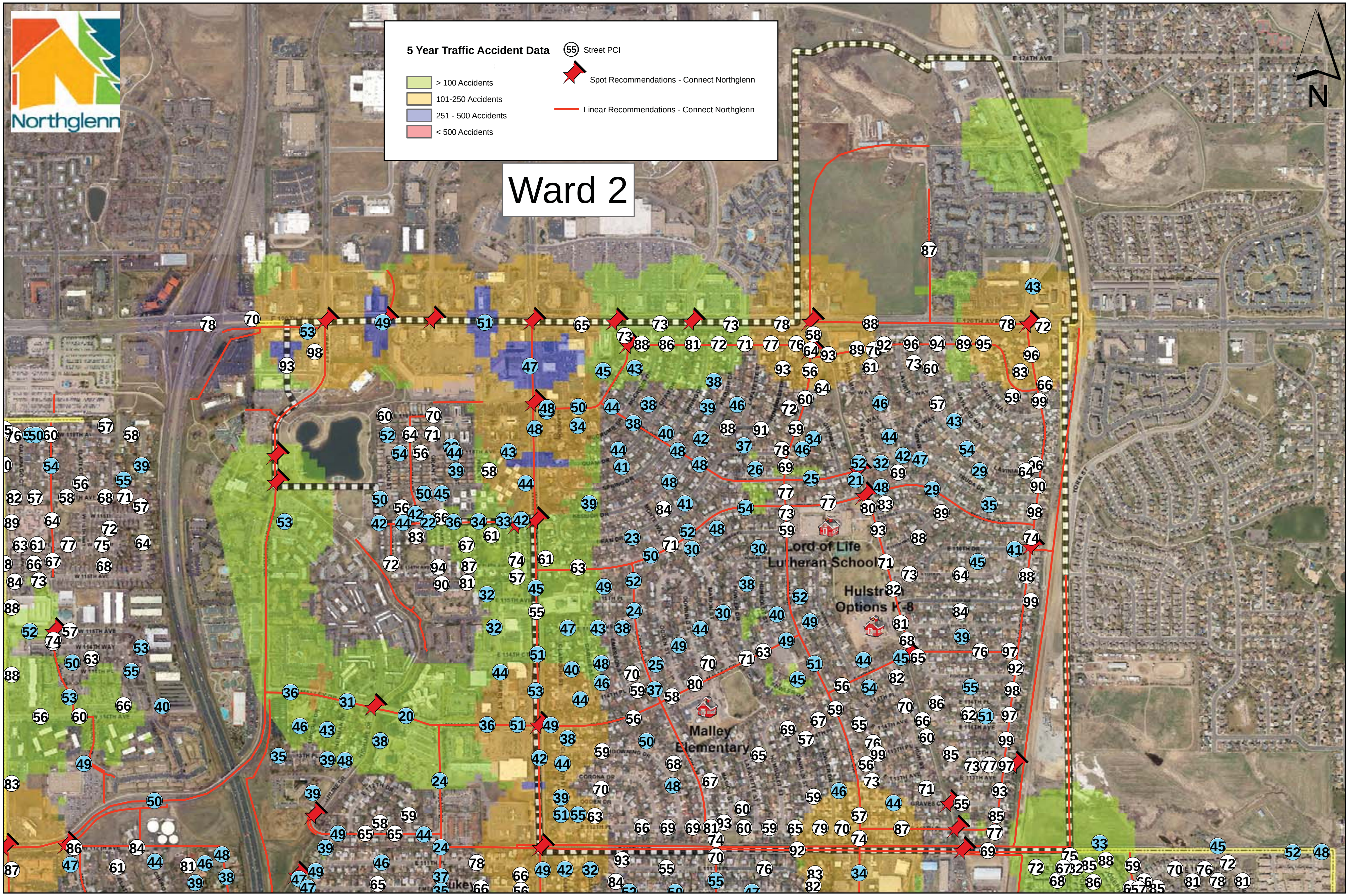
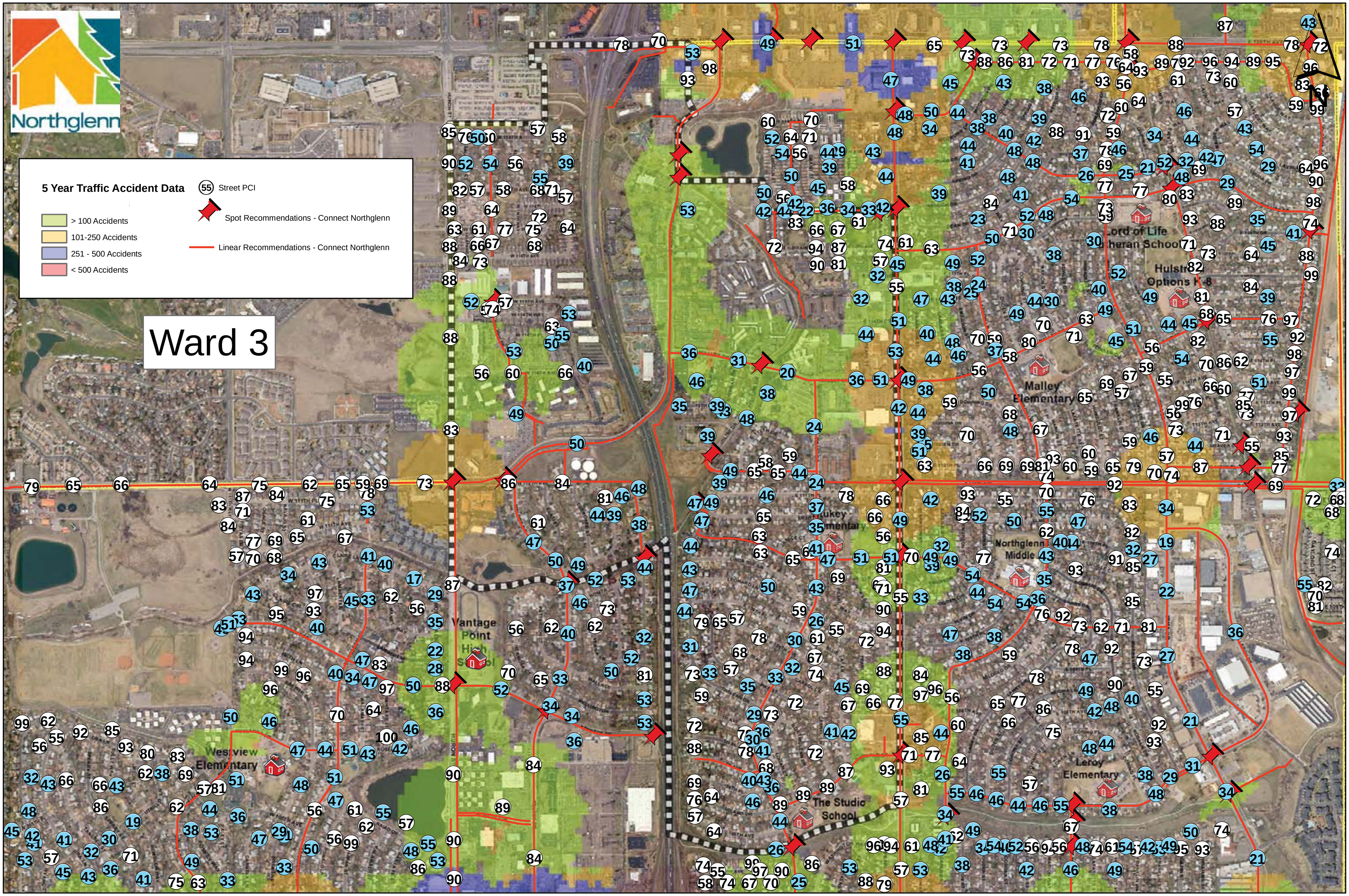
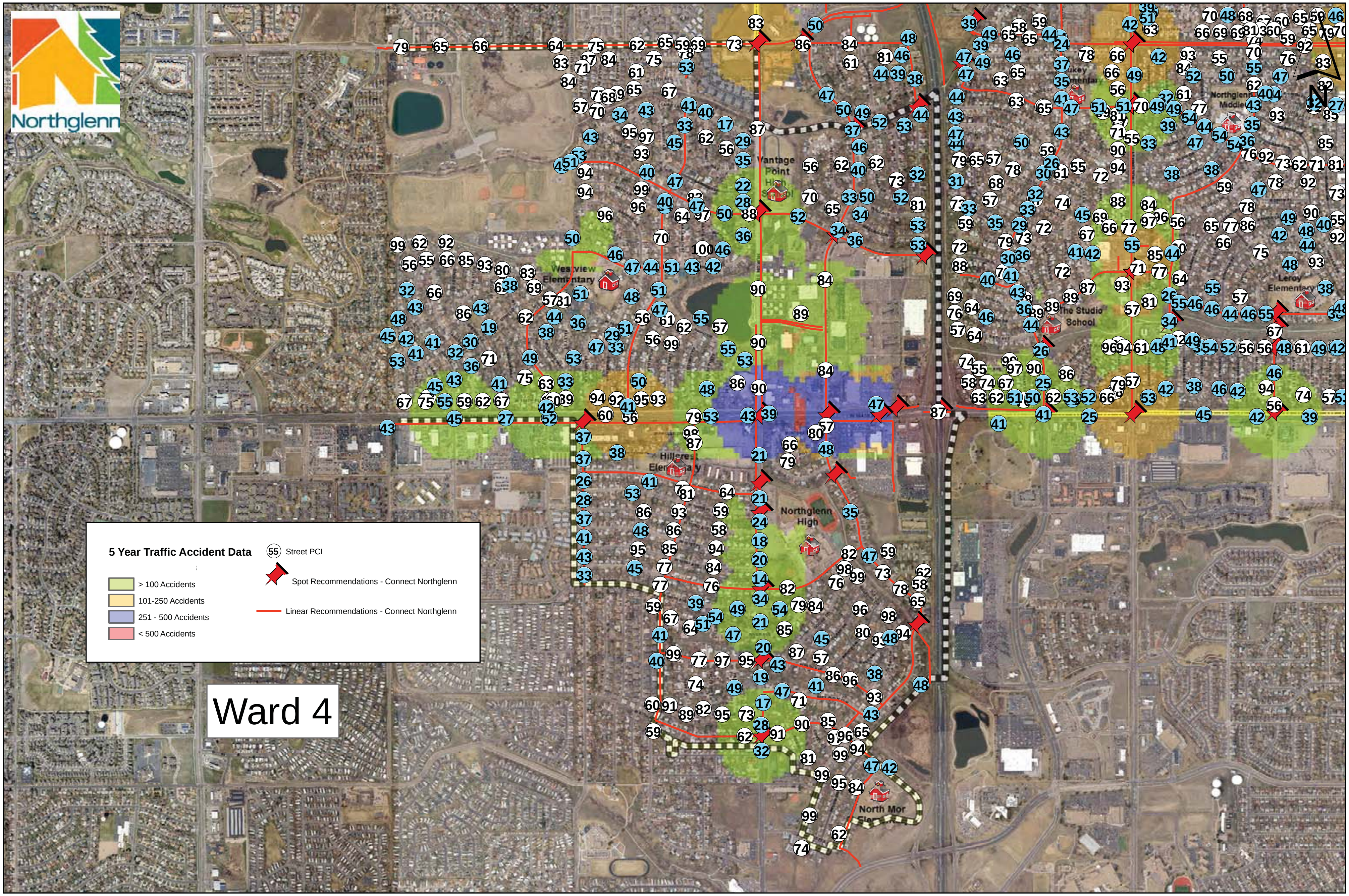
Daniel Martinez, PE, Civil Engineer II danmartinez@northglenn.org (303)450-8839

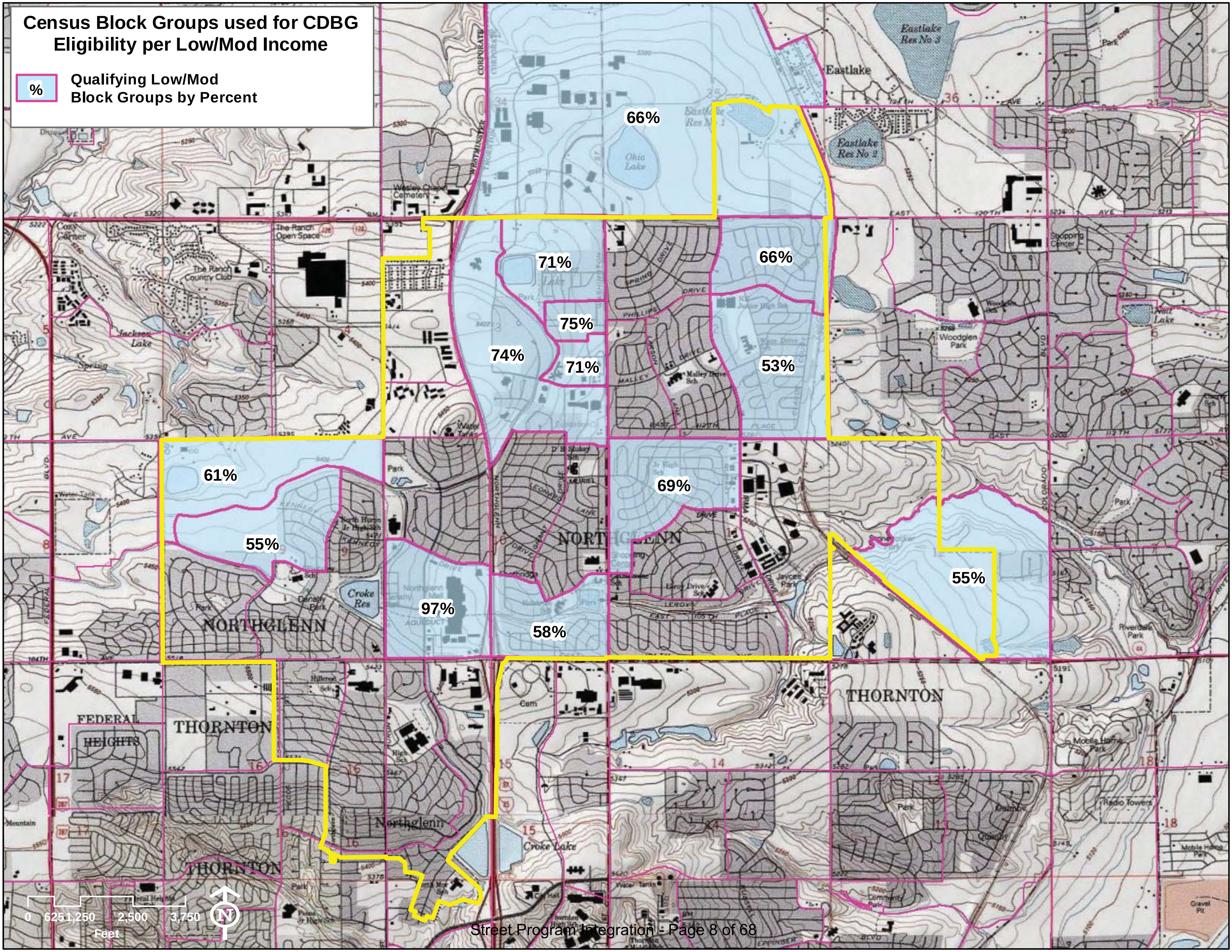
ATTACHMENTS
Ward Maps
CDBG Map
3D Crosswalk Package


Northglenn
N
Malley Elementary
Northglenn Middle
Leroy Elementary
The Studio School
Ward 1
5 Year Traffic Accident Data
> 100 Accidents
101-250 Accidents
251 - 500 Accidents
< 500 Accidents
55 Street PCI
Spot Recommendations - Connect Northglenn
Linear Recommendations - Connect Northglenn


Northglenn
5 Year Traffic Accident Data
> 100 Accidents
101-250 Accidents
251 - 500 Accidents
< 500 Accidents
55 Street PCI
Spot Recommendations - Connect Northglenn
Linear Recommendations - Connect Northglenn
Ward 2
N
Lord of Life Lutheran School
Malley Elementary


Northglenn
5 Year Traffic Accident Data
> 100 Accidents
101-250 Accidents
251 - 500 Accidents
< 500 Accidents
Street PCI
Spot Recommendations - Connect Northglenn
Linear Recommendations - Connect Northglenn
Ward 3
Vantage Point High School
Westview Elementary
Malley Elementary
Northglenn Middle
Leroy Elementary
The Studio School
Hulstrom Options K-8


Northglenn
5 Year Traffic Accident Data
55 Street PCI
> 100 Accidents
101-250 Accidents
251 - 500 Accidents
< 500 Accidents
Spot Recommendations - Connect Northglenn
Linear Recommendations - Connect Northglenn
Ward 4
Westview Elementary
Northglenn High
The Studio School
Leroy Elementary
N


Census Block Groups used for CDBG Eligibility per Low/Mod Income
%
Qualifying Low/Mod Block Groups by Percent
66%
71%
66%
75%
74%
71%
53%
61%
69%
55%
55%
97%
58%
NORTHGLENN
THORNTON
FEDERAL HEIGHTS
Northglenn
Eastlake
Ohio Lake
Croke Res
Croke Lake
0 625 1,250 2,500 3,750
Feet

Three Dimensional Crosswalk Markings

PURPOSE
This memo will outline available information regarding the effectiveness, cost, and applicability of 3D crosswalk markings.

BACKGROUND
During the May 21, 2018 study session, staff was directed to collect information on 3D crosswalk markings and assess the effectiveness, cost, and applicability of such an installation. Two studies, one completed and one nearing completion, were identified which provide relevant information.

Traffic Control Standards and Guidelines
The Federal Highway Administration (FHWA) has set forth standards and guidelines for traffic control through the Manual on Uniform Traffic Control Devices (MUTCD). This manual sets requirements for pedestrian crossing treatments as well as the use of colored pavements (or painted pavements). Additionally, in 2013 the FHWA released an official ruling regarding the application of colored pavement. The following is an excerpt with regard to colored pavement in crosswalks.

> "The FHWA's position has always been, and continues to be that subdued-colored aesthetic treatments between the legally marked transverse crosswalk lines are permissible provided that they are devoid of retroreflective properties and that they do not diminish the effectiveness of the legally required white transverse pavement markings used to establish the crosswalk. … All elements of pattern and color for these treatments are to be uniform, consistent, repetitive, and expected so as not to be a source of distraction. No element of the aesthetic interior treatment is to be random or unsystematic. No element of the aesthetic interior treatment can implement pictographs, symbols, multiple color arrangements, etc., or can otherwise attempt to communicate with any roadway user."

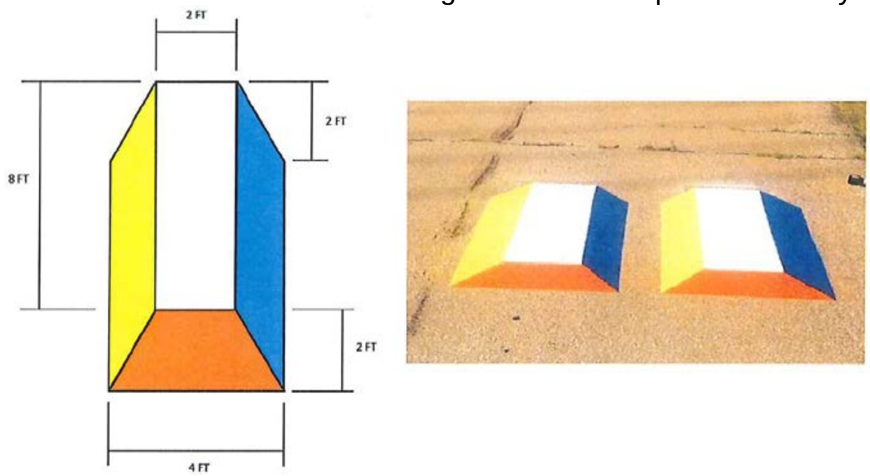
Effects of Symbol Prompts and 3D Pavement Illusions on Motorists Yielding at Crosswalks
This study, prepared by Nicole M. Cambridge of Western Michigan University, examined the effects of 3D pavement illusions as compared to 'Look for Pedestrians' markings. In this case illusions were used as part of the advanced warning for the crosswalk. This type of marking was conditionally approved for use in this study. While the illusions were initially effective at increasing yielding, over time as the 'novelty' reduced yielding rates normalized to match rates observed with the simpler 'Look for Pedestrians' markings.

3D Crosswalk Pavement Markings as used in Experiment/Study

Oklahoma Department of Transportation 3D Crosswalk Experiment/Study

The Oklahoma Department of Transportation (ODOT) was given permission by the Federal Highway Administration (FHWA) to experiment and study the results of implementing 3D crosswalk pavement markings. The main crosswalk markings used in this study do conform to MUTCD standards, however additional marking were added to give the crosswalk the appearance of being raised. This study is set to be reviewed and completed within the coming weeks. City staff has reached out to ODOT and will be sent the results of the study upon its completion and approval.

3D Crosswalk Pavement Markings as used in Experiment/Study



BUDGET IMPLICATIONS

MUTCD Approved Crosswalk Markings*	$750.00
3D Crosswalk Markings*	$2,150.00
"Look for Pedestrians" Marking**	$1,800.00
"Look for Pedestrians" w/ 3D Markings**	$4,750.00

*Estimate based on a midblock crossing installed on a normal width (~36') residential street by a City crew.
**Estimate based on four complete sets installed by a City crew.

RECOMMENDATION

Staff recommends that only MUTCD approved pavement markings are installed within the City. The use of 3D pavement markings should be reevaluated upon approval by the FHWA.

STAFF REFERENCE

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Kyle Kammermeier, Civil Engineer I kkammermeier@northglenn.org 303.450.4079

ATTACHMENTS

- MUTCD - Crosswalk Markings & Colored Pavement.docx
- MUTCD - Official Ruling 3(09)-24(I) - Application of Colored Pavement.pdf
- Effects of Symbol Prompts and 3D Pavement Illusions on Motorist Yielding at Crosswalks.pdf
- ODOT Experiment - Application to Experiment.pdf
- ODOT Experiment - FHWA Response.pdf
- 3D Crosswalk Visual
- Denver Crosswalk Articles

2009 Edition Chapter 3B. Pavement and Curb Markings

Section 3B.18 Crosswalk Markings

Support:
01 Crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops.

02 In conjunction with signs and other measures, crosswalk markings help to alert road users of a designated pedestrian crossing point across roadways at locations that are not controlled by traffic control signals or STOP or YIELD signs.

03 At non-intersection locations, crosswalk markings legally establish the crosswalk.

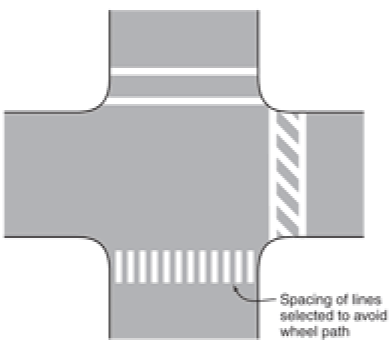
Standard:
04 **When crosswalk lines are used, they shall consist of solid white lines that mark the crosswalk. They shall not be less than 6 inches or greater than 24 inches in width.**

Guidance:
05 *If transverse lines are used to mark a crosswalk, the gap between the lines should not be less than 6 feet. If diagonal or longitudinal lines are used without transverse lines to mark a crosswalk, the crosswalk should be not less than 6 feet wide.*

06 *Crosswalk 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).*

Figure 3B-19 Examples of Crosswalk Markings

Figure 3B-19. Examples of Crosswalk Markings



07 *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).*

08 *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 the number of lanes, the presence of a median, the distance from adjacent signalized intersections, the pedestrian volumes and delays, the average daily traffic (ADT), the posted or statutory speed limit or 85th-percentile speed, the geometry of the location, the possible consolidation of multiple crossing points, the availability of street lighting, and other appropriate factors.*

09 *New marked crosswalks alone, 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:*

- A. *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*
- B. *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.*

Support:
10 Chapter 4F contains information on Pedestrian Hybrid Beacons. Section 4L.03 contains information regarding Warning Beacons to provide active warning of a pedestrian's presence. Section 4N.02 contains information regarding In-Roadway Warning Lights at crosswalks. Chapter 7D contains information regarding school crossing supervision.

Guidance:
11 *Because non-intersection pedestrian crossings are generally unexpected by the road user, warning signs (see Section 2C.50) should be installed for all marked crosswalks at non-intersection locations and adequate visibility should be provided by parking prohibitions.*

Support:
12 Section 3B.16 contains information regarding placement of stop line markings near crosswalk markings.

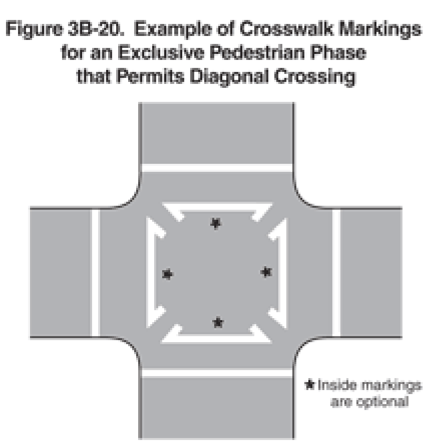
Option:
13 For added visibility, the area of the crosswalk may be marked with white diagonal lines at a 45-degree angle to the line of the crosswalk or with white longitudinal lines parallel to traffic flow as shown in Figure 3B-19.

14 When diagonal or longitudinal lines are used to mark a crosswalk, the transverse crosswalk lines may be omitted. This type of marking may be used at locations where substantial numbers of pedestrians cross without any other traffic control device, at locations where physical conditions are such that added visibility of the crosswalk is desired, or at places where a pedestrian crosswalk might not be expected.

Guidance:
15 *If used, the diagonal or longitudinal lines should be 12 to 24 inches wide and separated by gaps of 12 to 60 inches. 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.*

Option:
16 When an exclusive pedestrian phase that permits diagonal crossing of an intersection is provided at a traffic control signal, a marking as shown in Figure 3B-20 may be used for the crosswalk.

Figure 3B-20 Example of Crosswalk Markings for Exclusive Pedestrian Phase That Permits Diagonal Crossing



Guidance:
17 *Crosswalk markings should be located so that the curb ramps are within the extension of the crosswalk markings.*

Support:
18 Detectable warning surfaces mark boundaries between pedestrian and vehicular ways where there is no raised curb. 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. The "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11) contains specifications for design and placement of detectable warning surfaces.

2009 Edition Chapter 3G. Colored Pavements

Section 3G.01 General

Support:
01 Colored pavements consist of differently colored road paving materials, such as colored asphalt or concrete, or paint or other marking materials applied to the surface of a road or island to simulate a colored pavement.

02 If non-retroreflective colored pavement, including bricks and other types of patterned surfaces, is used as a purely aesthetic treatment and is not intended to communicate a regulatory, warning, or guidance message to road users, the colored pavement is not considered to be a traffic control device, even if it is located between the lines of a crosswalk.

Standard:
03 **If colored pavement is used within the traveled way, on flush or raised islands, or on shoulders to regulate, warn, or guide traffic or if retroreflective colored pavement is used, the colored pavement is considered to be a traffic control device and shall be limited to the following colors and applications:**

A. **Yellow pavement color shall be used only for flush or raised median islands separating traffic flows in opposite directions or for left-hand shoulders of roadways of divided highways or one-way streets or ramps.**
B. **White pavement color shall be used for flush or raised channelizing islands where traffic passes on both sides in the same general direction or for right-hand shoulders.**

04 **Colored pavements shall not be used as a traffic control device, unless the device is applicable at all times.**

Guidance:
05 *Colored pavements used as traffic control devices should be used only where they contrast significantly with adjoining paved areas.*

06 *Colored pavement located between crosswalk lines should not use colors or patterns that degrade the contrast of white crosswalk lines, or that might be mistaken by road users as a traffic control application.*

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **INFORMATION**: MUTCD – Official Ruling 3(09)-24(I) – Application of Colored Pavement

Date: AUG 15 2013

From: Jeffrey A. Lindley
Associate Administrator for Operations

In Reply Refer To: HOTO-1

To: Federal Lands Highway Division Engineers
Division Administrators

Purpose: Through this memorandum, the Federal Highway Administration's (FHWA) Office of Transportation Operations (HOTO) is issuing an Official Interpretation of Chapter 3G of the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) on the approved uses of colored pavement. For recordkeeping purposes, this Official Ruling has been assigned the following number and title: "3(09)-24(I) – Application of Colored Pavement."

Background: The FHWA is concerned that considerable ambiguity continues regarding how colored pavement can be used, especially between the white transverse lines of a legally marked crosswalk.

Colored pavements consist of differently colored road paving materials, such as colored asphalt or concrete, or paint or other marking materials applied to the surface of a road or island to simulate a colored pavement. Colored pavement is a traffic control device when it attempts to communicate with any roadway user or when it incorporates retroreflective properties. Colored pavement can also be a purely aesthetic treatment. When used in this manner, colored pavement is not a traffic control device provided that it does not attempt to communicate with the motorist or incorporate elements of retroreflectorization.

Colored Pavement in Crosswalks: In the late 1990s, the marketplace introduced and promoted aesthetic treatments for urban streetscape environments that included the opportunity to install a range of colors and a multitude of patterns. The most popular opportunity to implement these treatments was between the legally marked transverse lines of crosswalks. This was typically done as part of larger efforts by cities to enhance the aesthetics of an area that could include decorative luminaires, street furniture, sidewalk art, etc. These crosswalk treatments were publicized and marketed as a method to increase conspicuity of the crosswalk that would translate into increased safety and a reduction of pedestrian deaths. In December 2001, the FHWA issued its first Official Ruling[1]

[1] MUTCD Official Ruling 3-152 (I) as Memorandum of Action, December 7, 2001

regarding the use of these aesthetic treatments, which concluded that crosswalk enhancements of this type had no such discernible effect on safety or crash reduction.

The marketplace looked to capitalize on advancements in pavement retroreflectivity in the mid-2000s, and further advocated for these aesthetic treatments on public streets as a way to increase crosswalk visibility. This included the benefits of the increased recognition of crosswalks both during the day and at night since the materials were designing retroreflective properties into the aesthetic treatments. In 2004 and in 2005, the FHWA issued two separate but related Official Rulings[2, 3] concluding that incorporating retroreflectivity into an aesthetic crosswalk treatment renders it an official traffic control device. Further, these Official Rulings continued to discourage implementation of such treatments and also concluded that these enhancements still had no increased effect on safety or contributed to a reduction in pedestrian deaths.

The evolution of crosswalk treatments continued into the form of "crosswalk art" because it was becoming a common misconception that as long as the white transverse lines were present—thereby legally marking the crosswalk—then the agency was free to treat the interior portion of the crosswalk as it desired. In 2011, the FHWA issued an additional Official Ruling[4] that crosswalk art—defined as any freeform design to draw attention to the crosswalk—would degrade the contrast of the white transverse lines against the composition of the pavement beneath it. In deviating from previous Official Rulings on the matter that concluded an increased factor of safety and decreased number of pedestrian deaths were not evident after installation, this 2011 Official Ruling stated that the use of crosswalk art is actually contrary to the goal of increased safety and most likely could be a contributing factor to a false sense of security for both motorists and pedestrians.

The FHWA's position has always been, and continues to be that subdued-colored aesthetic treatments between the legally marked transverse crosswalk lines are permissible provided that they are devoid of retroreflective properties and that they do not diminish the effectiveness of the legally required white transverse pavement markings used to establish the crosswalk. Examples of acceptable treatments include brick lattice patterns, paving bricks, paving stones, setts, cobbles, or other resources designed to simulate such paving. Acceptable colors for these materials would be red, rust, brown, burgundy, clay, tan or similar earth tone equivalents. All elements of pattern and color for these treatments are to be uniform, consistent, repetitive, and expected so as not to be a source of distraction. No element of the aesthetic interior treatment is to be random or unsystematic. No element of the aesthetic interior treatment can implement pictographs, symbols, multiple color arrangements, etc., or can otherwise attempt to communicate with any roadway user.

Patterns or colors that degrade the contrast of the white transverse pavement markings establishing the crosswalk are to be avoided. Attempts to intensify this contrast by increasing or thickening the width of the transverse pavement markings have been observed in the field. These attempts to increase contrast are perceived to be efforts to circumvent the contrast prerequisite so that an intentional noncompliant alternative of an aesthetic interior pattern or color can be used. Further techniques to install an empty buffer

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[2] MUTCD Official Ruling 3-169 (I) – Section 3B.19 Retroreflective Colored Pavement, September 1, 2004
[3] MUTCD Official Ruling 3-178 (I) – Retroreflective Colored Pavement – Additional Clarification, April 27, 2005
[4] MUTCD Official Ruling 3(09)–8 (I) – Colored Pavement Treatments in Crosswalks, May 3, 2011.

space between an aesthetic treatment and the interior edge of the white transverse crosswalk markings have also been observed in the field. This strategy is also perceived to be an attempt to circumvent FHWA's prior position on contrast. However, an empty buffer space between a subdued-colored, uniform-patterned aesthetic treatment can be implemented to enhance contrast between the aesthetic treatment and the white transverse pavement markings. When used properly, buffer spaces can be an effective tool to disseminate a necessary contrast in order to visually enhance an otherwise difficult to discern white transverse crosswalk marking, provided that the aesthetic treatment conforms to the conditions in the preceding paragraph.

Colored Pavement in Medians: Several agencies nationwide have used aesthetic colored pavement in medians that separate opposite directions of travel. These treatments are typically simulated red brick patterns or pavers. This is allowable if the median is closed to traffic. Where the center portion of the roadway functions to facilitate turns or operates as a two-way left turn lane, aesthetic treatments cannot be used in that center area in accordance with Paragraph 3 of Section 3G.01 in the MUTCD. Further, provisions elsewhere in Part 3 of the MUTCD require or recommend the turning functions of turn lanes or two-way left turn lanes to be marked with pavement word markings or arrows where applicable. The use of aesthetic colored patterns or pavers in these lanes simulates a supplemental background to standard turn markings and is an attempt to enhance conspicuity of the median thereby serving as communication with the motorist. This practice to use aesthetic treatments is disallowed since the median is open to traffic.

Colored Pavement for Islands: Where an island is designated as a traffic-control device, curbs, pavement edges, pavement markings, channelizing devices, or other devices are used. Islands are most commonly used to separate traffic movements or to provide pedestrian refuge. Regardless of whether the island is raised or flush with the roadway surface, islands are a potential for providing aesthetic qualities. Islands that separate movements of traffic and choose to incorporate colored pavement into interior sections or to the top surface of their design are to comply with Item A or B of Paragraph 3 of Section 3G.01. This would be applicable when the island is used to address a need to facilitate traffic that would otherwise have difficulty navigating the roadway if the island was absent.

Islands that are intentionally aesthetic in nature only are to be designed similar to those aesthetic treatments for crosswalks as described above. The most common applications of these purely aesthetic treatments are pedestrian refuge islands and textured raised buffers between a bikeway and a motorized vehicular lane.

Colored Pavement for Bicycle Lanes: Green colored pavement is approved for use in bicycle lanes only to enhance the conspicuity of where bicyclists are required to operate, and areas of the bicycle lane where bicyclists and other roadway traffic might have potentially conflicting weaving or crossing movements. Approval to use green colored pavement shall be in accordance with Paragraph 17 of Section 1A.10 in the 2009 MUTCD.

The FHWA issued an Interim Approval (IA-14) for the use and application of green colored pavement on April 15, 2011. The information provided in the IA-14 memorandum remains in effect.

The use of green colored pavement in a bicycle facility other than a legally marked bicycle lane is either not approved or is experimental. FHWA's Bicycle and Pedestrian Web site (http://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/design_guidance/mutcd_bike.cfm) can be helpful in determining what is or is not approved and what is experimental. Agencies that desire to use bicycle facilities that are experimental are required to submit their request for approval in accordance with paragraphs 3, 4 and 8 through 10 of Section 1A.10 in the MUTCD.

The FHWA is aware that agencies might be using green colored pavement to supplement, fill in or outline parking stalls for electric vehicle charging stations in order to express the agency's commitment to environmentally friendly initiatives. Use of green colored pavement for this purpose is not allowed. Although the applicability of the MUTCD may be limited in certain settings involving parking stalls, agencies are encouraged to adhere to the MUTCD with respect to disallowing green colored pavement in parking facilities for the purpose of maintaining uniformity among similar facilities.

Colored Pavement on Freeways and Expressways: The FHWA is aware of agencies nationwide using colored pavement on higher speed facilities as a method to visually differentiate the shoulder or special-use lanes from the general-purpose lanes, to demarcate the exit gore area, or to differentiate a ramp terminal from the mainline facility. The FHWA maintains the position that contrasting techniques on high-speed facilities have no other intention than to communicate with the motorist, regardless of whether elements of retroreflectivity are implemented for the colored pavement.

Additionally, the 2011 edition of the American Association of State Highway and Transportation Officials' *A Policy on the Geometric Design of Highways and Streets* discusses various methods of contrasting the shoulder with the adjacent pavement traveled way. The policy states that with regard to bituminous pavements, "the use of edge lines as described in the Manual on Uniform Traffic Control Devices… reduces the need for shoulder contrast." Edge lines separating shoulders from the traveled way on Interstate routes have been required by the MUTCD since 1971, supplanting the practice of using contrasting material for shoulders when an edge line was optional. Therefore, there should be little need for such a contrast that cannot be accommodated by the allowable pavement colors prescribed by the MUTCD.

If a need to provide contrast on a high-speed facility has been determined, then that contrast can be accomplished by a number of alternatives. Asphalt mixtures can be tinted to provide a shade of grey. White colored pavement can also be implemented. Paragraph 3 of Section 3G.01 in the MUTCD allows the use of white colored pavement for exit gore areas and right-hand shoulders. In the event that the main traveled way is concrete, an asphalt top layer could be applied to the shoulder to provide contrast.

Colored Pavement for Public Transit Systems: The use of red colored pavement for public transit systems such as streetcar and/or bus-only lanes is currently experimental. The use of colored pavement in these settings requires approval from the FHWA's Office of Transportation Operations. Agencies that desire to experiment with colored pavement should only do so where an engineering study can determine that increased travel speeds will be expected by the public transit vehicle, reduced overall service time through the corridor will be expected by the public transit vehicle, and the implementation of the colored pavement to a converted general purpose lane in the traveled way will not adversely affect the traffic flow in the remaining general purpose lanes.

Blue Colored Pavement: Blue is not a colored pavement and is not to be used as such in accordance with Paragraph 3 of Section 3G.01. Blue as it applies to a pavement marking is exclusively reserved for the background color in the international symbol of accessibility parking symbol (see Figure 3B-22) and for the supplemental pavement marking lines that define legal parking spaces reserved for use only by persons with disabilities as provided in Paragraph 5 of Section 3A.05.

Applying blue colored pavement to entire stalls or entire areas of parking reserved for persons with disabilities is to be avoided. Although the applicability of the MUTCD may be limited in certain settings involving parking stalls, agencies are encouraged to adhere to the MUTCD with respect to blue colored pavement in parking facilities for the purpose of maintaining uniformity among similar facilities.

Purple Colored Pavement: Purple is not approved for use as a colored pavement in any application, including toll facility environments. Purple as a pavement marking color is permitted in accordance with Paragraphs 5 and 6 of Section 3E.01 of the MUTCD.

Chromaticity Coordinates: The acceptable ranges of chromaticity coordinates that define the standard colors for pavement markings are found in the Appendix to Subpart F of 23 CFR 655—Alternate Method of Determining the Color of Retroreflective Sign Materials and Pavement Marking Materials.

Acceptable ranges for the chromaticity coordinates defining the color green for use as a pavement marking are provided in the IA-14 memo dated April 15, 2011.

Conclusion: Chapter 3G of the 2009 MUTCD contains provisions regarding the use of colored pavements. If colored pavement is used to regulate, warn, or guide traffic or otherwise attempts to communicate with the roadway user, the colored pavement constitutes a traffic control device. Agencies cannot intentionally exclude elements of retroreflectivity as part of a systematic process to classify the color pavement as a purely aesthetic treatment in order to circumvent the provisions of Chapter 3G.

Paragraph 3 of Section 3G.01 in the MUTCD limits the use of colored pavement used as a traffic control device to the colors yellow and white. Interim Approval IA-14 permits the use of green colored pavement for marked bicycle lanes. All other colors for use on highway pavement in the right-of-way are either disallowed or are experimental as described above, unless the colored pavement is a purely aesthetic treatment and makes no discernible attempt to communicate with a roadway user.

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4-2012

Effects of Symbol Prompts and 3D Pavement Illusions on Motorist Yielding at Crosswalks

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EFFECTS OF SYMBOL PROMPTS AND 3D PAVEMENT ILLUSIONS ON MOTORIST YIELDING AT CROSSWALKS

by

Nicole M. Cambridge

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EFFECTS OF SYMBOL PROMPTS AND 3D PAVEMENT ILLUSIONS ON MOTORIST YIELDING AT CROSSWALKS

Nicole M. Cambridge, M.A.

Western Michigan University, 2012

Pedestrian safety remains a serious concern at busy non-signaled intersections in large metropolitan cities across the nation, because many drivers fail to stop or yield to pedestrians at marked crosswalks. Past evaluated devices either have obtained marginal effects during evaluation or are limited in availability, such as the High Intensity Activated Crosswalk (HAWK) beacon and the Rectangular Rapid Flash Beacon (RRFB), due to installation and maintenance costs. 3D pavement illusions have been previously studied in transportation application; however no formal evaluations have examined the effectiveness of 3D pavement illusions on motorist yielding behavior. A multiple baseline study was conducted across two uncontrolled crosswalks sites. Following a baseline condition, an in pavement "Look for Pedestrians" message marking was placed in advance of the crosswalk. Next, 3D pavement illusions were added to the pavement marking message. The pavement marking message increased yielding behavior and the initial installation of the 3D illusions were effective at increasing yielding further, however over time the novelty of the 3D pavement illusions reduced motorist yielding back to the previous pavement message only condition.

ACKNOWLEDGMENTS

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INTRODUCTION

Crosswalks are sites of frequent interactions between vehicles and pedestrians. In 2010, there were 70,000 pedestrian injuries and 4,280 pedestrian deaths attributing from pedestrian-vehicle collisions across the United States (USDOT, 2012). These numbers have increases of 19.0% and 4.2% respectively from 2009 indicating that the need for continued research in the area of pedestrian safety. The primary approaches to pedestrian safety include traffic engineering modifications, traffic law enforcement, and pedestrian education. Unlike the difficulty in assessing the effects of enforcement and educational programs on pedestrian-vehicle crashes, it is possible empirically evaluate engineering methods.

Retting et al (2003) reviewed evidence-based traffic engineering measures and found there to be three main categories to support the pedestrian in traffic designs; separating pedestrians from vehicles by time or distance, increasing pedestrian visibility, and reducing vehicle speeds. Due to regulations for crosswalk placement, it is difficult to separate vehicles and pedestrians by time or speed at crosswalk locations without the use of traffic signals or refuge islands. Pedestrian visibility interventions may also be limited in certain locations due to local, state, or federal traffic ordinances. Although speed reduction interventions can be effective, they often involve the use of costly traffic calming measures.

Although speed inventions may seem limited, Oxley et al. (2001) focused on determining cost-effective approaches to vehicle speeds in high pedestrian environments. Three of these interventions included increased speed limit signs, painted colored crosswalk, and painted section within the median (painted island versus a raised island). The results of these studies found little difference in speed after the implementation of the countermeasures.

Another approach to increase driver yielding to pedestrians is the use of in roadway markings and beacons devices. The more effective interventions, such as the Rectangular Rapid Flash Beacon (RRFB) and the Hybrid Beacon (formally called the High-Intensity Activated Crosswalk or HAWK beacon), may be too costly for cities. The use of advance stop lines placed 50 feet in advance of crosswalks designed to increase yielding further in advance of the crosswalk has also shown to be associated with a small increase in overall yielding behavior (Van Houten, 1998; Van Houten & Malenfant, 1992).

Past studies have indicated that illusions have decreased motorist's speeding behavior; therefore, illusions may increase drivers' yielding behavior as well. Illusions have been demonstrated to reduce speeds in several studies (Griffen & Reinhardt, 1996; Maroney & Dewar, 1987). Maroney and Dewar (1987) concluded that transverse lines painted at progressively reduced distances project the illusion of increased speed, which can lead to a reduction in speed. This is similar to lining a lane with traffic cones placed progressively closer together along the edge of the road. The cones would project a narrowing lane, decreasing driver's speed, although no cones were actually place further into the lane. The initial results were effective with a subset of drivers, but after three weeks the effect on driver's speed diminished.

Griffen and Reinhart (1996) also reported that the behavioral mechanism behind the observed effects may have been an effect of a marking alert rather than an illusion of speed. If a warning or alerting effect from the illusions is the mechanism responsible for the speed reductions, it is likely that more prominent illusions, such as raised three-dimensional (3D) illusions on roadways, may prove even more effective than basic illusions. It is also possible that the effect of a 3D illusion will habituate based on data with other types of illusions.

In 2001, The Organization for Traffic Safety in South Holland County in the Netherlands researched the effects of two types of 3D illusions, mountain and block type illusions, on motorist speeding behavior. The study assessed nine sites and data were collected via surveys, traffic counters, and the use of a laser gun. The surveys indicated little or no significant differences in motorist speeding behavior. The results stated that it was unclear if any change in speed attributed to the 3D illusions.

Researchers conducted awareness surveys and 86.0% (out of 377 surveyed individuals) stated that they did notice the 3D illusions. When asked the type of reaction to the illusions, the majority stated that the illusions stood out each time (24.0%, 85 out of 353 responses) and the illusions reduced their speed (21.0%, 74 out of 353). Only 5.0% (19 out of 353 responses) viewed the illusion as an obstacle. Although there was no significant speed reduction noted within the parameters of the study, perception of reduced speed was high in comparison to examining motorist perception of the illusions.

Blomberg and Cleven (2006) assessed multiple illusion types as part of the *Heed the Speed* program and found significant speed reduction from “raised” roadway illusions. The results of the Heed the Speed program established that 3D pavement markings were associated with a 94.0% and a 24.0% increase in driver compliance with the posted speed limit at two independent sites, and a reduction of 62.0% and 40.0% in drivers traveling seven miles per hours (mph) over the speed limit. Blomberg and Cleven observed these reductions maintain for three to four months after installation. Unfortunately, no measurements of the long-term persistence of the effect were evaluated. The study continued to state that roadway illusions could be an effective marking for pedestrian safety if paired with an appropriate public prompt or message. Because increased speed enforcement was implemented along with public education, it is not clear whether the speed reductions would have occurred in the absence of these interventions.

As indicated in the Heed the Speed study, 3D illusions may be beneficial to pedestrian safety, as indicated by the statistically significant results, even though the illusions were not evaluated on long-term reduction in speeding behavior. As drivers reduce their vehicle speed, the frequency and the severity of pedestrian crashes should decrease.

The present study compared a pavement marking prompt to “look for pedestrians” alone with the pavement marking prompt plus a 3D illusion.

PURPOSE

The application of 3D illusions in the field of transportation safety may have the capability to influence motorist's behavior beyond reducing speed. One possible application is to add 3D illusions to uncontrolled crosswalks to potentially achieve an increase in motorist's yielding behavior. The desired behavioral outcome in the uncontrolled crosswalk application is different from the previous use of the 3D illusion that addressed speeding. By applying 3D pavement illusions prior to the advance of the crosswalk, motorists will likely reduce speed, and therefore should have more time to yield right-of-way to the pedestrian in a crosswalk.

The 3D pavement illusion is a novel and unique prompt, signaling the motorist to slow in high pedestrian areas to allow pedestrians to cross the street. The purpose of this study is to 1) evaluate the efficacy of an in pavement marking prompt to look for pedestrians, 2) the effect of adding a 3D pavement illusion to the pavement marking prompt and 3) to evaluate the maintenance of any changes produced by these treatments.

METHOD

Setting

Data were collected at two uncontrolled marked crosswalks in the city of Chicago. Uncontrolled marked crosswalks were defined as painted crosswalks without traffic controls. These crosswalks were marked using continental markings. Researchers selected sites in the same neighborhood, approximately one mile apart, on parallel roads, having similar environmental conditions to minimize variability. Each road was thirty-seven feet wide, and located within a minimum block distance of 1,000 feet situated between consecutive intersections with traffic signals. Both sites were two-way streets with one lane in each direction for on-street parking, had high traffic volume, and had three or more pedestrian crashes within the last three years.

Participants

The data collection procedure was based on natural observation; therefore there was no formal recruitment of participants. Participants included motorists and pedestrians that approached the two crosswalk sites. When no pedestrians were present at a site, data collectors preformed staged crossings following the safe crossing protocol. In this study, only the motorist's behaviors regarding interactions at the crosswalk sites were recorded.

Materials

Walking Wheel. Data collectors initially used a walking wheel to mark dilemma zones for the two sites. A signal time formula, as described by Van Houten and Malenfant (2004), was used to calculate the length of the dilemma zone. The dilemma zone is the threshold or minimum distance required for a vehicle to safety stop at given speed limit under dry pavement conditions. Both sites were located in a 30 mile per hour (mph) zone. Using the signal timing formula, the minimum distance required to complete a safe stop at 30 mph was recorded and measured out in both directions at each site. A landmark situated near the dilemma point in each direction marked the dilemma zone for recording at each site.

Pavement Marking Prompt. Following a baseline condition, an in-pavement message marking was placed in the travel lane in advance of the crosswalk. This pavement marking prompt was constructed from white retro-reflective standard U.S. Department of Transportation (DOT) thermal plastic material. The thermal material was affixed to the roadway using a torch. The pavement marking prompt contained the words "LOOK FOR" with a standard pedestrian symbol. An illustration of the marking is depicted in Figure 1.

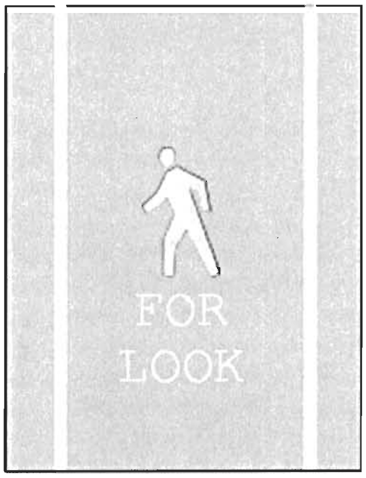
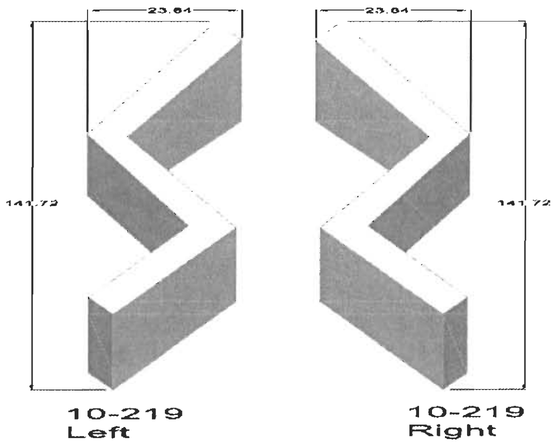
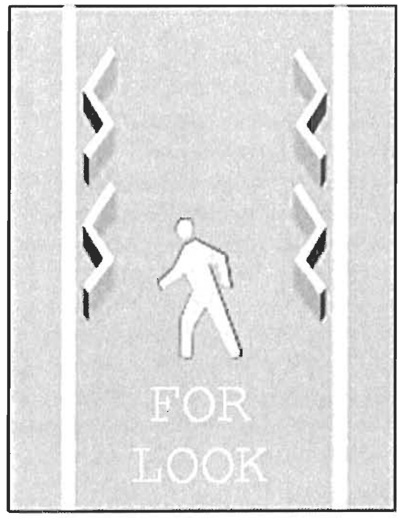


Figure 1: Illustration of Phase 1: Pavement Marker

3D Pavement Illusion. The 3D pavement illusion consisted of thermal plastic colored material that was arranged to produce a 3D effect suggesting a vertical deflection. A 3D illusion was placed on each side of inside lane directed above the "LOOK FOR" pavement message prompt. The 3D illusions were affixed in a mirror pattern onto the roadway using the same torch technique as previously mentioned. These markings are illustrated in Figures 2 and 3.





Figures 2: Design of 'Thunder' 3D Pavement Illusion Marker.

Figure 3: Illustration of Phase 2: Pavement Marking Plus 3D Illusions

Measures

Dependent Variable. The dependent variable was the percentage of motorists that yielded or failed-to-yield to a pedestrian in the crosswalk. Data collectors recorded the number of vehicles that yielded or failed to yield for each crossing. Yielding was defined as the motorist stopping or slowing down to permit a pedestrian to cross. Not yielding was observed as the motorist entering the crosswalk in front of the pedestrian, although sufficient time and distance would have allowed the vehicle to safely slow down or stop for the pedestrian in the crosswalk. The landmarks selected for the dilemma zone of each site determined if the motorist had sufficient time to yield when the pedestrian entered the crosswalk.

Motorists who had passed the dilemma point marker before the pedestrian entered the crosswalk were scored as yielding, but not failing-to-yield because they passed the marker indicating that there was sufficient time available to yield. Motorists who had not yet crossed the marker after the pedestrian placed a foot in the crosswalk were scored as yielding or not yielding because these motorists had sufficient distance to safely stop. For this study, a maximum of two cars (one in each lane) could be recorded as yielding for each crossing. An unlimited number of cars could be recorded as failing to yield at each crossing.

Independent Variables. There were two independent variables. The first was the placement of the pavement marking prompt containing the message "LOOK FOR" and the pedestrian symbol prior to the crosswalk in both directions. The second variable was the addition of the 3D illusion to the previous pavement marking prompt.

EXPERIMENTAL DESIGN

This study utilized a multiple baseline experimental design across two sites. Following a baseline condition, an in-pavement "Look for Pedestrians" prompt marking was placed in the travel lane in advance of the crosswalk. Next, 3D pavement illusions were added to the pavement marking prompt. In a multiple baseline design, a treatment site is compared with a control site that as subsequently treated. The staggered treatment approach controls for other variables that may have been correlated with the treatment at the first site, while later replicating the effect at the second site. It is possible to control for community wide variability that may have been responsible for the treatment effect through staging the treatment across sites. Through longitudinal data collection, it is possible to record that the variation is closely associated with the treatment introduction at both sites. This design is diagrammed below in Table 1.

	Phase 1	Phase 2	Phase 3	Phase 4	
Site 1	Baseline	Pavement marking prompt	Pavement marking prompt & 3D illusion	Pavement marking prompt & 3D illusion (6 month follow-up)	
Site 2	Baseline		Pavement marking prompt	Pavement marking prompt & 3D illusion	Pavement marking prompt & 3D illusion (6 month follow-up)

Table 1: Multiple baseline schedule across two sites

In all conditions, the start of a crossing or trial began when a pedestrian placed one foot inside the crosswalk and the approaching vehicle was beyond or at the dilemma point denoted by the previously determined landmark. In the baseline condition, motorist yielding behavior was recorded as pedestrians crossed the original uncontrolled marked crosswalk. During the pavement marking prompt condition, the "LOOK FOR" and PEDESTRIAN SYMBOL were placed onto the roadway in front of the crosswalk. In the following phase, the 3D illusions were placed slightly above the pavement marking prompt adjacent to the marked crosswalk. The final condition, a follow-up phase, continued to assess longitudinal effects from the pavement marking prompt plus the 3D illusions condition approximately six months after the markings and 3D illusions were initially installed.

PROCEDURES

Date Sheets

Each data sheet contains twenty crossings or trials. The average yielding compliance across the thirty-five trials was recorded as the yielding behavior for that session.

Participants Used in Collection Procedures

During sessions where only one data collector was present, only naturally observed pedestrians served as the pedestrian for each crossing. In sessions where two recorders were present, either naturally observed pedestrians or a research assistant (staged crossings) could serve as the pedestrian for each crossing. Staged crossings were only used in two conditions; 1) no pedestrians present or 2) the pedestrian was not actively approaching the crosswalk.

Natural Observation Crossings

In natural observational trials, one or two data collectors scored driver behavior. Data collectors observed in close proximity to the crosswalk within sight of the dilemma points. Motorist behavior was recorded independently if two data recorders were present at the session to assess for inter-observer agreement (IOA). A trail started when a pedestrian approached the crosswalk as a vehicle approached the dilemma zone (denoted by landmark) in the baseline, pavement marking prompt, pavement marking plus 3D illusions, or follow-up phase. If the vehicle yielded, the pedestrian then could cross the street safely and the vehicle would be scored as yielding. If the first vehicle did not yield, succeeding vehicles were recorded until a vehicle yielded or a gap occurred in traffic allowing the pedestrian to cross. If a vehicle was in the opposite lane, yielding was also recorded for that motorist and any subsequent motorists.

Staged Crossings

Staged crossings were only able to be used if two data recorders were present. The collectors alternated as the confederate while the other one recorded the crossings. The same recording procedure for yielding and non-yielding was used during confederate crossings.

Data Collection and Weather Conditions

Research assistants recorded sessions several days per week at each site. Data were not collected in rainy conditions due to changes in stopping distances for wet pavement. Observation sessions ranged from 20 minutes to 90 minutes.

IOA and Integrity of the Independent Variables

The standard practice for IOA is to obtain a minimum of 80.0% agreement across 20.0% of all observed sessions. Data collectors conducted IOA for 20.0% of the observations sessions. The data records for the two observers were compared on a crossing-by crossing basis. Recording an agreement for yielding occurred when both observers recorded the same number of cars yielding for that particular crossing. Scoring an agreement for failing-to-yield occurred when both observers recorded the same number of cars as not yielding for that particular crossing. IOA percentage was calculated using the formula: agreements divided by the sum of the agreements plus disagreements, multiplied by 100. Mean agreement for non-taxi cab drivers was 92.0%, with a range of 85.0% to 100%. IOA was calculated for 20.0% of sessions and obtained an average agreement of 93.0% on participating vehicles that were taxi cabs.

RESULTS

Figure 4 shows the mean percentage of motorists who yielded to pedestrians during each of the three conditions; baseline, pavement marking prompt, and pavement marking prompt plus 3D illusions, along with the six-month follow-up phase across the two sites. Motorists from site 1 started with an averaged yielding baseline of 31.0% while site 2 was slightly higher with an average of 34.0%. The pavement marking prompt phase increased yielding at both sites. There was a 20.0% increase in yielding at site 1, increasing yielding to an average of 51.0%. The introduction of the pavement marking prompt at site 2 produced an 11.5% increase bringing the average to 45.5%. The addition of the 3D illusions only showed marginal change increasing the averages to 53.3% and 48.8% respectively. The follow-up phase was conducted six months after the initial 3D installation at both sites. While site 1 maintained an average yielding of 53.0%, site 2 decreased 5.3%, dropping the average yielding back to 43.5%, which is slightly lower than the initial pavement marking prompt marking condition in phase 1.

From 2005 to 2007, taxi cabs were involved in a significant amount of pedestrian crashes. Taxi cabs accounted approximately 25.0% of crash during this period. The data collectors noted on the data sheet if a vehicle was a taxi cab. Figures 5 and 6 separate these data into two categories: motorists excluding taxi cab drivers and taxi cab drivers. Figure 5 shows the mean percentage of motorists (excluding taxi cab drivers) who yielded to pedestrians during each of the three conditions: baseline, pavement marking prompt, and pavement marking prompt plus 3D illusions, along with the follow-up phase across the two sites. Motorists (excluding taxi cab drivers) from site 1 averaged a baseline yielding percent of 30.0% while site 2 motorists averaged closely to site 1 with an average of 28.4%. The pavement marking prompt phase increased at both sites to average yielding of 42.0% and 46.4%, respectively. The addition of the 3D illusions did show a 10.0% increase at site 1, however site 2 did not show similar results, as the 3D illusions were only associated with an increase in yielding of 1.4% between phase 2 and phase 3. The follow-up phase was conducted six months after the initial 3D installation at both sites. While site 1 maintained an average yielding of 51%; only a 1.0% difference from the initial illusion phase, site 2 .decreased yielding from 48.0% in phase 2 to obtaining a mean of 40.0% in the follow-up phase.

Figure 6 shows the mean percentage of taxi cab drivers who yielded to pedestrians during the four conditions across both sites. Taxi drivers averaged a baseline yielding percent of 27.0% at site 1 and 40.3% at site 2. The pavement marking prompt phase increased yielding to pedestrians at both sites to an average yielding of 54.7% and 44.7%, respectively. The 3D illusions only produced an increase in yielding behavior in taxi cab drivers for site two with a 7.8% increasing bringing the average yielding for taxi cab drivers up to 52.5%. The follow-up phase produced mixed results regarding taxi cab drivers' yielding behavior. Site 1 jumped from a mean of 51.0% to 58.0% while site 2 slightly increased from a mean of 52.5% to 55.9%.

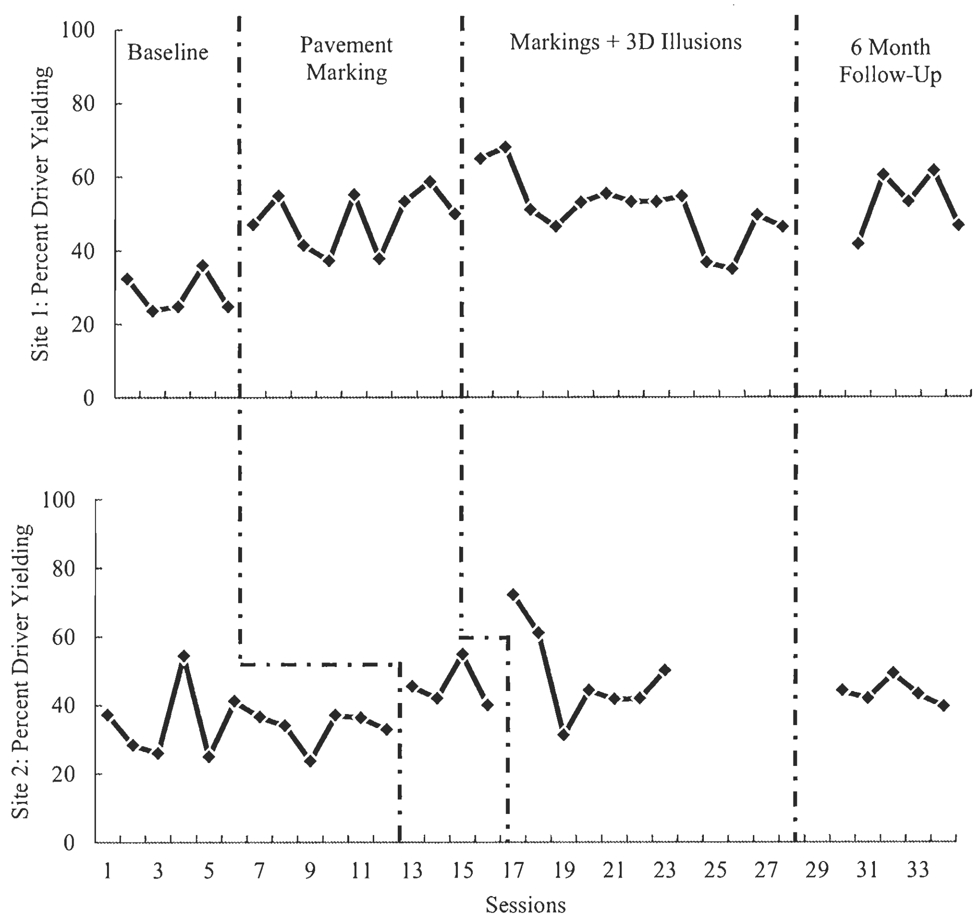


Figure 4: Percentage of All Motorists Yielding

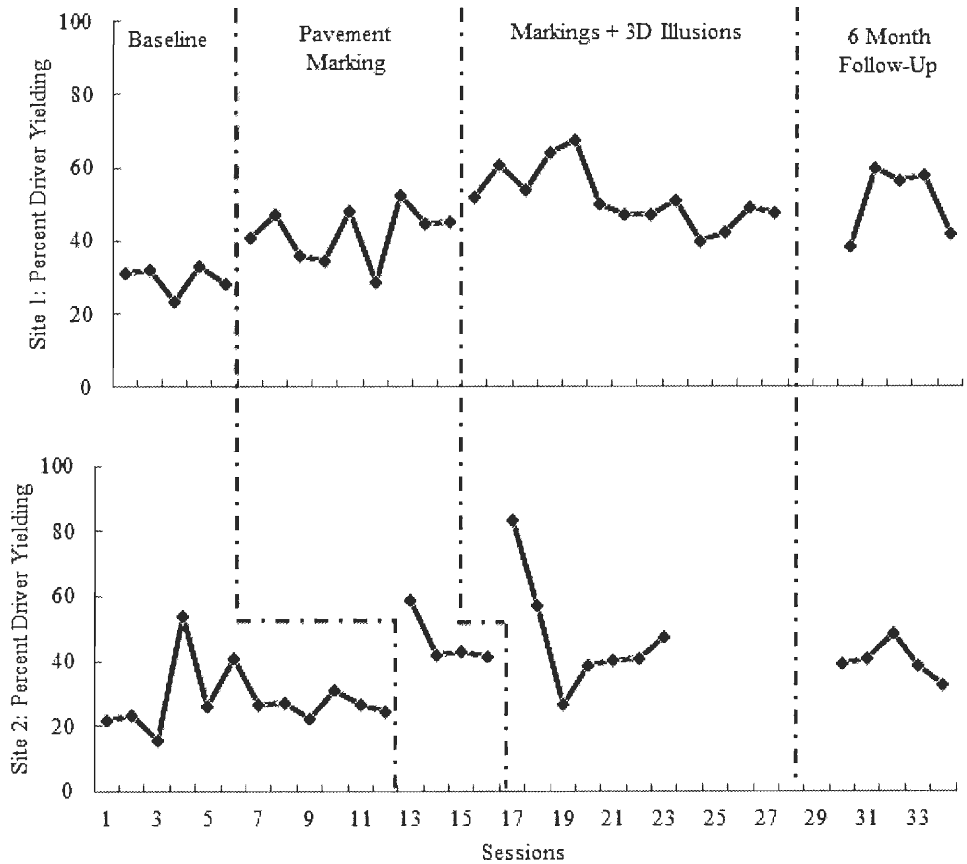


Figure 5: Percentage of Motorist (excluding taxi cab drivers) Yielding

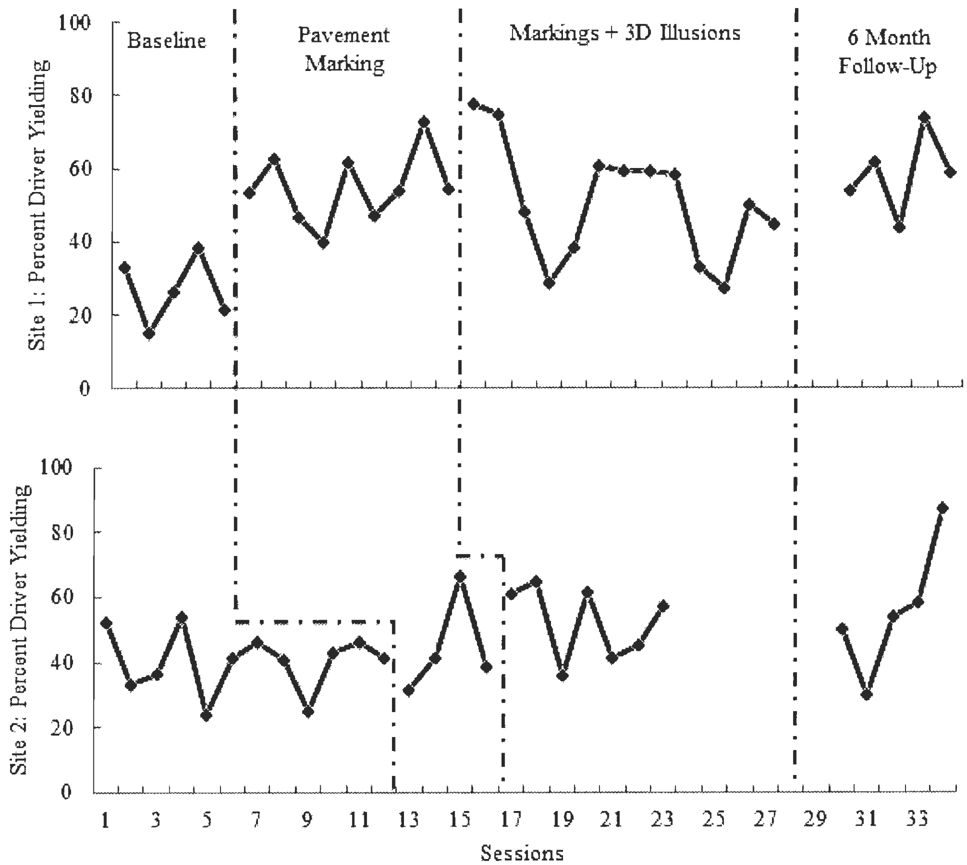


Figure 6: Percentage of Taxi Cab Drivers Yielding

DISCUSSION

Overall, the pavement marking prompt alone condition produced an increase in the percentage of drivers yielding to pedestrians and the 3D illusions seemed to add little to the effect of the prompt. The pavement marking prompt intervention may have produced better results over the 3D illusions because the novelty of the "raised" illusion wore off as motorists figured out that the illusion was not raised and would not harm their vehicle. The purpose behind the staged implementation of the two types of pavement markings were: to evaluate the pavement marking prompt independently from the 3D illusion and to attempt to create a pairing between the pavement prompt and the 3D illusion. Over time, motorists that traveled this particular stretch would learn that the illusion was not raised. By placing the 3D illusion with an in pavement marking prompt, it hoped that 3D markings would develop control of the rule(s) of "look for pedestrians, slow down or stop for pedestrians." The data did not support the development of rule-governed behavior in this experiment.

Similar to a stop sign, individuals can travel to another country, not be fluent in the native language, and still manage to respond properly to a stop sign in another country. Through parents, driver's education class, or a department of motor vehicles (DMV), individuals pair the word 'STOP' with a red octagon. When approaching a red octagon in the roadway with script that does not read the English world 'STOP', the individual refers to the governed rule of stopping prior to the sign as learned behavior and will stop prior to the stop sign.

Through the results, it is unlikely that the pairing of the 3D illusion with the "look for pedestrians" pavement prompt ever created an association between the illusions and the "look for pedestrians" prompt. The idea was for drivers to pair the thunder symbol with reducing speed and actively scan the roadway for pedestrians, thereby maintaining or increasing yielding behavior even after the novelty of the illusion wore off.

The six-month follow-up data were similar to the data collected in the marking prompt message plus 3D illusion condition. This suggests that the pavement markings, 3D illusions, or combination produced a long-term positive effect by maintaining a higher level of motorists yielding compared to the baseline yielding level.

It was difficult to determine empirically which stimulus maintained or increased yielding behavior starting in the 3D illusion phase, however vehicles were initially noted to avoid or straddle the illusions as the vehicle approached the crosswalk, supporting the initial data in phase 3. Unfortunately, applied research comes with potential risks, such as the coordination of many parties to successfully install roadway markings. The limitations in site selection may have been a factor in the difference in yielding behavior between the two sites. It is possible that the drop off in yielding at site 2 was due to differences in foot traffic between the two sites. Timeline modifications in the two installation phases and unforeseen inclement weather were other factors limiting the number of data points that were collected in each condition. Due to these constrains, data collectors periodically recorded a session in close succession to the previous session. Additional data points in each condition may have provided less degree of variability in each condition giving more stability and possibly more consistent results in each phase across the two sites.

Alternating with the illusions first and the pavement prompt second in one of the sites may have determined if the 3D pavement markings truly produce higher results or if the effect of the illusions were masked by effect of the pavement marking prompt.

The majority of sessions were conducted between 4:00 pm and 8:00 pm in the late afternoons and early evenings, to minimize variability due to difference in traffic volume. However, data collectors conducted some sessions between 8:00 pm and 11:00 pm in the afternoons and evenings due to conflicts in data collector's schedules and inclement weather. It is also possible that the novelty of the illusions did not produce significant effect on the habitual travelers that cross one or both of the sites in their daily commute. Larger and longer vehicles, such as buses, may have contributed to the little to no effect the 3D illusions added to the pavement marking prompt on motorists. Although no data were recorded on the visibility of the illusions, these longer vehicles may have covered these markings up for following vehicles, reducing or eliminating its visibility to motorists that are approaching the crosswalk.

CONCLUSION

In conclusion, the addition of the 3D illusions did not produce significantly more yielding to pedestrians when added to the simple pavement marking prompt. Although the illusions may have produced little increase in yielding behavior, a clear difference in yielding occurred between baseline and the initial pavement marking prompt installation. The results of these pavement interventions indicate that a simple pavement marking prompt may be the more efficient choice in locations where posted signs and costly beacons may not be available interventions. A pavement marking prompt can also be a good alternative for posted prompts hidden by large objects, such as trees, building awnings, and bus stops that prevent drivers from seeing the prompt.

In addition, any possible slight benefit of the 3D illusions is also offset by the upfront costs in terms of custom design and installation. Four sets of thermal plastic pavement markings were $1,787.68 compared to $4,736.64 for the four set of 3D pavement illusions used in this study. Although the thermal plastic materials is slated to outlast fading when compared to paint, the removal of these devices requires additional effort as the device has to be grinded out of the road instead blasted away as a painted marking.

Future evaluation of the 3D pavement illusion would be able to provide more in-depth analysis as to the mechanics of the "raise" illusion to maximize the effectiveness of the illusion. A logical next step would be to evaluate the effect of a stand-alone illusion compared to a stand-alone pavement prompt or posted sign. Future research could include a longitudinal cost benefits analysis on the use of thermal plastic pavement interventions (symbols, messages, illusions) in comparison to using painted interventions as well as comparing various pairings of different prompt interventions, such as a more direct prompt as "yield to pedestrian", "stop for pedestrians", or "state law yield to pedestrians" with an illusion.

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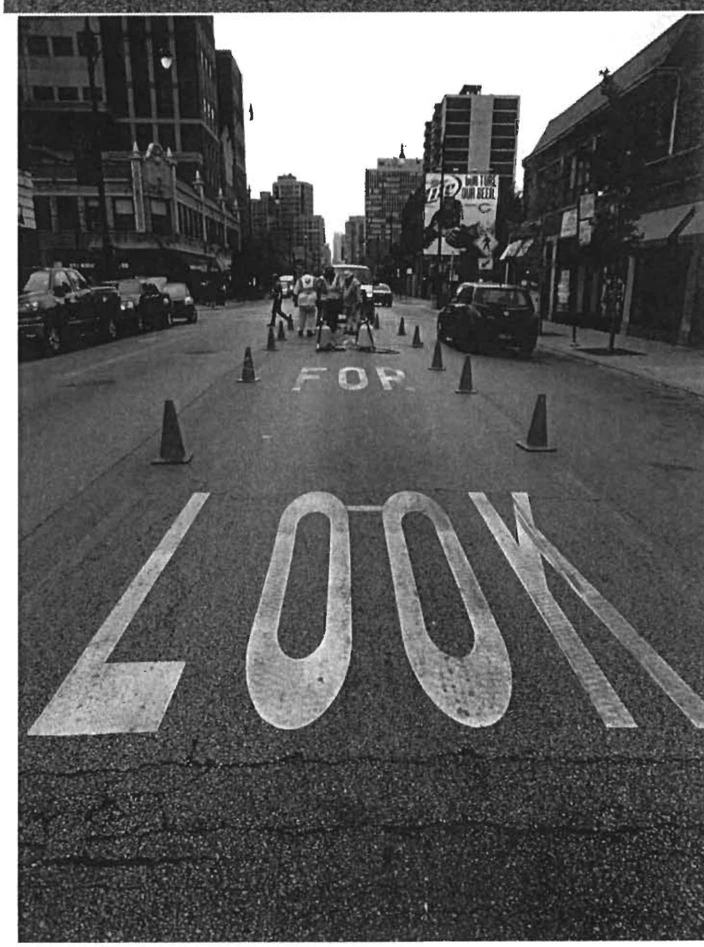
Appendix A

Installing Pavement Markings and 3D Illusions to the Roadway

Below are two illustrations of the installation of the pavement marking and 3D illusions to the roadway



Appendix B

Data Sheet

Below is an example of a data sheet

Recorder:______________________________ PRIMARY IOA

Date:___________________ BL TR WEATHER:________________

Location: ________________________________

Start Time: ______________ End Time: ___________

Enforcement_____ Follow-up _______

Staggered Xing	# Peds Xing	Cars Not Yielding		Cars Yielding		Yielding distance		Evasive Action		Ped Trapped in Center	Driver passed Stopped Veh	Veh Brake Hard
		Req	Taxi	Req	Taxi	<30ft	>30ft	Ped	Veh			
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

Unstaggered Xing	# Peds Xing	Cars Not Yielding		Cars Yielding		Yielding distance		Evasive Action		Ped Trapped in Center	Driver passed Stopped Veh	Veh Brake Hard
		Req	Taxi	Req	Taxi	<30ft	>30ft	Ped	Veh			
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
% yield Overall				% < 30 ft			% E.A. Veh			% Driver pass		
% Yield Taxi				% E.A. Ped			% Ped cen.			% Veh. brake hard		

Appendix C

Approval Letter from the HSIRB

Approval Letter from the HSIRB

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: March 7, 2012

To: Ron Van Houten, Principal Investigator
Nicole Cambridge, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair Amy Naugle

Re: HSIRB Project Number 12-02-70

This letter will serve as confirmation that the change to your research project titled "Effects of 3D Pavement Illusions on Motorists Yielding at Crosswalks" requested in your memo dated March 4, 2012 9chagne title to Effects of Symbols and 3D Pavement Illusions on Motorists Yielding at Crosswalks) has been approved by the Human Subjects Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of Western Michigan University.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: February 29, 2012

Walwood Hall, Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276

Oklahoma Department of Transportation
200 N.E. 21st Street
Oklahoma City, OK 73105-3204

October 11, 2013

Office of Transportation Operations, HOTO-1
Federal Highway Administration
1200 New Jersey Avenue, SE,
Washington, DC 20590

RE: Revised Request for Permission to Experiment- 3D Crosswalk

To whom it may concern,

In accordance with the guidelines provided in the Manual on Uniform Traffic Control Devices (MUTCD) section 1A.10, Traffic Engineering Division would like to formally request permission to experiment and study the effects of implementing 3D Crosswalk pavement markings to which the crosswalk appears slightly raised to the driver.

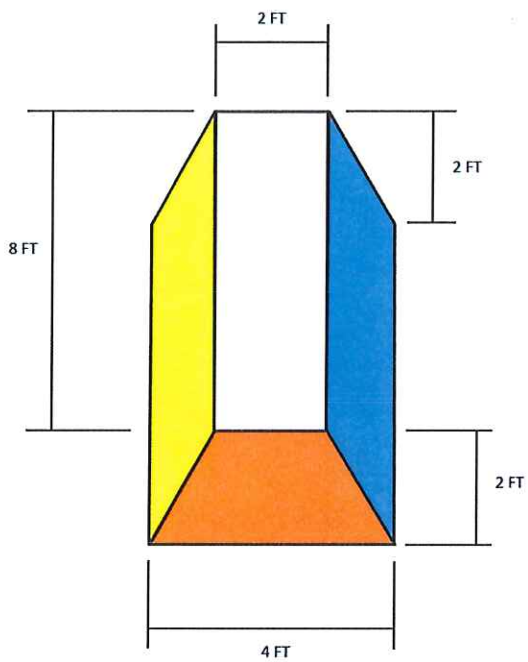
A. The Oklahoma Division 5 Traffic Engineer, along with the City of Snyder, came to the Oklahoma Department of Transportation (ODOT) Traffic Engineering Division with a request for improving the visibility of an existing crosswalk on US-62B. The City of Snyder and Division 5 Traffic Engineer were very concerned about this crosswalk location due to a small child being struck in the existing crosswalk earlier in the year. After reviewing several possibilities to improve the visibility of this particular crosswalk in Snyder, Tarek Maarouf had come across the promising idea of creating an optical illusion where the crosswalk appears to be slightly raised.

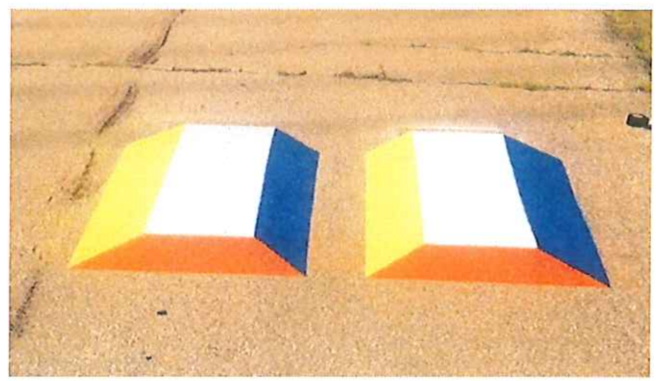
B. ODOT Traffic Engineering Division studied multiple 3D pavement marking images, but were unable to find one that matched our needs. Most of the 3D pavement markings we found were from a side angle and we wanted the crosswalk to appear elevated from the driver's perspective. The 3D crosswalk design also had to follow certain rules, such as not changing the continental striping of the crosswalk in color, size, or shape so as to follow MUTCD guidelines as well as ODOT Traffic Standards. Our design retains the continental crosswalk as detailed in MUTCD section 3B.18, but contains additional paint between the stripes. We also tried to stay within the directives provided in the FHWA: MUTCD – Official Ruling 3(09)-24(I)- Application of Colored Pavement that states,

> "The FHWA's position has always been, and continues to be that subdued-colored aesthetic treatments between the legally marked transverse crosswalk lines are permissible provided that they are devoid of retroreflective properties and that they do not diminish the effectiveness of the legally required white transverse pavement markings used to establish the crosswalk."

We then came up with several designs that created the image of a slightly raised crosswalk. On August 27th, 2013 Ken Phillips and I drove out to a test facility to paint the design options on concrete and asphalt pavements. The test crosswalk was produced with spray paint using the standard white continental crosswalk, blue and yellow to produce a shadow effect, and orange to further enhance the crosswalk. We preferred orange since it is typically used to caution drivers which is what we wanted to further indicate.

C. Below are the dimensions we have used and an image of the actual crosswalk that we painted at our test facility.





D. To further enhance our vision for a slightly raised crosswalk, we began researching other similar 3D applications. We came across Chicago Department of Transportation's (CDOT) experiment with 3D pavement markers. The study CDOT conducted was a series of 3D pavement markers prior to a residential area crosswalk along with 'Look for Pedestrians' wording. The experiment used Sekisui Jushi Corporation's Thunder Type pavement markings. According to the report Nicole M. Cambridge, M.A. produced titled 'Effect of Symbol Prompts and 3D Pavement Illusions on Motorist Yielding at Crosswalks' (2012), the initial effectiveness was high, but that the motorists' yielding behavior wore off over time.

Even with this slightly raised crosswalk appearance, we assume that the initial effectiveness will be great, but predict similar outcome to CDOT's experiment with the novelty of the design wearing off with time. While we expect some drop in yielding behavior after the 3D crosswalk has been in place for a period of time, we feel that this new design will greatly protect pedestrians from drivers that are new to the area or passing through for the first time and are not expecting a mid-block crossing.

E. The dimensions and appearance of the 3D Crosswalk shown above were solely designed within ODOT Traffic Engineering Division and are not protected by a patent or copyright.

F. ODOT Traffic Engineering Division would like to have this crosswalk design in operation for at least two years. The proposed area is located in Snyder, Oklahoma which is in Kiowa County. The existing crosswalk that we would like to enhance with our painted raised appearance is located on US-62 Business east of C Street which is a two-way, two-lane road with an Annual Average Daily Traffic (AADT) of 620 vehicles per day and a posted speed of 30 mph through town. Please see attachment for aerial image of existing area and crosswalk.

G. The Oklahoma Department of Transportation Planning Division will be studying this location to assess if the raised image is improving drivers' awareness of the crosswalk. We would like to measure the 3D Crosswalk's effectiveness on drivers similar to the way that Chicago Department of Transportation successfully observed their project. We will compare the crash data, vehicle to vehicle as well as pedestrian, before and after the crosswalk pavement marking is implemented and verify cause and type of crash. With the OkDOT Planning Division, we plan to measure when and where drivers touch their brakes to slow down for the crosswalk to measure the percentage of drivers yielding to pedestrians in and near the crosswalk. This will also include observing and tracking not only the initial driver that approaches the crosswalk, but also the reaction of any vehicle-drivers behind the initial driver.

   We will have an observer in an unmarked vehicle out in the field prior to and after the 3D pavement marking installation. Points will be marked in the field for the observer to note how far out a vehicle brakes. We will also be using radar equipment to verify speed. A few other items we would like to know more information on when observing the raise crosswalk would be the relative age of drivers, whether a driver really checks both directions for pedestrians in the crosswalk, whether or not the raised look would encourage drivers to swerve around the portion that looks raised to them. To adequately view many of these behaviors we will be videotaping the drivers' approach.

H. After the experimentation time is over, if the data indicates that the additional pavements markings produce a safety concern, the Oklahoma Department of Transportation will return the site back to its original condition.

I. The Oklahoma Department of Transportation Traffic Engineering Division will provide FHWA with semi-annual progress reports

Thank you for your consideration. If you have any questions or concerns please contact me at (405)522-5817.

Oklahoma Department of Transportation
200 N.E. 21st Street
Oklahoma City, OK 73105-3204

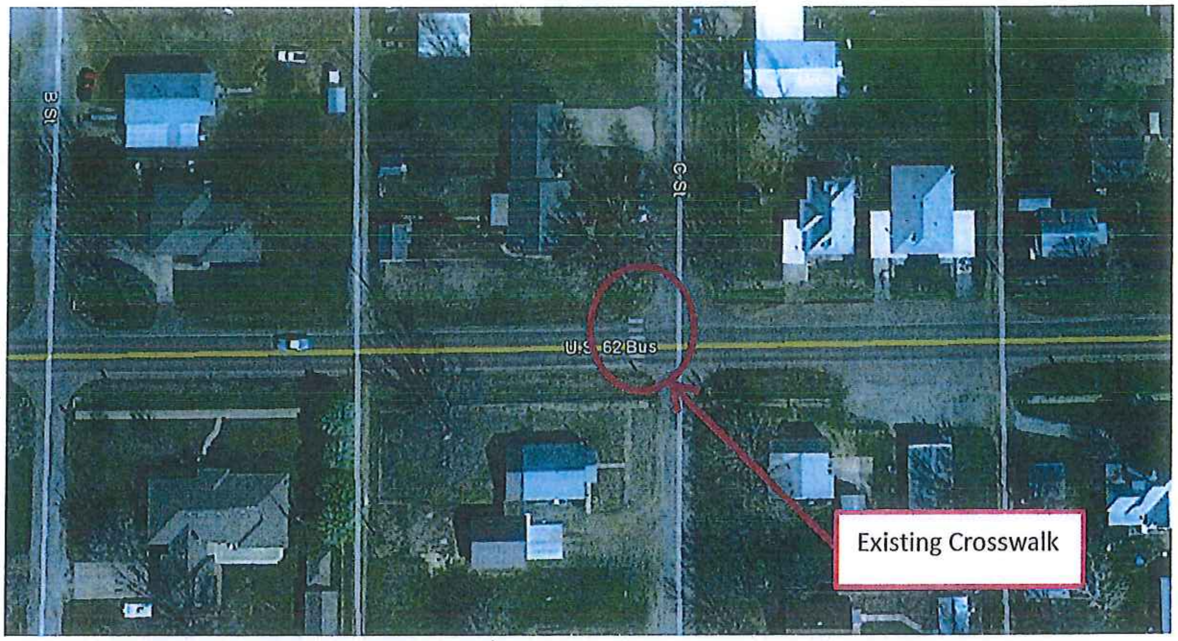
Sincerely,

Lauren P. Ludwig, P.E.
Professional Engineer
Traffic Engineering Division
Oklahoma Dept. of Transportation

Harold R. Smart, P.E.
Chief Traffic Engineer
Traffic Engineering Division
Oklahoma Dept. of Transportation

Enclosures (15)

Snyder, Oklahoma



U.S. Department of Transportation
Federal Highway Administration

1200 New Jersey Avenue, SE
Washington, D.C. 20590

OCT 21 2013

In Reply Refer to:
HOTO-1

Lauren Ludwig, P.E.
Traffic Engineering Division
Oklahoma Department of Transportation
200 N.E. 21st Street
Oklahoma City, OK 73105-3204

Dear Ms. Ludwig:

Thank you for your October 11 revised request to experiment with a three-dimensional alternative crosswalk pavement marking pattern on U.S. Route 62 Business in Snyder, Oklahoma.

Your revised request for experimentation is approved. We look forward to receiving your semi-annual progress reports and your final evaluation report at the end of the study period in accordance with Item I of Paragraph 11 in Section 1A.10 of the 2009 *Manual on Uniform Traffic Control Devices for Streets and Highways*.

For recordkeeping purposes, we have assigned the following official ruling number and title: "3(09)-25 (E) – Three-Dimensional Alternative Crosswalk Pattern – ODOT." Please refer to this number and title in future correspondence.

Thank you for your interest in improving traffic safety and mobility for roadway users.

Sincerely yours,

Mark R. Kehrli
Director, Office of Transportation
Operations

3D Crosswalks

Iceland

View from front

View from rear

Rainbow crosswalks planned for South Broadway to support LGBT community

POSTED 12:39 PM, APRIL 25, 2018, BY WEB STAFF, UPDATED AT 12:35PM, APRIL 25, 2018

DENVER — Drivers and pedestrians on South Broadway could soon notice a colorful addition to one intersection.

A number of community members are planning to install rainbow-colored crosswalks on the road at its intersection with West Irvington Place.

According to the project's website, the crosswalks will be "a visual demonstration of the neighborhood's spirit of inclusiveness and support for the LGBTQIA+ community."

The project is being organized by Buffalo Exchange Colorado, the Baker Broadway Merchant Association and Denver City Councilman Jolon Clark.

They are hoping to raise $25,000 for the project; they have received just more than $22,000 so far. Organizers are hoping to have the crosswalks complete by Denver PrideFest in June.

Source: Broadway Rainbow Crosswalk

It will not be funded by taxpayers.

The crosswalks will be painted with a thermoplastic material. Those planning the project said unlike regular paint, the thermoplastic "will be able to withstand the daily wear and tear of Broadway traffic."

There are already similar crosswalks in a number of American cities, including Atlanta and West Hollywood, California.

Project Website: https://broadwayrainbowcrosswalk.weebly.com/

Rainbow crosswalks in Denver? Business owners and councilman want to make it happen

The project would add a splash of color on Broadway to demonstrate the neighborhood's spirit of inclusiveness.

Author: Colleen Callander
Published: 5:21 PM MST February 8, 2018
Updated: 5:21 PM MST February 8, 2018

It’s not every day you see a rainbow in the sky, but how about on the ground?

That’s the goal for neighborhood organizers who are teaming up with the city to create a display of inclusivity and support for the LGBTQIA+ community.

Buffalo Exchange Colorado, the Baker Broadway Merchant Association and the Office of Councilman Jolon Clark want to install a rainbow crosswalk across S. Broadway and W. Irvington Place just outside of the Buffalo Exchange.

The rainbow crosswalk will span Broadway North and South of W Irvington Pl.

An illustration of one of the proposed designs of the crosswalk.

According to their website, the project would be a visual demonstration of the neighborhood’s spirit of inclusiveness. They are looking to raise $25,000 to cover the cost of installing it, and ideally, they hope to have it done by May for PrideFest.

The money raised will cover the cost of installing permanent thermoplastic pavement markers in the colors of the rainbow.

According to their site, these materials are more effective than paint because the thermoplastic “will be able to withstand the daily wear and tear of Broadway traffic.”

More information about the project and donations can be found here.

Rainbow crosswalks were installed in Midtown Atlanta last summer, costing the city $196,000 to install. They will last 10 years.