

# Innovative Intersection Safety Improvement Strategies and Management Practices: A Domestic Scan

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### Technical Report Documentation Page

1. Report No. FHWA-SA-06-016		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Innovative Intersection Safety Improvement Strategies and Management Practices: A Domestic Scan				5. Report Date September 2006	
				6. Performing Organization Code	
7. Author(s)* Hughes, Warren, Chappell, Debra, and Chen, Shyuan-Ren (Clayton)				8. Performing Organization Report No.	
9. Performing Organization Name and Address Vanasse-Hangen-Brustlin, Inc. (VHB) 8300 Boone Blvd., Suite 700 Vienna, VA 22182-2624				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. DTFH61-03-D-00105	
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Highway Administration (FHWA) Office of Safety 400-7 <sup>th</sup> Street, SW, HSA-10 Washington, DC 20590				13. Type of Report and Period Covered Domestic Intersection Safety Scan/Best Practices – February 2005	
				14. Sponsoring Agency Code FHWA/HSA-10	
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16. Abstract Intersection safety is and has been a major program at the Federal Highway Administration (FHWA). As a means to share best practices used in various locations, the FHWA and selected representatives of the transportation community conducted a domestic scan of issues related to intersection safety: safety management and comprehensive safety processes, traffic control devices for motorists, pedestrians and bicyclists, traffic operational practices, geometric design treatments, and enforcement practices and educational programs.  The goal of this Domestic Intersection Safety Scan was to reduce fatalities, personal injuries and crashes at intersections in the United States by documenting and subsequently promoting innovative intersection treatments and comprehensive intersection safety processes that have been implemented in this country.  One of the primary objectives was to identify and document selected innovative intersection treatments that have been implemented at intersections in the United States and have been demonstrated to, or have the potential to, improve safety at intersections. Another objective was to identify and document selected comprehensive safety processes and procedures that have been implemented by transportation agencies specifically to improve intersection safety.  A total of five locations were visited during this scan: Southeastern Michigan; North Central Texas; Portland, Oregon; Charlotte, NC; and West Palm Beach, FL. This report provides a discussion on the successes and challenges to enhancing safety for highway users.					
17. Key Words Intersection, safety, scan, signals, signs, markings, design, pedestrians, bicycles, data.				18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 104	22. Price



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# Executive Summary

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## Background

Intersection safety is and has been a major program at the Federal Highway Administration (FHWA). A highway intersection is defined in this context to be the at-grade junction of two or more public roads. Within intersections, vehicle-vehicle and vehicle-pedestrian conflicts occur as drivers, bicyclists, and pedestrians need to cross the path of other vehicles. Not surprisingly then, the intersection, whether or not it is under traffic signal control, can be a hazardous location as evidenced by various motor vehicle crash statistics.

Using the year 2002 crash database maintained, as part of the National Accident Sampling System, there were an estimated 2.7 million motor vehicle crashes at intersections in the United States in 2002. Approximately 1.4 million crashes were reported at unsignalized intersections and 1.3 million were crashes reported at signalized intersections. An estimated 925,000 people were injured in the crashes at intersections. Approximately 445,000 people were injured in crashes at signalized intersections and nearly 480,000 were injured in crashes at unsignalized intersections. In terms of fatalities based on the Fatality Analysis Reporting System, a total of 9,117 people died in 2004 as a direct result of crashes for which the relation to junction was classified as at an intersection (non-interchange) or intersection-related (non-interchange).

In May 2002, the FHWA and the American Association of State Highway and Transportation Officials (AASHTO) sponsored a scanning study of signalized intersection safety in Europe. With the goal of improving signalized intersection safety, the focus of the scanning study was on innovative signalized intersection safety practices in Europe. In December 2003, the FHWA published the final report on the study, which was entitled *Signalized Intersection Safety in Europe* as part of FHWA's International Technology Exchange Program. Given the relative success of that European scan and feedback on the report, FHWA decided that a scanning study should be conducted of select areas in the United States. It is hoped that a Domestic Scan will also produce tangible benefits through identifying and making highway agencies aware of innovative treatments and practices that have been successfully implemented in the United States.

## Domestic Intersection Safety Scan Goals and Objectives

The Domestic Intersection Safety Scan was conducted in February 2005. The goal of the scan was to reduce fatalities, personal injuries and crashes at intersections in the United States by promoting innovative intersection treatments and comprehensive intersection safety processes that have been implemented in this country.

One of the primary objectives was to identify and document selected innovative intersection treatments that have been implemented and have been demonstrated to or have the potential to improve safety. Another objective was to identify and document selected comprehensive safety processes and procedures that have been implemented by transportation agencies specifically to improve intersection safety.

The range of treatments considered within the scan included treatments that addressed and/or contained the following elements:

- Traffic control devices for motorists.
- Traffic control devices for pedestrians, bicyclists, and other non-motorists at intersections.
- Traffic operational schemes and strategies applicable to vehicular traffic flow including those for signal-controlled intersections.
- Geometric features and designs that enhance the safety of vehicle maneuvers at intersections.
- Enforcement practices and educational programs.

During the scan, a secondary objective was to gain knowledge about and document the processes and procedures that were employed to gain agency management's approval for successful implementation and deployment. To the extent that the treatments had been evaluated by local agencies, the scan endeavored to gain knowledge about the safety effectiveness of these treatments and comprehensive approaches to intersection safety.

### Study Scope

Because of limited resources, the scan team could not go to all areas of the United States to cover all relevant topics. A vetting process was conducted to identify areas where innovative intersection treatments and comprehensive safety processes were implemented and the local agencies were recognized for their prominence in selected areas and a willingness to participate and share their knowledge, time, and experiences. The following identifies the agencies and organizations that participated in the scan and their innovative intersection treatments and comprehensive safety processes:

- City of Detroit (MI), Traffic Engineering Department
  - Public-Private Partnership with American Automobile Association (AAA) Michigan
  - Intersection Turn Lane Additions
  - Road Diet Projects
  - Signal Head Upgrade Projects
- American Automobile Association Michigan Automobile Club
  - Public-Private Partnership with Detroit and Grand Rapids
- Michigan Office of Highway Safety Planning (OHSP)
  - Michigan Intersection Safety Action Plan
  - Crash Records System Accessible to State and Local Police
  - Red-Light Running Enforcement Pilot
- Michigan State Police
  - Michigan Intersection Safety Action Plan
  - Red-Light Running Enforcement Pilot

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- DLZ Michigan, Inc.
  - Michigan Intersection Safety Action Plan
  - Roundabout Design and Safety Evaluation
- Michigan Center for Truck Safety
  - Michigan Intersection Safety Action Plan
  - Truck Driver Simulators
- Wayne State University
  - Michigan Intersection Safety Action Plan
  - Intersection Safety Evaluations
- Federal Highway Administration, Michigan Division Office
  - Michigan Intersection Safety Action Plan
- Southeast Michigan Council of Governments (SEMCOG)
  - Web-based Crash Records System
  - Michigan Intersection Safety Action Plan
- Michigan Department of Transportation
  - Michigan Intersection Safety Action Plan
  - Enhanced Intersection Street Name Signing
  - Roundabout Design and Safety Evaluation
  - Projects to Enhance Safety of Elderly Drivers and Pedestrians
  - Intersection Improvement Projects
- Oakland County (MI) Roads Commission
  - Road Funding Process that Explicitly Considers Safety Benefits
- Oakland County Traffic Improvement Association (TIA)
  - Timely and Accessible Crash Data
- City of Grand Rapids, Michigan
  - Public-Private Partnership with AAA Michigan
  - Intersection Geometric Improvement/Road Diet Projects
  - Michigan Indirect Left-turn Treatments for Safety
- City of Wyoming, Michigan
  - Intersection Geometric Improvement/Road Diet Projects
- Kent County Roads Commission, Michigan
  - Intersection Geometric Improvement/Road Diet Projects
  - Signing Treatments for Rural All-Way Intersections
- City of Richardson, Texas
  - Local Data Entry for City Crash Record System
  - Dynamic All-Red Hold Experimentation
  - Red-Light Running Enforcement
- City of Dallas, Texas
  - Pedestrian Signal Timing Practices
  - Signal Phasing for Safety
- North Central Texas Council of Governments
  - Pedestrian and Grade Crossing Safety Programs
  - Educational Programs

- City of Portland, Oregon
  - Dynamic Extension of Pedestrian Clearance Interval
  - Dynamic Extension of Yellow Signal Phase Interval
  - Intersection Safety Treatments for Light Rail Systems
- Portland State University
  - Intersection Safety Evaluations
- City of Charlotte NC Department of Transportation
  - Intersection Treatments to Enhance Pedestrian Safety
  - Innovative Pedestrian Signal Equipment
  - City-wide Intersection Crash Database
  - Speed Management Program
  - Geometric Design to Enhance Bus Safety
- Charlotte Area Transit System
  - Geometric Design to Enhance Bus Safety
- Charlotte-Mecklenburg Police Department
  - Speed Management Program
  - Red-Light Running Enforcement
- Florida Department of Transportation, District 4
  - Speed Activated Road Edge Illumination in Advance of Ramp Terminal
- City of West Palm Beach, Florida
  - Intersection Geometric Changes in Downtown
  - Streetscaping Projects to Enhance Driver and Pedestrian Safety
  - Traffic Calming Treatments at Intersections for Safety
- Kimley-Horn and Associates, West Palm Beach office
  - Intersection Geometric Changes in Downtown
  - Streetscaping Projects to Enhance Driver and Pedestrian Safety
  - Traffic Calming Treatments at Intersections for Safety

Like many of the states, counties, cities and municipalities throughout the United States, the host agencies that participated in this scan are endeavoring to improve safety at intersections. The treatments that they have developed and implemented are not applicable to all intersections and may not be appropriate for a given municipality or state.

### **Intersection Safety Management**

Several host agencies agreed that the first step toward achieving significant improvements in intersection safety is to create a culture of safety within the organization. These organizations found that by assigning a greater prominence to safety in transportation investment decisions, they were able to produce significant reductions in crashes. Before this could happen, it was understood that the agencies had to raise the awareness and importance of highway safety throughout all branches of the state, county, city, and municipal government transportation departments. This required the development and implementation of processes and procedures to



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monitor the performance of the highway system in measurable safety criteria, including crash frequency, rates, and severity.

Safety management that is truly performance-based was judged to be the cornerstone. The greatest gains were experienced by those agencies that had established formal numerical goals and measurable objectives with respect to crash experience. Finally, several of the host agencies also pointed to public-private partnerships as a means of improving intersection safety. The project completed by the cities of Detroit and Grand Rapids, in association with AAA Michigan, was cited as a notable case study. Since AAA Michigan is somewhat unique in that it is an insurance provider as well, other business models could be applied to better fit the constraints and opportunities that exist throughout the United States.

### **Intersection and Safety Data**

Repeatedly, host agencies indicated that it was not possible to do a reasonable job in intersection safety unless accurate crash data was matched to the correct intersection. Similarly, the host agencies voiced many concerns attributable to highly suspect crash data. All levels of government must assume a commitment to improving the quality of crash data, as well as supporting intersection inventory data and traffic data. Without a set of clearly defined numerical goals and established performance standards, operating agencies will continue to wait excessively long periods until crash data becomes available for their use.

Most host agencies also indicated that better access to crash data is needed to further enhance intersection safety. Specifically, they desired to have quickly-generated spatial data displays. Agencies with access to tools that allow generating Geographic Information Systems (GIS) pin maps and other displays, such as those that can be generated from the SEMCOG Web site, felt empowered.

Several of the host agencies also discussed a need for a flow of safety-related information from the state's central agency. The scan revealed that there are multiple benefits to the two-way exchange of crash and intersection-related data. Certainly, many benefits accrue when data can be transported up from local police departments and the state patrol to the appropriate headquarters agency tasked with the responsibility for the central crash records system. However, the benefits are also large when the data is reduced, subjected to quality control checks and summarized in meaningful formats, and returned to the police departments and transportation agencies at the local government level.

### **Intersection Safety Research**

A few of the host agencies conducted rigorous before and after evaluations of the effects of these implemented treatments on crash experience. Therefore, there is still knowledge to be learned about many of the treatments cited in this report. Limited sample size and limited post-treatment



durations restrict the evaluator’s ability to generate strong conclusions on the effectiveness of these treatments.

In addition, there is a need to develop and maintain an accurate knowledge base of the effects of projects, including those with multiple treatments, on crash experience. Safety effectiveness estimates are especially needed for flashing yellow left arrow signal indications, pedestrian detection systems that seek to extend pedestrian clearance intervals, and treatments that delay the onset of the yellow interval, among the treatments encountered during the scan.

### **Traffic Control Devices at Intersections**

Within the area of traffic control devices at intersections, many of the host agencies implemented innovative treatments, including street name signs with larger lettering in Clearview font at signalized intersections and advance street name signs that were placed at locations on the major approaches upstream of the intersection. There were also numerous pedestrian treatments, including pedestrian countdown devices, more pronounced crosswalk markings, audible pedestrian signal heads, and pedestrian push buttons and signs designed for mobility-challenged pedestrians. Some have implemented activated, in-pavement lights for crosswalks and activated pedestrian crossing warning devices-systems that alert drivers of possible conflicts.

With respect to pavement markings, several host agencies made innovative use of dashed markings, which are frequently called “cat tracks” or “puppy tracks” text on pavement surfaces at locations where supplemental directional information is needed, and messages (e.g., “LOOK LEFT”) in the pavement where there is a greater need to communicate to pedestrians, such as a roundabout.

Some agencies installed internally illuminated traffic sign boxes, which are continuously lit at night that featured permanent regulatory restrictions, such as “NO LEFT TURN” and “STOP.” Other agencies installed internally illuminated “PEDESTRIAN CROSSING” signs at mid-block crossings that are illuminated in response to actuations of pedestrian push buttons. Fiber-optic and other dynamic regulatory signs (e.g., “NO TURN ON RED” to communicate time-dependent regulations) were effectively used by some host agencies.

### **Traffic Operations at Intersections**

Virtually every host agency identified traffic operations strategies and techniques that most would consider conventional practices. These included yellow and red clearance intervals for phases at signalized intersections that meet national guidelines/practices, the provision of additional crossing time for older pedestrians and at intersections where conditions warrant (e.g., high numbers of elderly pedestrians and/or school children), and protected left-turn phases that can be called back into service during the same cycle under certain conditions.

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Many of the host agencies also described their experiences with innovative practices. In addition to the “Dallas Phase” sequence for left-turn movements at intersections operating with lead-lag left turn phasing, the city of Dallas cited an innovative treatment that allows for longer pedestrian walk and pedestrian clearance intervals to be subsequently provided in response to continuously depressing the pedestrian push button for five seconds or more. The cities of Portland and Richardson have experimented with systems that delay the onset of the yellow interval or extend red clearance intervals, respectively. While it is common practice to vary the duration of green intervals in response to congestion conditions, it is hoped that in the future systems, processes, practices and/or procedures can be devised that would allow for the dynamic variation of yellow, red clearance, pedestrian walk and pedestrian clearance intervals in response to monitored conditions to reduce safety risks.

Other innovative treatments implemented included delaying the onset of the yellow interval based on detection of vehicles beyond the stop line at wide intersections, implementing longer pedestrian walk and pedestrian clearance intervals at different times of the day when students are present at intersections near schools, time-of-day phasing in which left-turn phasing sequencing can be varied by time of day and day of week, and flashing yellow left turn arrows.

### **Intersection Geometric Design**

Innovative, non-traditional geometric design treatments, which were implemented by the host agencies, included the Michigan Indirect Left Turn treatment, the New Jersey “jug-handle” treatment, roundabouts, mini-roundabouts, and the Michigan “Loon,” which facilitate U-turns by large trucks at intersection sites with narrow medians and less than three opposing travel lanes. Several host agencies also implemented road diet projects that converted four-lane cross sections to three-lane cross sections. Median island treatments were constructed on several intersection approaches to limit the effects of nearby driveways and other access by eliminating crossing maneuvers from minor access points. Other treatments include intersection bulb-outs and offsetting left turn lanes to improve sight distance at intersections with opposing left turn lanes and permitted left turn signal phasing.

Several of the host agencies had installed unique crosswalks, which included brick crosswalks, blue bike lanes, raised crosswalks, and novel intersection designs, such as raised intersections that are similar to speed tables. At a few downtown intersections where some of these treatments were constructed, the corner curbing was concurrently removed to make the corner landing flush with the roadway. Although these geometric treatments are clearly innovative, there is a healthy debate on their appropriateness by road, functional classification, area context, vehicle speeds, and volume.

### Intersection Safety-Oriented Enforcement and Education

Although enforcement and driver education were not the focus of this scan, several notable programs were identified by host cities. Enforcement treatments implemented by the host agencies pertained to the vigilant enforcement of unsafe driving behavior at intersections. These included so-called “rat lights,” which assist police agencies to identify drivers that violate red signal indications at intersections, and photo enforcement systems.

Other enforcement programs featured enforcement target maps, which have been developed by traffic engineering agencies to pinpoint the clustering of selected crash types for given “targets,” such as red-light running, speeding, and aggressive driving, among others. Driver education treatments for intersection safety included multi-jurisdictional education campaigns aimed at red light running and widely distributed brochures in Spanish that explain traffic control devices at intersections.

Other innovative education programs included a mobile truck simulator for truck driver training and portable, radar-based dynamic speed signs. Innovative traffic control or geometric design treatments should not be implemented without advance public information. Wherever new treatments, especially those that are non-intuitive, are to be implemented, consideration should be given to developing and conducting a comprehensive public education program prior to deployment and updating driver training materials to ensure that the message is communicated to new drivers.

Readers of this scan report are encouraged to contact the individuals in Appendix B to learn more about the treatment and processes that are described. It is hoped that better and more effective intersection safety treatments can be developed and implemented by others as a result of this search for innovative ideas.

### Disclaimer

Some of the traffic control devices or applications described in this report are not in compliance with the *Manual on Uniform Traffic Control Devices (MUTCD)* and are considered experimental. Any jurisdiction wishing to use a non-compliant device or application on a road open to public travel must request and receive approval from the Federal Highway Administration for experimentation. Please refer to Section 1A.10 of the *MUTCD* (<http://mutcd.fhwa.dot.gov>) for procedures regarding experimentation.”



## **CHAPTER 1. INTRODUCTION**

### **Background**

Intersection safety is and has been a major program at the Federal Highway Administration (FHWA). Within intersections, vehicle-vehicle and vehicle-pedestrian conflicts occur as drivers, bicyclists, and pedestrians need to cross the path of other vehicles. Not surprisingly, the intersection, whether or not it is under traffic signal control, can be a hazardous location as evidenced by various motor vehicle crash statistics.

Utilizing the year 2002 crash database maintained as part of the National Accident Sampling System, there were an estimated 2.7 million motor vehicle crashes at intersections in the United States in 2002. Approximately 1.4 million crashes were reported at unsignalized intersections and 1.3 million were crashes reported at signalized intersections. An estimated 925,000 people were injured in the crashes at intersections. Approximately 445,000 people were injured in crashes at signalized intersections and nearly 480,000 were injured in crashes at unsignalized intersections. In terms of fatalities based on the Fatality Analysis Reporting System, a total of 9,117 people died in 2004 as a direct result of crashes for which the relation to junction was classified as at intersection (non-interchange) or intersection-related (non-interchange).

Drawing upon information in a recent 2001 paper by Harwood, et al., entitled “Overview of Current Intersection Safety Conditions”<sup>(1)</sup> and a compilation of crash statistics, the following statements further describe the crash experience at intersections in the United States:

- Approximately 22 percent of fatal crashes on all roads are intersection-related.
- Seventy-five percent of the fatal intersection-related crashes were multiple-vehicle crashes. Angle/turning collisions accounted for the vast majority of the multiple-vehicle crashes.
- Signalized intersections consistently have higher percentages of multiple-vehicle crashes than stop-controlled intersections.
- Twenty-two percent of the intersection-related fatal crashes involved alcohol compared to 39 percent for all fatal crashes.
- The percentage of fatal and serious injury crashes is generally higher at rural intersections reflecting the higher speeds and greater response times for emergency medical services.

As these crash statistics demonstrate, intersection safety is a significant problem in the United States. Achieving a higher level of intersection safety has become a priority of the safety community as evidenced by the following:

- Intersection safety is one of the emphasis areas in the American Association of State Highway and Transportation Officials’ (AASHTO’s) Strategic Highway Safety Plan.
- Intersection safety is also included in the Safety Action Plan of the Institute of Transportation Engineers (ITE).

- Achieving a significant reduction in the number and severity of intersection crashes was identified by the Future Strategic Highway Safety Program (F-SHRP) of the Transportation Research Board as a critical strategy in making a quantum leap in highway safety.
- With the input of numerous public agencies and private organizations FHWA has established a national agenda for intersection safety.

In May 2002, a scanning study of signalized intersection safety in Europe was sponsored by the FHWA and AASHTO. With the goal of improving signalized intersection safety, the focus of the scanning study was on innovative signalized intersection safety practices in Europe. In December 2003, the FHWA published *Signalized Intersection Safety in Europe*<sup>(2)</sup> as part of FHWA's International Technology Exchange Program. A copy of the cover is presented in figure 1. Given the relative success of that European scan and feedback on the report, FHWA decided that a scanning study should be conducted of select areas in the United States. It was hoped that a Domestic Scan would also produce tangible benefits through identifying, and making highway agencies aware of, innovative treatments and practices that have been successfully implemented in the United States.



**Figure 1.**  
**FHWA's Report on**  
**Signalized Intersection**  
**Safety in Europe.**

### Study Goals and Objectives

The goal of this Domestic Intersection Safety Scan was to reduce fatalities, personal injuries and crashes at intersections in the United States by documenting and subsequently promoting innovative intersection treatments and comprehensive intersection safety processes that have been implemented in this country.

One of the primary objectives was to identify and document selected innovative intersection treatments that have been implemented at intersections in the United States and have demonstrated, or have the potential to improve safety at intersections. Another objective was to identify and document selected comprehensive safety processes and procedures that have been implemented by transportation agencies specifically to improve intersection safety.

The range of treatments to be considered within the scan included treatments that addressed and/or contained the following elements:

- Traffic control devices for motorists.
- Traffic control devices for pedestrians, bicyclists, and other non-motorists at intersections.
- Traffic operational schemes and strategies applicable to vehicular traffic flow, including those for signal-controlled intersections.
- Geometric features and designs that enhance the safety of vehicle maneuvers at intersections.
- Enforcement practices and educational programs.



## *Innovative Intersection Safety Improvement Strategies and Management Practices: A Domestic Scan*

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During the scan, a secondary objective was to gain knowledge about and document the processes and procedures that were employed to gain agency management's approval for successful implementation and deployment. To the extent that the treatments had been evaluated by local agencies, the scan endeavored to gain knowledge about the safety effectiveness of these treatments and comprehensive approaches to intersection safety.

### **Study Scope**

Because of limited resources, the scan team was limited to visiting five areas of the country. A search was conducted to identify areas where innovative intersection treatments and comprehensive safety processes have been implemented and the local agencies were recognized for their prominence in selected areas and expressed a willingness to participate and share their knowledge, time, and experiences. Additional weight was given to areas that were in states that are participating with FHWA on strategic safety programs. The areas that were ultimately selected are presented in figure 2, including the following:



**Figure 2. Areas Visited**

- The cities of Detroit and Grand Rapids, Michigan, and the counties of Oakland, Kent and Livingston, Michigan.
- The city of Richardson, Texas, and the Greater Dallas/Ft. Worth Metropolitan Area.
- The city of Portland, Oregon.
- The city of Charlotte, North Carolina.
- The cities of West Palm Beach and Fort Lauderdale, Florida.

The rationale for the selection of these areas is summarized below:

**The cities of Detroit and Grand Rapids, Michigan, and the counties of Oakland, Kent and Livingston, Michigan.** Several years ago, the American Automobile Association (AAA) Michigan, in concert with several agencies, conducted safety studies of target intersections selected based on crash severity. Improvements were designed and implemented, and a post-implementation evaluation study was performed. Since the AAA Michigan studies were so well documented, the focus for this scanning study was on the process that the local agencies subsequently incorporated into their practices.

Another notable program in Michigan is their intersection safety action plan, which was developed by the Governor's Traffic Safety Advisory Commission (GTSAC). The plan was developed by a diverse group of agencies involved in a variety of aspects that affect intersection safety. The multi-agency group developed a plan that included actions for each group and have

continued to work together to foster improved intersection safety. For the purposes of this scanning study, the level of success achieved through interagency coordination was another primary reason for selecting Michigan.

While in Michigan, the scan team visited two transportation organizations. The Southeast Michigan Council of Governments (SEMCOG) developed a Web-accessible crash records system. The SEMCOG also participated in several other projects that had a high relevance to intersection safety, including the development of a very thorough traffic safety manual. The Oakland County Traffic Improvement Association (TIA) has been involved in the capture and distribution of crash reports for Oakland County, Michigan, since the late 1960s. It also has a long history of involvement in intersection safety improvement projects and programs in Oakland County. A joint meeting was held with the Road Commission for Oakland County (RCOC) and the Oakland County TIA.

**The city of Richardson, Texas, and the Greater Dallas/Ft. Worth Metropolitan Area.** The city of Richardson, Texas, has been involved with progressive red light running enforcement. Of particular interest was an experimental dynamic Red Light Hold (RLH) system that had been tested in the city. Conceptually, the red clearance interval is extended if a vehicle approaching at a relatively high rate of speed is predicted to enter the intersection when the signal indication was red. The RLH system alerts the controller and applies a “stop time” during the timing of the red clearance interval to permit safe passage of a red light runner. In addition, Richardson has been heavily involved with the use of the so-called “rat light” or “enforcement light,” which is a light wired to the signal that illuminates when the traffic signal section displays a red indication. A police officer can observe the intersection and the “rat light” from a position downstream of the intersection and can determine when a vehicle runs a red light.

The second agency visited was the city of Dallas, which has been involved in many innovative intersection projects, especially in the area of traffic signal control. Dallas had implemented a software routine to the traffic signal controllers that allows pedestrians to depress the pedestrian push button for five seconds, triggering a longer flashing “DON’T WALK” interval. Consequently, a longer time to cross the street is provided to a pedestrian with reduced mobility capabilities. The process that Dallas has used includes meeting with elderly pedestrians at the intersections and walking with them.

The scan team also visited in the Fort Worth-Dalla area, the North Central Texas Council of Governments (NCTCOG). The NCTCOG is involved in several areas related to intersection safety and its leadership is very knowledgeable and progressive in promoting intersection safety within the region.

**The city of Portland, Oregon.** Several innovative intersection treatments geared toward pedestrians and bicyclists at intersections were identified in the city of Portland. Notably, the city’s efforts to improve intersection safety have included the deployment of technologies for sensing pedestrians as they cross the street and lengthening the pedestrian clearance interval as needed. Portland also has a comprehensive traffic-calming program at intersections, and has implemented and evaluated several innovative safety treatments to enhance bicyclists’ safety at locations where they cross-vehicular traffic paths.



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**The city of Charlotte, North Carolina.** The city of Charlotte was recently selected by the FHWA to become an urban center for the Highway Safety Information System (HSIS). This decision was made because Charlotte has and maintains many unique data sets such as roadway inventory data that includes driveway density and curb types, turn movement counts with pedestrian crossing volumes, crash records for crashes reported on all streets in the city except Interstates (responsibility of State Patrol), traffic calming inventory data, sidewalk data, bike lane data, and transit bus stop data, among others. In terms of innovative treatments, Charlotte has an extensive amount of speed humps, speed tables, and unique pedestrian crossings. Charlotte was recognized by ITE for their programs in pedestrian safety.

### **The city of West Palm Beach and Florida DOT District 4 (Office: Fort Lauderdale)**

A location with innovative geometric intersection treatments was desired for the scanning study. One area identified was the city of West Palm Beach. The city has been known for innovation in traffic safety, notably being one of the first police forces to provide laptops to their officers for the automated preparation of police crash reports. It has recently been involved in new urbanism for street design. West Palm Beach redesigned and reconstructed a corridor in its downtown, specifically Clematis/Narcissus Street, as one of the first traffic calming/redevelopment projects for the city. The street was narrowed and shifted laterally, with trees, landscaping and storefront improvements. At the intersections, curb extensions slowed turning traffic and offered improved pedestrian crossings. Since the successful implementation of that project, the city developed a downtown master plan that featured similar intersection geometric projects.

While looking for other agencies in the West Palm Beach area, a very interesting project was initiated in the Fort Lauderdale area by the Florida Department of Transportation, District 4. The project was developed in an attempt to reduce the speed of drivers on a freeway off-ramp that terminated in a very sharp right turn onto a state highway. The system consisted of a series of activated in-pavement lights that flashed in a sequential manner if vehicles entering the ramp were detected to be traveling above 50 mph. It is important to note that while the junction of the ramp with the state highway was technically a ramp terminal, the potential for application to at-grade intersections was very appealing.

### **Scan Team**

The participants on the scan team were selected to bring a different perspective to the team. They were selected to represent broad constituencies in city, county and State government and in the research field. Each invited participant had over 30 years of directly relevant experience in a wide range of areas related to intersection safety. These participants devoted 13 consecutive days to participating on the scan, and provided a wealth of knowledge and input to the development of this report. The team members included the following:

- Eugene Calvert, P.E., Interim Director, Transportation Engineering & Construction Management (TECM) Department, Transportation Services Division, Collier County, Florida.
- Douglas W. Harwood, P.E., Transportation Section Manager, Midwest Research Institute, Kansas City, Missouri.

- Loren Hill, P.E., State Traffic Safety Engineer, Office of Traffic, Security and Operations, Minnesota Department of Transportation, St. Paul, Minnesota.
- Stan Polanis, Director of Transportation, Transportation Department, city of Winston-Salem, North Carolina.

In addition to these individuals named above, Warren E. Hughes, P.E. and Jennifer Weigle of Vanasse-Hangen-Brustlin, Inc. served as scan team facilitator and scan logistics coordinator, respectively. Debra Chappell and Shyuan-Ren (Clayton) Chen, Ph.D., P.E., members of the FHWA Office of Safety Intersection Team, served as observers of the scan, and collaborators to this report.

### Organization of Report

The report is organized in the following manner:

Chapter 1 covers the scan background, goals and objectives, scope, team and organization.

Chapter 2 presents information on comprehensive safety management systems and processes that have the potential to positively improve intersection safety.

Chapter 3 covers innovative treatments involving traffic control devices for motorists.

Chapter 4 describes innovative traffic control and other devices for pedestrians and bicyclists at intersections.

Chapter 5 presents items related to traffic operations and not tied to specific traffic control device hardware.

Chapter 6 covers intersection geometric treatments.

Chapter 7 presents a concise discussion of selected enforcement and educational programs uncovered during the scan. Although the scan focus was not on enforcement or education, several items related to enforcement and education were identified and discussed during the scan by the host agency.

Chapter 8 presents the scan team's conclusions.

Appendix A presents information about the scan team members, their affiliations, and brief biographies.

Appendix B contains a list of the agencies and their personnel who participated in the scanning tour and provided significant contributions.



**Figure 3. Scan Team (From left: Gene Calvert, Loren Hill, Stan Polanis, Clayton Chen, Doug Harwood, Jen Weigle, and Warren Hughes). Not pictured: Debra Chappell.**

## **CHAPTER 2. SAFETY MANAGEMENT AND COMPREHENSIVE SAFETY PROCESSES**

This chapter presents findings related to safety management and comprehensive safety processes that were identified and discussed during the scan. It is believed that these processes have a positive influence on intersection safety, although there have been limited attempts to correlate specific crash reductions with the specific processes. It is important to recognize that several of the items discussed in this chapter are broader in scope than just intersection safety. However, it became apparent during many of the interviews and site visits that intersection safety is positively affected by safety management practices of agencies and communities. For these reasons, safety management should be discussed first, before the focus of this report shifts to traffic control, traffic operations, and intersection geometric treatments.

### **An Uncompromising Commitment to Safety**

In terms of intersection safety, there was one public agency that stood out with the scan team due to its concentrated attention to safety. The Road Commission of Oakland County (RCOC), in Michigan is responsible for the design, operation, maintenance, and construction of all 2,700 miles of county roads – about half of its public roads – in this large, rapidly urbanizing county north of Detroit. The notable item about the RCOC is its fundamental commitment to safety. Many years ago, the RCOC management essentially made safety a priority in road decisions. The RCOC created a process in which crash data were to be used to measure the safety of its highways. In addition, RCOC instituted formal documentation of its safety performance goals. Not only that, but the RCOC set about to assure that improvements in safety were the direct result. For example, when the Council of Governments solicits projects as part of the regional constrained long-range transportation plan, the RCOC considers safety as one factor in selecting improvement projects.

In deciding where and how Michigan Transportation Economic Development Fund (TEDF-Category C funds) money is distributed, Oakland County employs a project priority rating that assigns a weight of 30 points out of a possible 103 points for a project's assessed potential to reduce crashes. Table 1 (*page 8*) presents the factors and their associated weights used in the rating scheme. For the application of Surface Transportation Program (STP) funds, they employ a slightly different project priority rating scale that actually weights crash reduction even higher (35 points out of 103 points). Oakland County's 40 cities and villages, which are eligible recipients of both TEDF (C) and STP funds, also had to agree to the point system (in effect, the Road Commission and the cities/villages compete for the use of these funds). Safety improvements have been taking place on both county roads and city/village streets across the county.

Along the way, the RCOC has created a culture of safety that has allowed significant improvements in highway safety while growing from a county of 300,000 in 1967 to 1.2 million people in 2004. During the scan team's visit, the RCOC indicated that they were able to achieve this safety culture by building safety as a highly weighted factor into federal investment decisions, by requiring safety to be the Number One priority of the agency so that it is driving decisions, and by getting good crash data.

**Table 1. Factors and weights used by the Road Commission for Oakland County for project prioritization using Michigan Transportation Economic Development Funds (TEDF-Category C Funds) and Surface Transportation Program (STP) Funds.**

Category		Criteria	Weights	
			TEDF – C	STP Projects
I. Planning	A. Importance of Project in the System	1. National Functional Classification	3	3
		2. Consistency with SEMCOG 25 Yr. Plan	1	1
		3. Improvement in System Continuity	3	3
		4. Improvement in Lane Consistency	2	2
		5. Pavement Classification	2	2
		6. Urban Boundary	2	2
		7. Impact of R.O.W. Acquisition	3	3
	<b>Subtotal</b>	<b>16</b>	<b>16</b>	
	B. Coordination with Other Modes	1. Coordination with Transit	2	2
2. Coordination with Non-Motorized		2	2	
<b>Subtotal</b>		<b>4</b>	<b>4</b>	
II Engineering	A. Crash Reduction	1. Decrease Crash Frequency	10	10
		2. Decrease Crash Rate	10	10
		3. Decrease Crash Severity	10	15
		<b>Subtotal</b>	<b>30</b>	<b>35</b>
	B. Improved Physical Roadway Conditions	1. Improvement in Base	1	3
		2. Improvement in Drainage	1	3
		3. Improvement in Lane Width	2	2
		4. Improvement in Pavement Surface	6	7
		5. Improvement in Curb/Shoulder	2	4
		6. Improvement in Roadside Obstacle Clearance	1	2
		7. Improvement in Passing Sight Distance	2	2
		8. Improvement in Stopping Sight Distance	0	2
	<b>Subtotal</b>	<b>15</b>	<b>25</b>	
	C. Improved Traffic Operations	1. Congestion Reduction Under Existing Traffic Levels	12	7
		2. Congestion Reduction Under Future Traffic Levels	10	5
3. Improvement in Driveway Conflicts		3	2	
4. Improvement in Lane Balance		3	2	
5. Improvement in Turning Movements		4	2	
6. Improvement in Roadside Park Conflicts		3	2	
<b>Subtotal</b>	<b>35</b>	<b>20</b>		
III. Funding Considerations	A. Local Considerations		3	3
		<b>Subtotal</b>	<b>3</b>	<b>3</b>
		<b>TOTAL POINTS</b>	<b>103</b>	<b>103</b>

# Innovative Intersection Safety Improvement Strategies and Management Practices: A Domestic Scan

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## Performance-Based Safety Systems

To achieve appreciable and meaningful reductions in intersection crashes, several agencies indicated that there is a pressing need for a performance-based safety management system. In order to advance the safety agenda in the United States, especially with respect to intersection safety, systems are needed to ensure that the safety performance can be measured and compared to performance standards. Many highway agencies do not have such a system in place and point to a variety of obstacles and impediments; however, the RCOC has implemented a system. Agency administrators learned years ago that it was not simply enough to claim expected safety benefits from projects. Rather, RCOC learned that it needed to evaluate the effects of its road decisions on safety, specifically crashes. Hence, it was determined that continuously monitoring the safety performance of roads was needed, in terms of reported crash frequency, crash rates, and crash severity. This, in turn, allowed better decisions to be made in roadway investments. It is because of the systems put in place by the RCOC that the organization can cite the statistics in table 2, which show that over a period of nearly 40 years, despite a four-fold growth in travel in the county, traffic fatalities have been reduced by 64 percent and traffic fatality rates have been reduced by more than 91 percent.

**Table 2. Changes in Oakland County’s Population, VMT, Crash Fatalities, and Crash Fatality Rate.**

	1967	2004
Population	300,000	1,200,000
Annual Vehicle Miles Traveled (VMT)	3.0 Billion	13.1 Billion
Traffic Fatalities	206	75
Traffic Fatality Rates, in fatalities per 100 MVM:		
Oakland County, Countywide average	6.8	0.57
Michigan, Statewide Average	No data	1.1
United States, National Average	5.3	1.4

**MVM = Million Vehicle Miles**  
**Source: TIA and SEMCOG**

### **Timely and Accurate Crash Data**

Throughout the scan, many agencies voiced similar sentiments about the importance of timely and accurate crash data. Several agencies indicated that this is recognized as the first fundamental step towards improving traffic and pedestrian safety in their communities. One of the reasons that the RCOC is able to achieve such a positive effect on highway safety is due in a large part to the efforts of the Oakland County Traffic Improvement Association (TIA). This 38-year-old private/public non-profit corporation, which receives funding from public sources, grants, private donations and corporate sponsorship, collects, compiles, and analyzes crash data for all roads in Oakland County.

The TIA established standards for capturing and returning crash data so that almost all of the reported crashes are accurately located, incorporated in an electronic database, and summarized. Data with accompanying detailed individual reports are available to agencies within 60 days of the date of the reported crash. The TIA has established good working relationships with 68 cities and villages, the RCOC and more than 45 police agencies. TIA staff collects or receives reports after the police supervisor, such as a lieutenant, completes a review of the investigating officer's report. The TIA has developed a cooperative arrangement with the Michigan State Police in which it is permitted to receive crash reports from local police agencies and enter the reports into a database before they are forwarded to the State Police. When one or more officers note a particular quality issue, the TIA can contact the appropriate police agencies and affect positive improvements in reporting practices. This may explain why TIA's claim of 100 percent accuracy with respect to location, although they frequently must use officers' estimates recorded on the form.

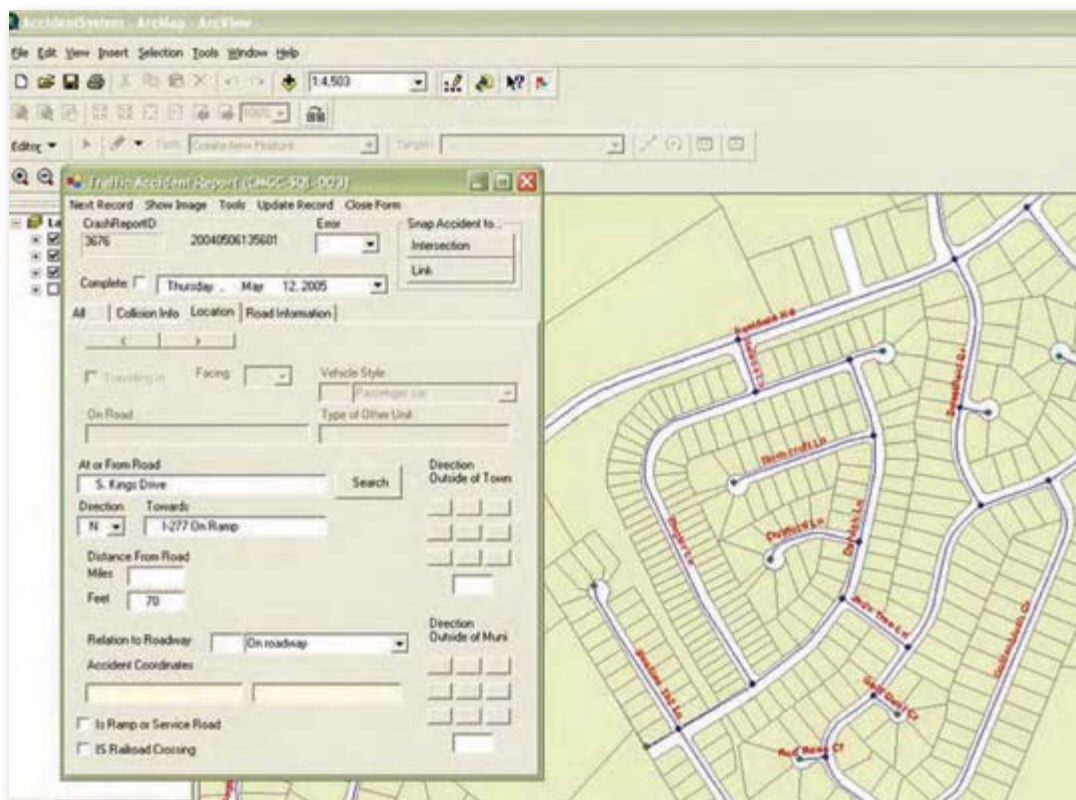
### **Distributed Responsibility for Crash Data Entry**

It is noted that the Oakland County TIA is somewhat unique in that it is a private, non-profit organization providing services that are typically handled by public agencies. Moreover, TIA is unique in that it can obtain the police crash report forms directly from numerous police agencies. When talking about intersection safety with other agencies during the scan, there were some expressions of frustration with waiting for highly inaccurate crash data from the central unit within the State agency responsible for processing the crash data. Charlotte, North Carolina, and Richardson, Texas, also code their own crash data with their own local agency personnel and maintain their own crash records systems. The benefits resulting from this investment of local agency resources can be significant, depending on the relative backlogs and processing efficiency of the responsible state agency. If the city experiences a relatively manageable number of crashes reported in a year, then it may be possible for one individual to devote a percentage of his/her time to entering crash data. If there are a relatively large number of reported crashes, then one or more people may need to be exclusively dedicated to code crash data. Representatives from Charlotte and Richardson claim that the benefits from coding their crashes were invaluable and well worth the investment. The data entered into their local crash records systems gives them the ability to identify high crash locations, to assess the costs to their communities, to generate yearly comparisons of crashes, and to investigate crashes by potential contributing factors, among other items.

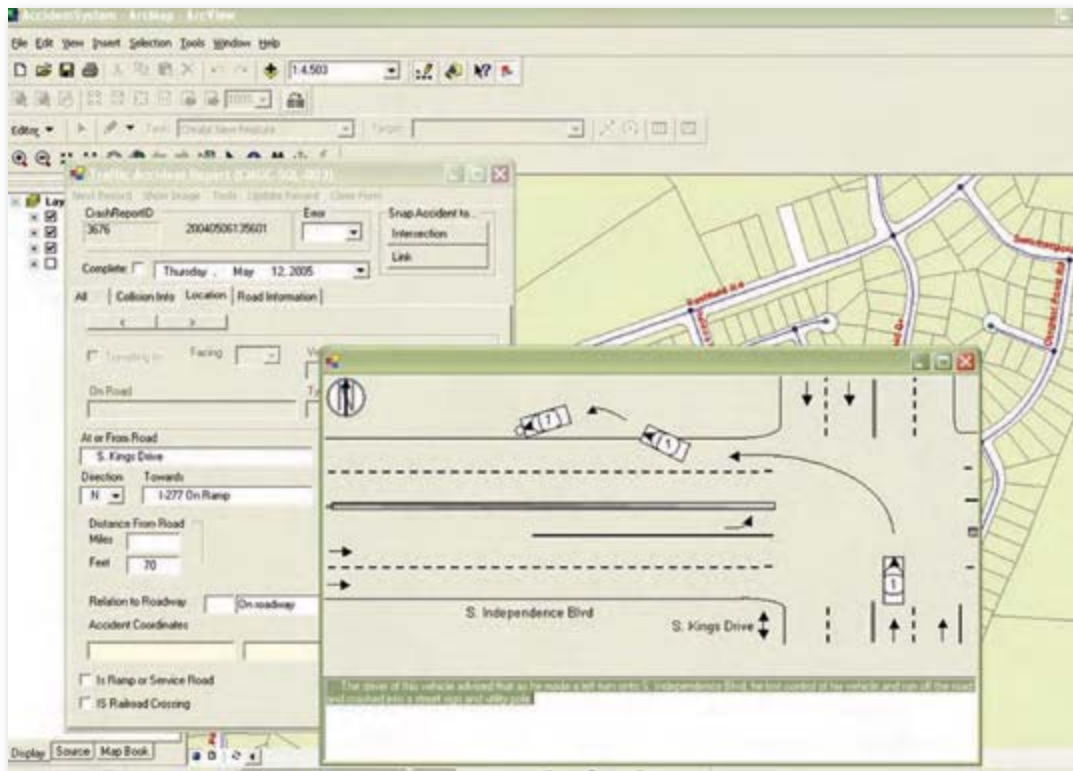


## Innovative Intersection Safety Improvement Strategies and Management Practices: A Domestic Scan

Charlotte developed a series of tools to assist its analysts in locating crashes from the crash reports. This is presented in figure 4. The underlying map to the right in the screen view is a map showing the location of the subject intersection as a red dot. The information to the left is information for various location fields. Charlotte's transportation officials indicated that this is most helpful in resolving uncertainty about whether a crash has been tied to the correct intersection. Like many cities, Charlotte has many of the same challenges with respect to locating crashes. These challenges include streets with multiple street names, two sets of roads that cross twice creating duplicate intersections, route numbers and street names used to indicate the same road, and various errors. Like any system, improvements are made over time.



**Figure 4. Photograph of screen showing Charlotte's tool to find crash location.**  
(Courtesy of Charles Jones, Charlotte DOT)



**Figure 5. Screen view of sketch with narrative for individual crash location reported captured in Charlotte's crash records system.** (Courtesy of Charles Jones, Charlotte DOT)

In addition to this locating-assistance tool, Charlotte has also created other capabilities within its crash record software system to assist the analyst. Specifically, it has devised a way for the user to create sketches of the crash diagram and to enter the narrative such that it becomes part of the crash record stored and therefore retrievable by analyst. Figure 5 depicts the screen showing the narrative and sketch of a specific crash report.

### Web-Based Safety Data Systems

During the scanning study, a few agencies indicated that they have created and maintained their own crash records systems and have made them available to others. This could ultimately produce improved intersection safety benefits. The Michigan State Police makes its crash data available to local police agencies by means of a Web-based tool that features additional security features (e.g., passwords). This allows the local police agencies to not only check the data that was extracted from the police crash reports that they prepared, but also to run statistical summaries and execute selected queries of a limited number of fields in the crash records database. The Michigan State Police and the Governor's Traffic Safety Advisory Council (GTSAC) are expanding this system to make it available to Metropolitan Planning Organizations, State University Transportation Research Centers, road commissions, and others.



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Currently there are 50 non-law enforcement users, but they project that there could ultimately be as many as 2,500 users.

The Southeast Michigan Council of Governments (SEMCOG) has created a resource tool that can be used by its member agencies and others as well, since it is a Web-based system that runs on SEMCOG's Web site, [www.semco.org](http://www.semco.org). SEMCOG's Transportation Data tool allows users access to crash and traffic data. As expressed in the information on the SEMCOG Transportation Planning Web site (<http://www.semco.org/TranPlan/TransportationDataTool.htm>):

“By reducing the time needed for data gathering, more time is available for analysis. By providing linkages across many data sets, less time is needed for gathering data, and resources can be maximized for greater insights in analysis. Ultimately, this should result in more timely and informed decisions, and a better transportation system.”

“Up to now, the process of compiling data to analyze a problem has often involved searching for data sources, contacting various data providers to get the data, repeated contacts to get more information about the data, then sorting through the data and integrating data from various sources for analysis. This can be a very labor-intensive process, often taking months. The Transportation Data Tool is an initiative aimed at streamlining this whole process.”

### **Spatial Analysis Systems and Analytical Tools**

Clearly, law enforcement agencies and local governmental units benefit greatly from improved access to crash data. When combined with complementary analysis tools, notably spatial analysis tools, even greater benefits to improved intersection safety are possible. Figure 6 presents a GIS-based map of the location of pedestrian deaths reported over a six-year period. The source data was the Injury Prevention Center of Greater Dallas. Spatial representations of crash locations allow technical personnel, management, and the general public to quickly see crash patterns.



**Figure 6. Dallas County pedestrian deaths map.**  
(Courtesy of NCTCOG)

Similarly, figure 7 presents a crash map for a high crash location in Michigan that was generated from the SEMCOG Web site. This particular 3-D plot represents crashes reported between 1997 and 2002, inclusive, within 150 feet of an intersection. For this map, one chip represents five crashes. The color coding is as follows:

- **Red:** Fatal crashes.
- **Orange:** A-level injury crashes, in which A-injuries are non-fatal incapacitating injuries that prevent victims from functioning normally (e.g., paralysis, broken/distorted limbs, etc.).
- **Yellow:** B-level injury crashes, in which B-injuries are non-incapacitating but visible injuries (e.g., abrasions, bruises, swelling, limping, etc.).
- **Green:** C-level injury crashes, in which C-injuries are probable but not visible injuries (e.g., sore/stiff neck).
- **Blue:** Property damage only crashes.



**Figure 7. Illustrative example of spatial crash summary generated by SEMCOG.**

The intersection with the most “stacked chips” is the intersection with the highest number of reported crashes in that county for that five-year period. The crash map shows the crash experience at the other nearby intersections within the grid view. Detailed tabular summaries are also available to the user, but this map visually demonstrates how information shown graphically can present a much more interesting story in far less time than a table of numbers. It is important to note that the data on the SEMCOG Web site can be accessed by the public and that no password is needed. The data elements available do not include any personal information.

### Interagency and Intra-Agency Cooperation

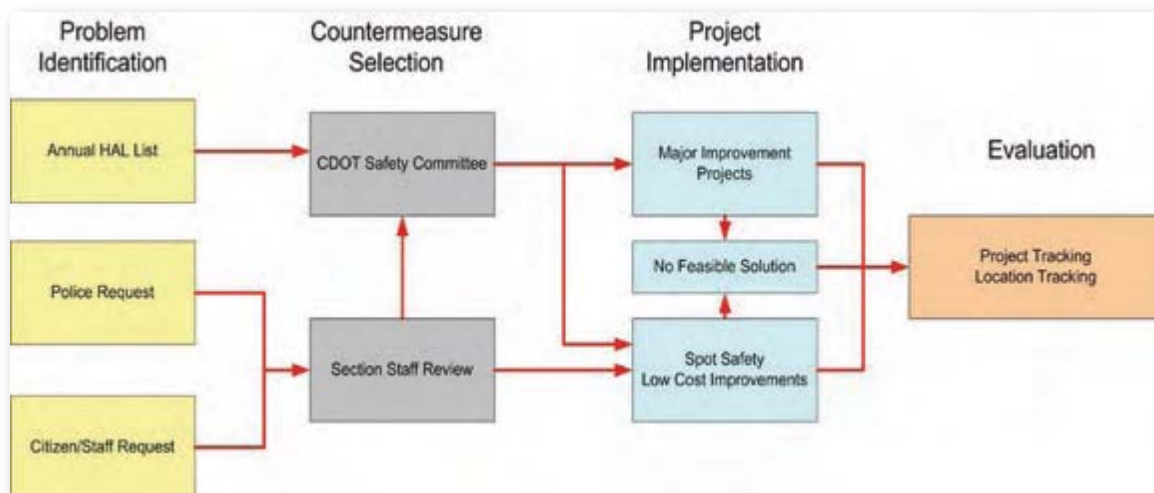
Several of the host agencies described programs that were created as a direct result of inter-agency and intra-agency cooperation. Portland, Oregon, identified several notable examples where diverse groups of people were brought in to develop programs that ultimately will produce improvements in intersection safety throughout the city. These included the following:

- Community and School Traffic Safety Partnership (CSTSP) Strategy, which involves citizens from the Traffic Calming Citizen Advisory Committee, the Director of the Portland Office of Transportation, the Portland Police Bureau, traffic operations staff, activist groups, a representative of the Mayor’s office, schools, and various agencies with the Office of Transportation.
- The Smart Moves Middle School curriculum, which is intended to help students identify real transportation, planning, and environmental issues in their community, to learn traffic and safety rules, and to see the connection between transportation habits and the environment, among others.

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- The Opportunity Analysis Pedestrian and Bicycle Enhancement Project, which involves training of police officers involved with pedestrians and bicycles. One of the goals is that officers will gain an understanding of where collisions are occurring and then match up enforcement to those crash location clusters. The focus on the education of police is so that they can gain an appreciation of the differences of where citations can be given versus where safety can be positively affected.

Charlotte created a process (figure 8) that involves a number of different offices from within the city's Department of Transportation and other agencies. The Charlotte Department of Transportation Safety Commission includes representatives from the traffic safety section, the engineering and operations (i.e., signs, signals, and markings) division, the city engineering and property management division, the planning and design division, the implementation section (which monitors signal installations), a police officer involved with higher-level interdiction, and a representative for the transit system. As a group, efforts are made to identify locations that will need correction by means of major improvements and projects for which low cost improvements are appropriate. This group is also involved in reviewing and scoping major improvement projects to determine if there may be no feasible solutions. Since they represent different groups from within the Department, they also serve as conduits of safety considerations for their respective groups.



**Figure 8. Charlotte's safety improvement project selection and evaluation process.**  
(Courtesy of Charlotte DOT)

The Michigan State Intersection Safety Action Plan is one example of where interagency and intraagency coordination can truly affect a positive change in intersection safety. The plan was initiated by the Governor's Traffic Safety Advisory Commission (GTSAC). Recognizing that on a national level, 40 percent of all crashes reported in 2002 were intersection-related, the GTSAC identified intersection safety as one of its three main issues to address. The GTSAC created an Intersection Safety Action Team. Using the "National Agenda for Intersection Safety"<sup>(3)</sup> as a guide, it developed the Michigan Intersection Safety Action Plan. The plan included specific goals to achieve annual reductions in total intersection crashes, total intersection fatalities, and total intersection injuries. The goals are that in 2009 there will be less than 100,000 intersection-

related crashes reported in Michigan, less than 3,000 people injured as a result of intersection-related crashes, and less than 300 people who die as a result of intersection-related crashes.

The plan included strategies to address the following:

- Legislative/Political Outreach
- Safety Management
- Research
- Data
- Safety Analysis Tools and Practices
- Engineering Countermeasures
- Red Light Running
- Enforcement
- Communication and Education

The agencies involved on the Intersection Safety Action Team included the Michigan Department of Transportation, the Office of Highway Safety Planning (which is an office within the Michigan State Police), the Michigan State Police (specifically the Traffic Services Section of the Special Operations Division), the Federal Highway Administration's Michigan Division Office, SEMCOG, the RCOC, the city of Troy, the Michigan Center for Truck Safety, Wayne State University, and DLZ Michigan, Inc. (a private consulting firm involved in the design of roundabouts). Each agency voluntarily assumed responsibility for aspects of the plan relevant to its purviews. One of the most significant benefits from the plan was the formation of strong bonds between and among various agencies. By sharing in the plan and working closely in various meetings, the level of interagency and intra-agency cooperation achieved made it possible for diverse interests to share common ground.

There is still an ongoing discussion over the next steps for the plan and whether further encouragement is needed or governmental mandates are required. Since its approval in February 2003, the Intersection Safety Action Plan lists several of its many accomplishments to date:

- In 2003, intersection crashes resulted in 337 fatalities, which accounted for 26 percent of total Michigan highway fatalities. The 2003 goal in the Intersection Safety Action Plan was 362 fatalities.
- In 2003, there were 3,774 incapacitating injuries resulting from intersection-related crashes, which accounted for 33 percent of total Michigan incapacitating injuries. The 2003 goal was 3,918 incapacitating injuries.
- In 2003, fatalities and incapacitating injuries were lower than the plan's goals, although the total intersection-related crashes were higher than the goal (i.e., goal of 119,161 intersection crashes compared to 119,360 intersection crashes actually reported).
- Provided high-crash-location data to eight counties as part of the Safe Communities activities being conducted by the Office of Highway Safety Planning (OHSP).
- Developed a secure Web-based tool to allow local police agencies in Michigan to identify high-crash intersections and capture tabular summaries of a limited number of data fields from the crash reports that they create. This is somewhat novel in that a useable database can be accessed and used by the agencies and individuals who recorded the data at the scene. It has created a better rapport between data recorders and other data users.

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- Conducted a fact-finding meeting with MDOT, SEMCOG, and OHSP to understand activities currently being undertaken in the area of mapping high-crash locations.
- Developed, published, and promoted the *Michigan Traffic Safety Fundamentals Handbook*, of which more than 1,100 copies have been distributed to law-enforcement agencies, county road associations, and MDOT regional offices.
- Created a Michigan Signal Summit Team that meets every three months to review issues and activities related to traffic signal projects.
- Earmarked and distributed approximately \$1 million to the local safety program, which funded eight intersection improvement projects.
- Funded the Metropolitan Planning Organization (MPO) traffic safety study.
- Assisted in advocating and helping with the design and implementation of a new roundabout.
- Initiated a joint project involving MDOT and OHSP to combine efforts to develop and promote a multi-year plan to update all signal heads in the state to 12-inch lens and ensure proper visibility and shielding of signal heads at intersections throughout Michigan.
- Initiated a study to install and evaluate red light enforcement lights or “rat boxes” (“rat lights” will be described in Chapter 7 on enforcement later in this report). Also, the OHSP sponsored intersection enforcement activities in fiscal year 2005.
- Developed and taught a course entitled *Intersection Safety for Non-Engineers*.

### **Public-Private Partnerships**

In an age of limited resources, public-private partnerships offer substantial promise to create an environment to implement and sustain safety process improvements. One of the most notable examples of a successful public-private partnership is the well-documented road improvement demonstration project sponsored, in part, by the American Automobile Association Club of Michigan (AAA Michigan). The project was implemented jointly with Detroit and Grand Rapids, and resulted in the implementation of specific improvements at selected intersections. Since AAA Michigan is also an auto insurance provider to citizens in Michigan, it too had a vested interest in improving intersection safety. Fewer crashes mean fewer claims and lower payouts for damages that result from crashes. Sharing a mutual goal was sufficient incentive for AAA Michigan to get actively involved. Moreover, this AAA club has a full-time traffic engineer, who is one of three employed in all of the AAA clubs throughout the United States. It was only a natural extension of the engineer’s interest and background that AAA Michigan would be the lead in a public-private partnership with traffic engineers working for public agencies to devise a way to implement intersection improvements. The scan team also learned that AAA Wisconsin, which also is an auto insurance provider, is endeavoring to implement a similar project.

The North Central Texas Council of Governments (NCTCOG) is currently considering a means to solicit the involvement of one or more insurance agencies to capture claims data to complement or supplement the crash data that is provided. There has been a significant delay in the processing of crash report forms at the Texas statewide level so that the lag time between when a crash occurs and when it is retrievable from a records system has exceeded two years.



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## CHAPTER 3. TRAFFIC CONTROL DEVICES FOR MOTORISTS

### Traffic Signals



**Figure 9. Signal head with LED sections.**

**D**uring the scanning study, there were two signal treatments that captured the attention of the scan team; they are described below.

**LED Signal Sections.** In addition to being more energy efficient, LED signal sections are an average of 30 percent brighter than incandescent bulbs, and therefore are more conspicuous. Figure 9 depicts a signal head with LED sections in Michigan.

**Signal Backplates.** In preparation for the 2004 North American Conference on Elderly Mobility, the Michigan DOT installed a variety of backplates at signal heads in Downtown Detroit. Although no formal evaluation was done, there was interest in several concepts. Figure 10 illustrates reflectorized yellow backplates with black signal heads. Backplates, which have been used extensively in many areas of the country, serve several safety purposes: improve signal visibility during periods of glare, provide contrast against background colors, provide contrast against confusing or cluttered backgrounds, and frame signal indications to draw attention to them.



**Figure 10. Black signal faces with reflective yellow backplates.** (Photo courtesy of Kimberly Lariviere, Michigan DOT).

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### **Traffic Signs**

This section identifies and discusses several of the innovative signs that were identified and discussed during the scan.

Static Regulatory Signs for Traffic Signals. A wide variety of regulatory signs hung on span wires and mast arm poles were encountered. One specific example of that was the U-TURN YIELD sign, as illustrated in figure 11. The signal arrangement indicates that there are two left turn lanes on this approach to a signalized intersection. While not visible on this photo, there is a right-turn overlap for the side road approach to the left. Hence, there are times when a right turning vehicle may conflict with a U-turning vehicle from the outside (i.e., closest to the median) left turn lane. This regulatory sign clearly indicates that the driver from that left turning lane must yield to opposing traffic.



**Figure 11. “U-TURN YIELD” regulatory sign for Left turn signal head on an approach with dual Left turn lanes in south Florida.**

Fiber Optic, Overhead Regulatory Signs for Traffic Signals. Another innovative signing treatment was identified at an intersection in Livingston County, Michigan. The innovative sign was a fiber optic sign with white letters on a dark (black) background indicating “NO TURN ON RED.” Since this was implemented with lead-lag phasing, it is important to understand that the opposing left is seeing a green left arrow indication at the same time that the “NO TURN ON RED” sign is displayed. Figure 12 displays a photograph of the treatment when the opposing left turn traffic receives a green left arrow signal indication. Figure 13 displays a photograph of the treatment when the opposing left turning traffic receives a red left arrow signal indication. Hence, the dynamic turn restriction greatly reduces the probability of a conflict between a vehicle that turns right on red from this approach and a left turning vehicle from the opposing approach.



**Figure 12. Dynamic regulatory sign at intersection in Michigan, with the “NO TURN ON RED” message displayed (when a left green arrow signal indication is displayed to opposing left turning traffic).**



**Figure 13. Dynamic regulatory sign at intersection in Michigan, with no message displayed (when a red left arrow is displayed to the opposing left turning traffic).**

Another version of this type of sign is presented in figure 14, which shows two fiber optic signs mounted on a mast arm with a static one-way regulatory sign and two traffic signal heads. This treatment was found at the intersection of two one-way streets in Portland where the Portland Trolley runs. As can be seen in this figure, the fiber-optic/blank out sign to the left indicates “TRAIN” while the other sign indicates “NO TURN ON RED.” When no trolleys are present, drivers on the approach served by these traffic control devices can make a right turn on red. However, when a trolley is present and ready to move, the phase is terminated early and the sign displays “NO TURN ON RED.” The trolley actually turns right from the left lane at this intersection. Vehicles on both approaches must stop when the trolley makes the turn. Without the fiber optic signs, drivers in the right-most lane on the approach may believe that they can safely turn right. But since the trolley crosses this path, it is necessary to prohibit vehicles from turning right on red. The fiber optic signs fulfill a time-dependent motorist information need.



**Figure 14. Dynamic regulatory and information signs used in Portland at an intersection where a trolley line crosses.**

Internally Illuminated, Overhead Regulatory Signs. Internally illuminated signs were quite common in Michigan. Figure 15 shows an illuminated case stop sign hung on a span wire on which overhead flashing beacons are also mounted. Another example is presented in figure 16. In this case, the illuminated case includes four faces that each indicate the simple message “LEFT” to indicate that the displays in the signal head below are for left turning vehicles.



**Figure 15. Crosshead illuminated case “STOP” sign in Michigan.**



**Figure 16. Overhead illuminated case “LEFT” sign in Michigan.**



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### Activated Internally Illuminated Warning Signs.

In Portland, Oregon, signs such as the one presented in figure 17, were used frequently at signal-controlled mid-block pedestrian crossings. The signs would not be illuminated until the pedestrian phase was activated. The signs would begin to flash when the pedestrian call button was pushed and remain flashing until fifteen seconds after the pedestrian phase was displayed. While it is somewhat difficult to perceive that the light is activated during the day, the illumination of the sign is quite dramatic at night.



**Figure 17. Activated, internally illuminated "PED XING" warning sign hung from a mast arm.**



**Figure 18. Overhead, internally illuminated street name sign with 12" letters in Clearview font (Photo courtesy of Kimberly Lariviere, Michigan DOT).**

### Internally Illuminated Street Name Signs.

Figure 18 depicts an internally illuminated street name sign. It is hung from a mast arm signal pole in Detroit prior to the North American Conference on Elderly Mobility. The letter heights are 12 inches and the font is Clearview. For the conference, a variety of letter heights and fonts were used, but research results are not available. The perception was that 12-inch Clearview was superior in readability and driver legibility.

Larger Street Name Signs. Several agencies indicated that they have programs to replace existing street name signs with larger street name signs cantilevered from signal poles or other poles. Figure 19 sharply contrasts the old style street name sign and the new one with six-inch letter height in Clearview font on high-intensity sheeting.

Reverse-side mounting of signs at stop-controlled intersections. With respect to traffic control devices, most of the scan discussions were focused on traffic signals, without much time being devoted to stop-controlled and yield-controlled intersections.



**Figure 19. "OLD" and "NEW, improved" street name signs mounted on signal poles. (Photo courtesy of Kimberly Lariviere, Michigan DOT).**

One treatment, implemented by the Kent County Roads Commission in western Michigan, warrants some discussion. At all-way, stop controlled intersections with overhead flashing intersection beacons, Kent County placed “ALL WAY” signs on the back side of stop signs on the far corners of the intersection as presented in figure 20. While no scientific studies have been completed for this treatment, the opinion of the Kent County traffic engineer was that they are beneficial to drivers by providing a supplemental piece of information to motorists. Similarly, at two-way, stop controlled intersections with overhead flashing intersection beacons, rectangular warning signs have been placed on the back side to indicate “CROSS ROAD TRAFFIC DOES NOT STOP” in black letters on a yellow background. Figure 21 depicts this treatment, although the sign appears to be orange in color. It is important to note that Kent County’s practice is to place stop signs on both the near left side and the near right side of the road at approaches where needed for increased clearness. While relatively simple, this treatment has promising potential to improve intersection safety.



**Figure 20. Signing treatment for all-way stop controlled intersection. (Photo provided by Tim Haagsma, Kent County Roads Commission).**



**Figure 21. Signing treatment for two-way stop controlled intersection. (Photo provided by Tim Haagsma, Kent County Roads Commission).**

Several additional signing treatments, which were identified by one or more of the participating agencies, deserve brief mention. Although not considered innovative, these are considered effective treatments.

- Supplemental rectangular plaques below the intersection warning sign (W-11 series in the *Manual on Uniform Traffic Control Devices (MUTCD)*), with the street name spelled out in black letters on a yellow background. Kent County’s standard practice was to install these in advance of every intersection on primary roads.
- “NEXT SIGNAL” signs are typically guide signs that provide advance information to motorists about the name of the crossing streets at the next downstream signal-controlled intersections.

### Pavement Markings

While the innovative markings that were seen during this scanning study were related to pedestrian crossings, there were some for vehicle traffic. One example followed by several agencies was the use of “cat” tracks or “puppy” tracks on the pavement through an intersection as depicted in figure 22 enhanced safety at the intersection, although no definitive supporting research could be provided. Figure 22 depicts an intersection with markings continued through the intersection on the mainline.



**Figure 22. Intersection in Richardson with “cat” tracks, which are also called “puppy” tracks.**

Other examples of markings include the following:

- Wider edgelines and lane lines.
- Pavement markings with text identifying lane destinations on roads with confusing or complex geometry and/or need for supplemental information (see figure 23).
- Pavement markings for pedestrians entering crosswalk (see figure 24).



**Figure 23. In-lane pavement marking message designating Michigan State Route 10 (M-10) applied in advance of an exist ramp.**



**Figure 24. Pavement message for pedestrians at crosswalk.**



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## In-Pavement Lighting Systems

The scan team visited District 4 of the Florida Department of Transportation to view a site that was actually the terminal of an off-ramp from an Interstate freeway. While the site was not an intersection, it was selected because there was a keen interest in high-speed approaches to intersections, like at-grade intersections on high-speed expressways. The application of the technology on high-speed approaches to isolated intersections could have positive safety benefits. For example, in-pavement lights could be installed along the edgeline and the centerline in advance of unexpected or sight-restricted, high-speed intersections so that the in-pavement lights flashed when the speed of a vehicle on the major road approach to the downstream intersection exceeded a specific threshold. The system may also be applicable to other intersections where speed on the major road is a contributing factor to crashes, especially nighttime crashes where the value of the flashing in-pavement lights is expected to be even greater. It is theoretically possible that an analogous system could also be operated so that the in-pavement lights only flash when the detected speed of a vehicle on the major road approaching the intersection exceeds the threshold and a vehicle is detected as stopped on the side road.

The ramp is located on southbound I-95 at the exit to westbound Florida State Route 84 in the Fort Lauderdale area. The ramp is north of Fort Lauderdale's International Airport and close to several tourist attractions. The ramp is approximately one-half mile long and forms a T-intersection with westbound Florida S.R. 84. At the ramp terminus with westbound Route 84, a 10 mph advisory speed is posted for a sharp right turn. Speed measurements on the ramp indicated that the 85<sup>th</sup> percentile speed on the ramp on weekdays and on weekends is on the order of 51 to 60 mph. Crash data showed that from 1997 to 1999 and from 2001 to 2003 there were 86 crashes, with the majority being angles and right turns, and that an estimated 77 percent of these crashes were attributed to speeding. The results of the six months evaluation demonstrated that the speeding was reduced and no crashes have occurred during this period of time. Based on preliminary assessments, the system looks promising in its influence on speeds at the end of the ramp; thus, the system should enhance safety.

The concept implemented made use of in-pavement lights similar to those currently used for in-pavement crosswalks. It should be understood that the 2003 edition of the *MUTCD* currently limits the application of in-pavement lights to pedestrian crosswalks. The FHWA approved Florida DOT's plan to test the system during a two-year period. For this experimental application, a series of lights were installed along the edgelines on the ramp. Photos of the actual devices from an angled downward view of the device without the lights on, from an angled downward view looking at the devices with the lights activated, from a top down view of the device with the lights activated, from the profile view looking straight on without the lights on and from a profile view looking straight on with the lights on are displayed in Figures 25a, 25b, 25c, 25d, and 25e, respectively. (*see next page*)

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**Figure 25a.** Angled view of device with lights not activated. (Photo courtesy of Gilbert Soles, Florida DOT District 4).



**Figure 25b.** Angled view of device with lights activated. (Photo courtesy of Gilbert Soles, Florida DOT District 4).



**Figure 25c.** “Top-Down” view of device with lights activated. (Although lights appear to be red in this picture, the actual color is yellow).



**Figure 25d.** “Front-On” view of device without lights activated. (Photo courtesy of Gilbert Soles, Florida DOT District 4).



**Figure 25e.** “Front on” view of device with lights activated. (Photo courtesy of Gilbert Soles, Florida DOT District 4)

The devices have dimming capability so that they were brighter during daylight hours and dimmer during nighttime hours, and also included speed detection. A total of 50 devices were deployed. Figure 26 presents a view of the ramp where the devices were deployed. The lighting devices flash in a sequential manner when the detected speed of a vehicle entering the ramp was 50mph or greater. The system is operated by a controller unit that was mounted on a pole (see Figure 27) below the elevated ramp. Figure 28 depicts the contents of the controller cabinet.



**Figure 26. View of the ramp of in-pavement lighting device.**



**Figure 27. View of pole mounted controller cabinet for in-pavement speed reduction system mounted on an elevated ramp above.**



**Figure 28. View of inside of the controller cabinet for Florida ramp.**



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The sealant along the outside of the edgeline in figure 29 presents the cable run for the in-pavement lighting devices. The speed of a vehicle entering the ramp just beyond the gore on the freeway is captured by means of an inductive loop detector, which is depicted in figure 30. Figures 31 and 32 present photographs of the system, with the in-pavement lights activated, at night and during the day, respectively. The deployment specifications used by Florida DOT are shown in Figure 33. By reducing the spacing, the decreasing strobe-like effect appears more pronounced.



◀ **Figure 29. View of in-pavement lighting device and sealant showing sawcut for cable.**



**Figure 30. Loops used for speed detection near "beginning" ramp upstream of sharp curve.**



**Figure 31. Two views of SR 84 off ramp before (left) and after (right) installation of LED modules. Note: Roadway conditions before and after LED modules installation. (Photo courtesy of Gilbert Soles, Florida DOT District 4).**



**Figure 32.** View of the system at night with the in-pavement lights “on.”(Note: Photo courtesy of Gilbert Soles, Florida DOT District 4).



**Figure 33.** View of the system during daylight hours with the in-pavement lights “on.” (Photo courtesy of Gilbert Soles, Florida DOT District 4).

## **CHAPTER 4. TRAFFIC CONTROL DEVICES AND OTHER DEVICES FOR PEDESTRIANS AND BICYCLISTS**

This chapter presents information on innovative traffic control devices and other devices for pedestrians and bicyclists, including signs directed at drivers that warn or provide regulatory information about pedestrians or bicyclists. While the topic of pedestrians and bicyclists is a different focus area of the FHWA when compared to the intersection safety area, these treatments have the potential to improve pedestrian safety by reducing pedestrian crashes at intersections. As such, some of these pedestrian treatments at intersections are highlighted and described in this report. It is noted that while the topic was intersections, facilities that “behave” like intersections, such as trail crossings and pedestrian crossings and bike lane crossings, were also considered since effective treatments at these junctions are generally applicable to intersections. Within this broad category, there is very limited documentation on the direct effects of these treatments on intersection crashes. Notwithstanding that lack of knowledge, the treatments discussed in this chapter were deemed to be noteworthy by the scan team and, to a certain degree, innovative based on the experiences of the scan team.

### **Pedestrian and Bicycle Crosswalks**

During the scanning study, a variety of crosswalk designs were observed. There are three included in the scan report that are clearly novel. The first are the so-called blue bike lanes that have been implemented in Portland. The blue color applied to the pavement is meant to increase the conspicuity of the area of conflict and therefore heighten both drivers and bicyclists’ awareness in the intersection areas. Figure 34 is an example of one that is not actually at a conventional intersection but rather crosses an exit from a roadway on a bridge structure. A greater challenge is faced when a “through” bike lane crosses a dedicated right turn lane. Figure 35 (page 30) depicts how Portland handles this challenge. A series of dashed markings indicate where vehicles can weave across the bike lane. Another even more challenging situation is where there is a dedicated right turn lane and an additional shared used right-and-through lane. Figure 36 depicts how the bike lane is located between the dedicated right turn lane and a shared use, right-and-through lane. In an attempt to evaluate the effectiveness of these crossings, a study of driver and bicyclist behavior was conducted in 1999 by the city of Portland. It was concluded that the percentage of drivers who yielded to bicyclists increased after implementation from 72 percent to 92 percent. More information can be found in *Portland’s Blue Bike Lanes*.<sup>(4)</sup>



**Figure 34. Example of a blue bike lane in Portland.**





**Figure 35. A blue bike lane and dedicated right turn lane at an intersection in Portland.**



**Figure 36. Example of a blue bike lane between a dedicated right turn lane and a shared use right-and-through lane in Portland.**

The second type was a raised, textured crosswalk. Scan team members observed such a crosswalk outside the offices of the city of Charlotte at a mid-block crossing. Figure 37 presents a close-up view of this crosswalk. There have not been any known formal evaluations of raised or textured crosswalks on safety.

The third type was a brick crosswalk. Figure 38 depicts brick crosswalks that were recently implemented as part of an intersection improvement project in Charlotte.



**Figure 37. Raised textured crosswalk in Charlotte.**



**Figure 38. Brick crosswalks in Charlotte.**

### **Traffic Signals and Signs Related To Pedestrian and Bicycle Crossings**

While this category of treatments could have been classified and included in the chapter on Traffic Control Devices for motorists, since they are displayed to drivers, it is considered more appropriate to include these in the chapter on pedestrians and bicycles.

Regulatory Signs. It was apparent to the scan team that there was a significant amount of creative thinking that went into the design of the regulatory signs to warn drivers of pedestrian and bicycle crossings at the sites visited as part of this scan. Figure 39 presents a sign used in Portland prior to a blue bike lane crossing on an exit from a roadway on a bridge structure. The sign assembly endeavors to communicate in a symbolic manner, which is complemented by a simple text message, “YIELD TO BIKES.” Similarly, where the bike lane will straddle a dedicated must turn right only lane and a shared use, right-and-through lane, the regulatory sign advising drivers of this situation is presented in figure 40.



**Figure 39.** “YIELD TO BIKES” regulatory sign in Portland.



**Figure 40.** A regulatory sign for the situation where a blue bike lane “straddles” a dedicated right turn only lane and a shared-use, right-and-through lane.

Warning signs. There were several sites where local agencies endeavored to create greater awareness of pedestrians in upcoming intersections and trail crossings. Figure 41 presents a large pedestrian warning sign with a supplemental sign posted below that reads “STATE LAW YIELD TO PEDESTRIANS IN CROSSWALKS.”

Another system that was investigated was a crosswalk at an intersection in Dallas that had both in-pavement flashing lights and a solar-powered, responsive flashing beacon (atop a pedestrian crossing warning sign). The warning sign and flashing beacon are shown in figure 42. The flashing beacon and in-pavement lights activate whenever a pedestrian pushed one of the two pedestrian push buttons located on the far sides of the crosswalk.



**Figure 41. Pedestrian crossing warning sign and supplemental sign in Charlotte.**



**Figure 42. Activated flashing beacon that complements static warning sign and in-pavement crosswalk lights in Dallas.**

A novel sign was encountered in Portland that attempted to provide warning information to bicyclists that were traveling on streets with rail tracks for light rail and trolleys. The sign, which symbolically shows a bicyclist “tripping” on an indentation in the pavement, is presented in figure 43 below.



**Figure 43. Symbolic bicyclist “tripping” warning sign in Portland.**



## Pedestrian Push Buttons, Signal Heads and Other Devices

As part of their progressive pedestrian safety program for pedestrians with visual impairments, Charlotte implemented audible devices that allow pedestrians to hear instructions on when it is time to cross. The system was devised to also allow pedestrians with visual impairments to hear a tone that would orient them when they cross the intersection. An example of these audible signal heads with integrated countdown devices are shown in figures 44 and 45.



**Figure 44. Audible pedestrian signal heads and speakers in Charlotte.**



**Figure 45. Speaker on underside of a pedestrian head in Charlotte.**

Several different types of pedestrian push button devices were used at the intersections in Charlotte. One type featured a tone that would sound and a small indicator light that would be displayed after the push button was depressed. Figure 46 depicts this device. The accompanying sign provides basic information about the meaning of the displays, but also includes information in Braille. Charlotte also uses a white nylon fabric on wood poles to protect the hands of visually impaired pedestrians from staples and splinters as they feel for the push buttons. Figure 47 shows this treatment. Another pedestrian push button device that was also implemented in Charlotte is shown in figure 48.



**Figure 46. Pedestrian push button device in Charlotte with supplemental information in Braille on sign.**



Figure 47. Pedestrian push button device in Charlotte with supplemental information in Braille on sign.



Figure 48. Example of another pedestrian push button device with supplemental raised arrow device mounted above the push button.

One last item of note with respect to pedestrian signals is installation of pedestrian crossing signs in both English and Spanish at intersections that serve areas with large populations that speak only Spanish.



Figure 49. Pedestrian push button signs in both English and Spanish at an intersection in Charlotte.

Figure 49 presents a pedestrian push button with both signs. Figure 50 presents a more detailed view of the sign in Spanish.



Figure 50. A close up of the pedestrian crossing sign that shows the information in Spanish.

### **Automated Detection of Pedestrians**

In downtown Detroit, a unique pedestrian detection system was implemented as a showcase project at a mid-block, unsignalized crossing with actuated-responsive in-pavement flashing lights and dynamic flashing “signs” inside pedestrian warning signs. The technology features motion detectors such as the one shown in figure 51.

Another example of pedestrian detection technology is one deployed to detect pedestrians still present in the crosswalk at an intersection in Portland. The detection is used to extend the clearance interval (flashing “DON’T WALK”) while the pedestrians are in the roadway. Figure 52 shows the location of the pedestrian detection on the signal pole. A closer view of the device is shown in figure 53. There is still debate on their relative effectiveness of both systems. Passive detection technology for pedestrians is still not developed enough for nationwide use. However, the technology offers promise for the future in terms of enhancing pedestrian safety.



**Figure 51. Pedestrian detection system that employs motion detection technology in Detroit.**



**Figure 52. Pedestrian detection system that detects pedestrians in crosswalk in Portland.**



**Figure 53. Closer view of the pedestrian detection device deployed in Portland.**



### Automated Detection of Bicycles

There were several sites in Portland where devices and systems had been implemented to assist in the passive detection of bicyclists. The first was at a trail crossing of a major four-lane road, which technically is not an intersection. However, the application is transferable to at-grade intersections where there is significant bicycle traffic. A loop detector for bicycles was installed in the trail as presented in figure 54. While some bicyclists may actuate pedestrian push buttons at some intersections, the loop detector would detect their presence even if the bicyclist does not depress the pedestrian call button. The detection is also used to extend the green phase for platoons of bicycle drivers.



**Figure 54. Loop in trail crossing to detect bicyclists in Portland.**



**Figure 55. Video cameras deployed to detect bicyclists in Portland.**

Figure 55 presents another innovative application of existing technology for the automated detection of bicyclists. The camera's field of view is set to capture bicyclists as well as pedestrians and vehicular traffic. Figure 56 depicts a closer view of the video camera.



**◀ Figure 56. A closer view of the camera mounted on the luminaire arm.**

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Figure 57 presents a closer view of the signal heads and signs. Please note that sign adjacent to the right-most signal indication with the thru green arrow indicates a bicyclist diagram with the words “BIKE SIGNAL.” The sign next to the left-most signal indication showing the solid red right arrow indicates “NO TURN ON RED.”



**Figure 57. Signal heads and phasing for bicycle movement at intersection where video cameras are used in Portland.**

## CHAPTER 5. TRAFFIC OPERATIONAL PRACTICES

The previous two chapters were devoted primarily to signal equipment and traffic control devices related to safety, although there are certainly operational aspects of traffic control devices. Chapter 5 is devoted to traffic operational practices that promote, or have the potential to promote, improvements in intersection safety. This chapter discusses operational practices that are not directly related to specific hardware. Rather, they are items that largely fall under the domain of traffic operations engineers in state and local governments.

### Dallas Left-Turn Display for Left-Turn Lead-Lag Signal Phasing

A signal display known as the Dallas Left-Turn Display for Left-Turn Lead-Lag Signal Phasing, or “Dallas Phasing” has been used in the area for well over 15 years, and is not considered innovative. However, many others around the United States involved in signal operations do not know of it. For this reason, the topic of Dallas Phasing is included in this report. Essentially, the objective of the left-turn display is to more safely accommodate left turning drivers at intersections using protected-permitted lead-lag left-turn sequencing. Consider a left turn phasing scheme in which the northbound drivers get a leading green left arrow and green ball indications for the through traffic. Then, the protected portion is terminated and left-turning drivers would normally receive a green ball indication in which they are permitted to turn left in the absence of opposing vehicles. Left turning drivers may think that when this phase ends for their approach, it is also ending for the opposing through movement, when in reality the opposing through traffic receives a continuous green ball indication because of the lag left on that approach.



**Figure 58. View from left-turn pocket where a Dallas (city in the background) phasing is in operation.**

The Dallas Display was conceived to avoid the risk that left-turning drivers would see the signal indication for through traffic on their own approach and make an incorrect assumption about the signal indication being presented to through traffic on the opposing approach. By displaying a separate signal indication to left turn traffic that is seen only by them and not drivers in adjacent through lanes, a green ball indication can be shown to drivers in the left lane while a yellow and then red indication can be displayed to adjacent through traffic, as shown in figure 58. Left turning drivers are still permitted to turn left in the absence of opposing vehicles, and they will



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not expect that the opposing through traffic is receiving yellow and then all red when the adjacent through traffic is receiving those indications. The left-turn display is shielded from the view of the adjacent through traffic lanes by placing louvers in the red ball, yellow ball and green ball signal hoods. In the left-turn signal head, the red, yellow and green ball indications are activated using overlaps. A Kittle & Associates Web page provides an animation of the Dallas Phasing signal indications and sequence at [http://projects.kittelson.com/pplt/displays/dallas\\_horiz\\_lead.htm](http://projects.kittelson.com/pplt/displays/dallas_horiz_lead.htm). Intersections requiring lead-lag operation in all four directions require a 16 bay load-switch cabinet to accommodate eight vehicle phases, four pedestrian phases, and four Dallas left-turn display overlaps.

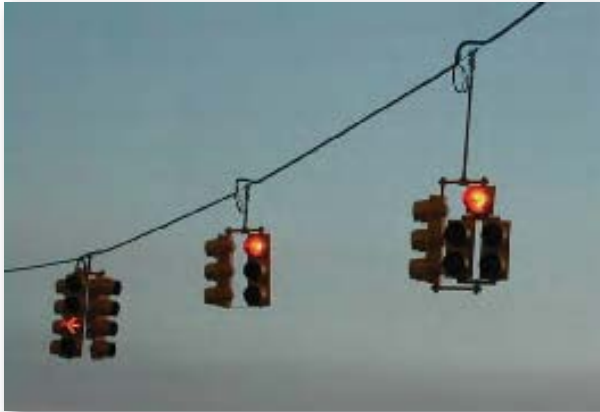
### **Flashing Yellow Arrow Displays**

Although not yet approved for inclusion in the *MUTCD*, flashing yellow arrow displays are currently being evaluated as experimental devices. Intuitively, the flashing yellow left arrow may offer potential safety benefits to agencies that now utilize flashing red balls, such as the Michigan DOT or the Dallas Phasing, on one or more approaches. Consequently, this is included in the scan report.

Preliminary studies have indicated that public reaction to flashing yellow arrows is positive. In addition, studies suggest that flashing yellow arrow signals offer greater degrees of safety compared to other signal displays used for permitted-protected phasing.

During the scan, the team visited an intersection in Livingston County, Michigan, where the flashing yellow left arrow had been approved for experimental use and was in operation. In Michigan, the standard practice is to provide permitted-protected left-turn phasing (i.e., where the left green arrow lags) and not protected-permitted left-turn phasing (i.e., where the left turn green arrow leads). In other words, the protected left-turn green arrow follows a signal interval in which the signal indication displayed to drivers in the left turn lane is a flashing red ball. Drivers can turn left during the presence of a flashing red ball in the absence of oncoming opposing vehicles or when there is a sufficient gap to safely do so.

Figure 59a (*page 40*) displays a view of the signal displays when the yellow arrow, which is in the third section down from the top of the signal head, is flashing. During this first photo, a set of green balls and left green arrow is being displayed to the opposing oncoming traffic on the opposite approach (which has a leading protected-only left turn phase). After the opposing left turn phase has maxed or gapped out, then the display shown in Figure 59b (*page 40*) is presented. The flashing left arrow is on during the same time that the adjacent signal heads display solid green ball indications. During this interval, solid green balls are being displayed to the opposing through approach and a solid red left arrow is being displayed to the opposing left turning traffic. Figure 59c (*page 40*) presents the next sequence when the solid left green arrow is displayed concurrently while the solid green balls are displayed on the adjacent heads that serve the through lanes and right turn maneuver. During this interval, steady red balls and a steady red left arrow indication are displayed to the opposing approach. After the phase has gapped or maxed out and the signal indications have gone through their clearance intervals, then



**Figure 59a. First set of signal indications when flashing yellow left arrow is displayed.**



**Figure 59b. Second set of signal indications when flashing yellow left arrow is displayed.**



**Figure 59c. Third set of signal indications when steady left green arrow is displayed.**



**Figure 59d. Fourth set of signal indications when steady left red arrow is displayed.**

the next displays are presented in Figure 59d, in which a steady left red arrow is displayed to the left turning traffic and steady red ball signal indications are displayed to the through traffic.

Livingston County has received approval to operate four additional intersections with flashing yellow arrows, and they intend to install flashing yellow arrows in the future on all signals in which they wish to show a separate signal head for “permitted” use.

### **Controlling When the Yellow Interval Is Displayed**

For nearly 20 years, Portland, Oregon, has used vehicle detection to control when the yellow is displayed. The detector furthest from the stop bar is set at the safe stopping distance for the approach. One or two intermediate loops are installed on the approach and the gap time is set so that the yellow is displayed just as the driver arrives at the stop bar. When the detection is used, the city has documented a two-thirds reduction in rear-end crashes in which the driver disregarded the signal indication. The city has also documented a two-thirds reduction in the frequency of drivers entering an intersection during a red display when the display of yellow is controlled by the detection.

### **Delayed Onset of Pedestrian Walk Interval**

The transportation officials in Portland and Dallas indicated that they have implemented, attempted to implement, or considered delaying the onset of the pedestrian walk interval by one or more seconds as an additional safety measure to ensure vehicles that entered from conflicting approaches have cleared the intersection. The delay in the onset of the walk was thought to have a safety benefit, although this could not be substantiated by available documentation.

### **Modified Pedestrian Intervals**

One treatment that has been implemented by Dallas was both relatively simple and very creative. The treatment included programming the signals such that if a pedestrian pushed the pedestrian push button by less than five seconds, then the “normal” pre-programmed times for pedestrian walk and pedestrian clearance (i.e., FLASHING DON’T WALK) intervals are called into service. However, should a pedestrian press the push button continuously for longer than five seconds, a second set of pre-programmed times for pedestrian walk and pedestrian clearance phase is called into service. By analogy, it can be considered



**Figure 60. Intersection in Dallas’ Central Business District where longer walk and “FLASHING DON’T WALK” intervals can be put into service by depressing the push button for five or more seconds.**

similar to a Max I green and a Max II green in which the Max II green interval is called into service during specific times, or in response to certain volume conditions. Dallas officials have implemented this operational treatment at several intersections, as shown in figure 60, and have spent time to instruct elderly pedestrians in the area on how to depress the button for five seconds or more. Moreover, the Dallas transportation officials have worked with individuals to set the most applicable pedestrian clearance intervals that would be based on the walking speed and behavior of local citizens who cross at that intersection.

### Responsive Audible Pedestrian Signals

In a manner similar to the situation described, Dallas also has developed a software routine in which audible pedestrian signals can be activated after a pedestrian has depressed a pedestrian push for a longer time (e.g., five or more seconds). The audible signal speaker is mounted on the far side of the crosswalk and serves as an audible indication for sight-impaired pedestrians. The sounds correspond to the walk display (solid sound) and flashing don't walk display (beeping sound). The controller logic was programmed in response to complaints by nearby residences and businesses about the frequency of the audible sound when activated by all pedestrians or continuously activated during push button malfunctions. The controller logic only activates the audible signal if and when a pedestrian pushed the button for an extended (i.e., five or more seconds) period.

### Activated Extension of Pedestrian Clearance Interval

Portland tested the concept of extending the pedestrian clearance interval, i.e., when the pedestrian signal displays a flashing “DON'T WALK” (FDW) indication. The pedestrian clearance interval is extended when microwave detectors sense the presence of a pedestrian still in the crosswalk. This was implemented at an intersection where elderly pedestrians cross frequently to a meal site. The “normal” FDW interval was 20 seconds, but the city made provision to allow the interval to be extended up to 27 seconds when pedestrians were still in the crosswalk at the end of the 20 seconds. The results show that the FDW interval was extended for approximately one-third of the signal cycles, but less than three percent of the times were the FDW interval extended to the maximum 27 seconds.

### Variable Red Clearance Interval

Portland had recently implemented a treatment that seemed both relatively simple and potentially promising. By placing loops beyond the stop line at an intersection, the Portland signal personnel have devised a way to extend the red clearance interval for vehicles that cross the loops late in the yellow interval or during the red clearance interval. While they have yet to complete a rigorous controlled evaluation of the effects, the raw crash counts and anecdotal experience suggests that this treatment does have a true positive safety effect. Figure 61 shows the intersection approach in Portland where loops have been installed beyond the stop line to provide a variable extension of the red clearance interval.



**Figure 61. Intersection approach in Portland where loops beyond the stop line are used to delay the onset of the yellow interval.**



### Activated Extension of Red Clearance Interval

Taking a slightly different approach compared to Portland, the city of Richardson worked with a local software company to develop an application of a “smart” signal controller that can be programmed to react to speed trajectories of arriving vehicles and determine the need to responsively extend the all-red interval to reduce the possibility of red light running crashes. This was done on a trial basis and the results were encouraging, although the costs are likely to be prohibitive for wide scale or even experimental applications. Richardson’s experimental concept relied on the logic presented in figure 62. There was a significant concern about the effect of holding the all-red interval on signal coordination and progression of flow.



◀ Figure 62. Speed prediction algorithm for Richardson experimental red clearance interval hold. (Courtesy of the City of Richardson).

### Traffic Signal Coordination Treatments

At a joint meeting with the Michigan DOT, the Michigan State Police, and the Federal Highway Administration’s Michigan Division Office, the question was raised on what is the true effect on safety of implementing or improving coordinated signal timings. Signal coordination is the process whereby the signal controllers at intersections that are in close proximity are operated as a system. The start and end of selected signal phases are “synchronized.” For example, the controllers can all operate on the same cycle length and have pre-established maximum phase intervals when the synchronized phase(s) are terminated. The information provided at the meeting was that for a county-wide signal coordination and re-timing project done in Oakland County, the initial research report found that traffic delay was reduced throughout the corridor, as expected, but also there was a substantial reduction in crashes. Funding was sought by Michigan DOT to provide a more comprehensive before and after crash analysis.



## CHAPTER 6. GEOMETRIC DESIGN TREATMENTS

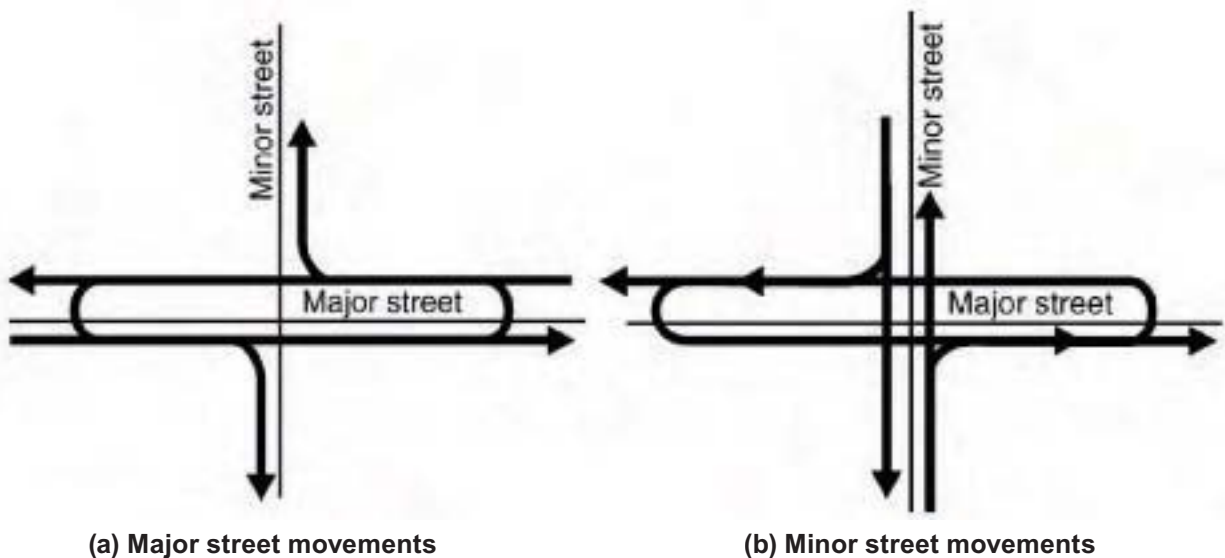
This chapter presents findings with respect to intersection geometric design treatments that were identified and investigated during the scanning study. Since very few of these treatments have been evaluated by the host agencies, it is not possible to reach a conclusion about their safety effectiveness. Many of these geometric treatments could produce a positive effect on intersection safety, but that will not be known until evaluations are done.

### Michigan Indirect Left Turns Junction

After arriving in Michigan for the first set of meetings, several members of the scan team indicated that they did not have much personal experience in negotiating the Michigan Indirect Left Turn Junction, which is a fairly typical design in southeast Michigan. Their initial reaction was that these junctions were markedly different and therefore may be less safe compared to conventional intersections with left turn lanes. Before proceeding, it is necessary to describe a Michigan Indirect Left turn junction. Figure 63 is an aerial photograph of several intersections using the indirect left turns, where no left turns are allowed at the major intersection. As depicted in figure 63, drivers desiring to turn left from the major road (i.e., the road that is laid out horizontally) need to go through the intersection and then make a U-turn at a point downstream. Figure 64 (page 45) illustrates some vehicle movements at such an intersection. For many cases, signal control has been added at the intersection of the U-turn roadway and the directional roadway configuration. Several variations of this junction were encountered in Michigan. In fact, this type of intersection treatment has been in Michigan for well over 30 years. Since this type of intersection was not identified as a key treatment of interest on the original agenda for the scan, there were no prepared questions on this design. However, information was provided subsequent to the visit indicating that this treatment is safe. A Michigan DOT study, *The Comparative Accident Experience of Directional and Bidirectional Signalized Intersections*,<sup>(5)</sup> concluded that the operation of an intersection with a pair of stop-controlled directional crossovers where left turns are prohibited at the crossroad carry higher volumes at a lower accident rate than the standard signalized intersection type where all turns are permitted. The study concluded that the use of the Michigan Indirect Left Turn provides the following safety benefits to traditional intersection design and operation: 80 percent reduction in rear-end left-turn crashes and head-on left-turn crashes and 60 percent reduction in right-angle crashes.



**Figure 63. Michigan Indirect Left Turn Junction. Source: AAA Michigan**



Source: FHWA's *Signalized Intersections: Information Guide*, Report No. FHWA-HRT-04-091, August 2004, Chapter 10, *Alternative Intersection Treatments*<sup>(6)</sup>

**Figure 64. Vehicular movements at a Michigan Indirect Left Turn Junction.**

### **Intersection Bulb-out**

In terms of intersection safety, there is still much debate about the safety value of bulb-out intersections. Some can clearly see safety benefits that they offer to pedestrians by reducing the width needed to cross. Others see safety benefits more in terms of traffic calming benefits. There is intrinsic safety value if motorists drive slower. Since bulb-outs are perceived to induce drivers to drive slower, some perceive that safety benefits are accrued from their implementation. However, some question the safety benefits attributable to reduced speed if they produce more potential for rear-end crashes or if the design of the island is inadequate for certain design vehicles or if the design does not explicitly consider the turning radii of larger vehicles. It should be recognized that the safety benefits attributable to intersection bulb-outs are likely to range widely due to site conditions, traffic flows, vehicle mixes, and speeds, among other factors.



**Figure 65. Intersection bulb-out for a light rail/trolley transit stop in Portland.**

Figure 65 depicts a bulb-out that effectively created a landing area for a light rail/trolley car stop in Portland. Note how the parking lane has been created between an edgeline that effectively extends from the face of the curb for the raised bulb-out island. The photograph was taken looking south, approximately 50 feet south of the intersection.

Figure 66 presents a photograph of an intersection bulb-out in a residential area in West Palm Beach. Note the evident tire marks on the face of the curb. One observation made by the city’s engineering department was to note the telltale items that would indicate potential safety problems. It is conceivable that the turn was too tight or that a large vehicle off-tracked while making a turn.



**Figure 66. An example of an intersection “bulb-out” in West Palm Beach, Florida.**

Figure 67 presents a residential street where the throat was reduced by bulbing out the intersection corners. The effective street width is wider upstream of the intersection.



◀ **Figure 67. Intersection bulb-outs to reduce the street width opening in a residential area in West Palm Beach.**

Figure 68 illustrates an intersection bulb-out island created at an intersection for a commercial area. Note how the edgeline wraps around the bulb-out to define the curvature of the bulb-out and then delineate the parking lane. The transverse line at the bottom left of the photograph is a crosswalk.



**Figure 68. Intersection bulb-outs to define parking lane in a commercial area of West Palm Beach.** ▶



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An example of a slightly more ornate intersection geometric treatment is illustrated in Figure 69. Again, there is a bulb-out in the corners of the intersection, although it is not as discernible in figure 69. This is a fairly unique treatment since the white “zebra-style” markings at the top of the photo are the crosswalk markings. The brick pavement is not the crosswalk, as one might have originally guessed. The white lines that border the brick pavement are concrete headers on which white markings have been applied. The brick “border” around the intersection is a technique to “define” the intersection space. Figure 70 is a photograph of the same intersection showing how a school crossing warning sign is at the



**Figure 69. Illustrative example of an ornamental intersection bulb-out and pavement design.**



**Figure 70. Photograph of same intersection in West Palm Beach showing the traffic signal heads, the loop, the brick pavement, the transverse crosswalk markings and the school crossing sign.**

**Figure 71. Island implemented in median of a two-lane road at an intersection that serves as a gateway to a corridor in West Palm Beach.** ►



signal-controlled intersection. Barely visible on the right side of figure 71 is a pedestrian crosswalk across the major street. There is no crosswalk across the left leg in figure 70. There is a time and place for traffic calming practices, and clearly they have their greatest application in residential areas. However, the need for the brick “border” should be questioned if it was not meant to be used as the crosswalk. The tire marks on the curbs, which can be seen on figures 67, 70, and 71, raise concerns about the adequacy of the radii. Since there were no before and after speed data nor before and after crash data made available, conclusions could not be made on whether the treatment depicted in figures 69 and 70 resulted in enhanced safety.

### Road Diets (Conversions of Four-lane Undivided to Three-Lane Cross-Sections)

As part of the AAA Michigan Road Improvement Project, road diets, which are a commonly accepted term to define projects where a four-lane undivided cross section was changed into a three-lane cross section, were implemented at several intersections in Detroit and Grand Rapids. Statements made by the host agencies suggest that this treatment is effective in terms of safety, citing results of a study of eight Michigan corridors where the following crash reductions were observed: 25.4 percent in total crashes, 30.1 percent in injury crashes, 36.5 percent in crashes involving 65 years of age or older, and 37 percent in pedestrian and bicycle crashes.<sup>(7)</sup> However, these considerable observed reductions lacked statistical testing and control group methodology.

### Median Treatments

There were several median treatments that were identified by host agencies. In West Palm Beach, Florida, median islands were introduced on several streets just beyond intersections. Figure 71 (page 47) presents an illustrative example. They were apparently installed for traffic calming purposes, but they also have served as gateways into corridors. They were not implemented to achieve an improvement in intersection safety but more for traffic calming and aesthetics. Figure 71 is therefore presented to show the median islands that were encountered in West Palm Beach.

Another streetscaping project involved the replacement of a center Two-Way Left Turn Lane (TWLTL) with a raised median. Figure 72 presents a view of the treatment at a three-legged intersection, with the intersecting third leg to the right in the photograph. This treatment intuitively has a greater traffic safety benefit compared to an alternative cross section treatment in which the sidewalk, curb and gutter area are extended to reduce the overall street width. Such an alternative treatment would remove left turn lanes at intersections. Left turn lane pockets have intrinsic safety value.



**Figure 72. Median treatment at intersections in West Palm Beach.**



**Figure 73. Channelizing median device used in Charlotte.**

Charlotte, North Carolina, identified a very promising treatment that they thought was effective in terms of safety. The treatment consists of installing a raised channelizing barrier in the median on an undivided roadway as presented in figure 73. The intersection had experienced a relatively high number of crashes. Subsequent investigations revealed that many left turning drivers were turning at various locations to get through gaps in the opposing traffic stream. The device shown below was



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very effective in forcing drivers to turn left at the preferred location. It is easily applied to the pavement, although there were maintenance concerns after it was first applied. The device itself does not appear to be a hazard.

Offsetting left turn lanes enhances intersection sight distance and therefore improves intersection safety. Depending on the width of the median, there are many methods to achieve this. Figure 74 was taken in Wyoming, Michigan. The painted island allows the particular left turn lane in the photo to be pushed farther into the median. By doing the same on the opposite approach, the probability of having a vehicle in one left turn lane pocket block the view of a driver in a vehicle in the other left turn pocket is greatly reduced.



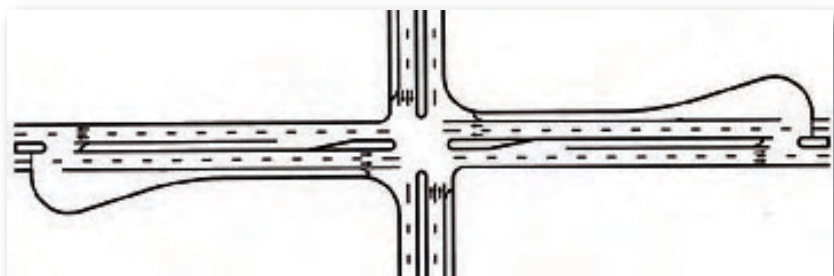
**Figure 74. Illustrative example of one method to offset a left turn lane.**

### **Michigan “Loons”**

In addition to the Michigan Indirect Left Turn Junction that was described earlier, there is also a variation of that design in Grand Rapids. The treatment is frequently called a Michigan Loon, getting its name from the shape of the pavement. Figure 75a provides a photo of one and figure 75b provides an aerial sketch. When the median is too narrow for a Michigan Indirect Left Turn, larger vehicles will have difficulty making the U-turn. The Michigan Loon attempts to solve this problem by widening the outside pavement edge of the opposite direction so that the swept path of a larger vehicle can be accommodated. Grand Rapids indicated that this treatment was effective in improving intersection safety, but documented evaluations could not be found to confirm this. The scan team did believe that this was a notable practice that does positively affect intersection safety.



**Figure 75a. A Michigan “Loon.”**



**Figure 75b. Aerial sketch of a Michigan Loon.**

## Roundabouts

In the Insurance Institute for Highway Safety May 13, 200 *Status Report* on Roundabouts, it was found that overall roundabouts produced highly significant reductions on the order of 39 percent for all crash severities combined and 76 percent for all injury crashes. Reductions in the numbers of fatal and incapacitating injuries were estimated to be about 90 percent, based on a study of 24 intersections that had been converted to roundabouts. The Michigan Intersection Safety Action Plan, developed jointly by the Michigan Department of Transportation and DLZ Michigan, which is a consulting firm, includes an action item to promote the design and construction of roundabouts on a trunk highway and to evaluate the effectiveness in both crash reduction and crash characteristics. Figures 76 and 77 present two roundabouts that have been implemented in Michigan. More about roundabouts can be found in *Roundabouts: An Informational Guide*.<sup>(8)</sup>



**Figure 76. Aerial view of roundabout constructed in Michigan. (Photo courtesy of Wes Butch, DLZ Michigan, Inc.)**



**Figure 77. View of another roundabout constructed in Michigan. (Photo courtesy of Wes Butch, DLZ Michigan, Inc.)**

## Mini-roundabouts

At the end of our meeting with the agencies involved with the Michigan Intersection Safety Action Plan, the traffic engineer from AAA Michigan and the program officer for the Office of Highway Safety Planning identified a junction where a mini-roundabout had been successfully implemented in close proximity to Lansing. Both felt that this was an innovative treatment. The scan team was able to drive to the junction and concurs with the assessment. Figure 78 depicts the central portion of the mini-roundabout.



**Figure 78. Mini-roundabout in Michigan.**

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The diameter of the domed middle of the roundabout was approximately 16 feet, and drivers seemed to understand the traffic control devices. Figure 79 depicts one approach to the mini-roundabout. Despite the snow, the word “YIELD” is clearly visible on the pavement, adjacent to the YIELD sign.



**Figure 79. Approach to mini-roundabout in Michigan.**

Figure 80 presents a close-up view of the splitter island, which features a small sign. The island itself is about 3 feet wide at its narrowest and about 7 feet wide at its widest. It is about 17 feet in length. Figure 81 presents an upstream view of the other approach. The yellow warning sign is clearly visible in the foreground. In the background is a yield-ahead warning sign.



**Figure 80. Detailed view of channelizing island on approach to mini-roundabout.**



**Figure 81. View of warning sign on approach to mini-roundabout.**

The scan team felt that this treatment was a safe intersection treatment for a junction that features a significant amount of turning traffic.



### Speed Humps and Speed Tables

Both Charlotte and West Palm Beach have speed humps, speed tables, and raised intersections. Raised intersections are a special kind of intersection where the elevation of the entire intersection is raised and the transition between the elevation of the upstream pavement and the elevation at the intersection is discernable by the motorist. This has a traffic calming effect in a manner that drivers slow down as they negotiate the elevated intersections. Figures 82 and 83 provide views of this application at two intersections—note the pedestrian warning sign in figure 83.



**Figure 82.** View of raised intersection/speed table in West Palm Beach.



**Figure 83.** Closer view of raised intersection/speed table in West Palm Beach.

### Non-Traditional Intersection Geometric Treatments

Non-traditional intersections have been covered in great detail in *Signalized Intersections: Information Guide*, published by FHWA. Several non-traditional intersection treatments with potential application in other locations were identified in the study. Figure 84 presents a jughandle intersection design implemented in Bend, Oregon. Left turns are not allowed from the side road onto the major road at the signalized-intersection in the middle of the photo. Drivers can make a left turn maneuver at the junction where the ramps intersect the side road, which is shown vertically in the figure 84. This intersection configuration is a promising geometric treatment, given that it is reducing the number of conflicts in the intersection. It is key to note that similar designs are used extensively in New Jersey.



**Figure 84.** At-grade intersection with jug-handle ramps in two quadrants located in Bend, Oregon.

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**Figure 85. Intersection in West Palm Beach.**



**Figure 86. Illustration of alternative intersection.**

Figure 85 presents a fairly unique intersection treatment that has been implemented at other intersections in the downtown area of West Palm Beach. The treatment consists of flush gutter, brick pavements, and crosswalks defined in different brick colors and styles. Photographs of another intersection with similar geometrics are presented in figure 86.

A close examination of figures 85 and 86 reveal that the sidewalk blends into the curb and that the intersection has the appearance of a plaza. This treatment has application only in highly developed areas at the intersections of roads with lower speed and lower volumes. The primary goal of these geometric treatments is improved aesthetics. It must be noted there is a lack of knowledge of the safety effects of these treatments, and there are potential safety challenges attributable to the lack of retroreflective pavement markings for the crosswalks and stop lines. Jurisdictions should exercise engineering judgement on the use of this treatment when compared to the need to enhance safety.



**Figure 87. Photograph of Clematis Street in West Palm Beach, looking west.**



**Figure 88. Photograph of Clematis Street in West Palm Beach looking east.**

In terms of intersection design, one of the first streets retrofitted in West Palm Beach for traffic calming was Clematis Street, which is cited as an illustrative landmark example of new urbanism. Figures 87 and 88 provide photos of Clematis Street in the midblock area. It was here that traffic calming was tailored-made in applicability. Figure 89 (*page 54*) presents the intersection of Clematis and Narcissus Streets, which essentially is a continuation of a plaza. Figure 90 depicts the intersection of Narcissus and Datura Streets. In all of these intersections,





**Figure 89. Plaza at east end of Clematis Street.**



**Figure 90. Intersection of Narcissus Street and Datura Street in West Palm Beach.**

the design is very similar—an ornate brick pattern, flush corners with no curbs. In the last two figures, small bollards are visible. Although clearly these are different intersection designs, the applicability based on safety concerns are limited.

Charlotte, North Carolina, also identified several sites where innovative geometric treatments were installed. Figure 91 (*page 56*) presents an aerial photograph view of an intersection before it was reconstructed. The geometry is somewhat complicated in that the main road splits into a one-way pair. A large medical center is located in the lower right corner. Consequently, traffic turning left from the top to the right is heavy.



**Figure 91. Aerial view of intersection in Charlotte prior to implementation of geometric treatment.** (Courtesy of Charlotte DOT).

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Charlotte developed a fairly comprehensive design for the intersection. At the time of the scanning study, construction was about completed with the exception of an accessible curb cut ramp and the construction of relocated sidewalk. The finished design is illustrated in figures 92, 93 and 94. The project included many notable items, such as brick sidewalks, raised concrete islands, LED signals, pedestrian signal heads, and street lighting.

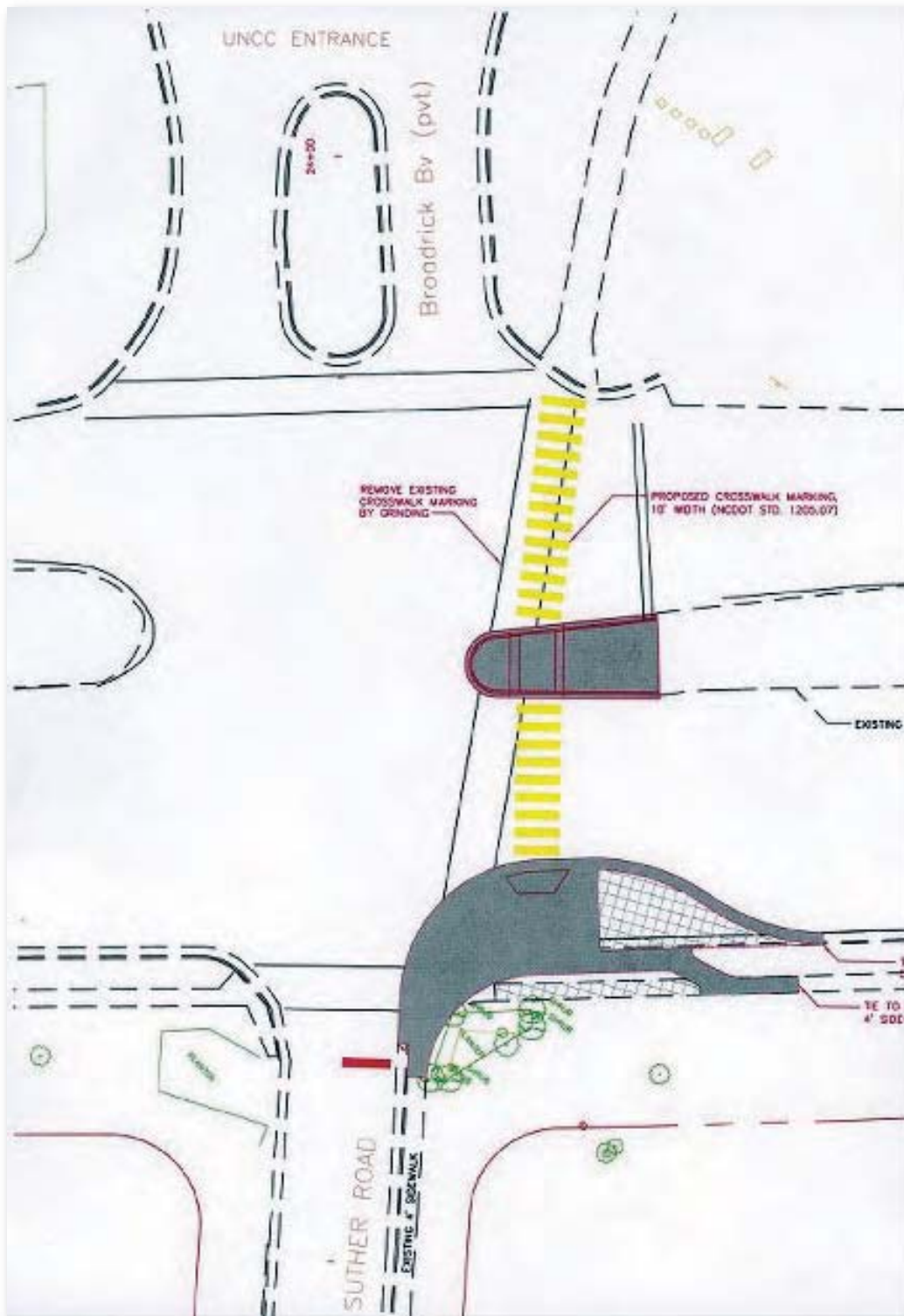
One final example of innovative intersection geometric design is illustrated in the design plan presented as figure 94. The building on the far side of the photograph is part of a college campus. Hence, there were significant pedestrian volumes crossing at this location. The challenge was how to better accommodate the movement of pedestrians given the intersection site constraints. As seen in figure 94, the project consisted of bulbing out one corner and extending the median to create a median refuge for pedestrians. A decision was made to install a pedestrian signal head and set of push buttons in this median island and to reroute the pedestrian crosswalk to reduce



◀ **Figure 92. Photograph of Charlotte intersection after improvement.** (Courtesy of Charlotte DOT)



**Figure 93. Two photographs of pedestrian refuge at an intersection in Charlotte after improvement.** (Courtesy of Charlotte DOT).



**Figure 94. Design plan showing geometric modifications and changes to pedestrian crossing at a somewhat complex intersection in Charlotte.**  
(Courtesy of Charlotte DOT).



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the exposure of pedestrians to traffic.

Photographs of the intersection after construction was completed are presented in figures 95, 96



◀ **Figure 95.** Depiction of completed intersection geometric treatment implemented in Charlotte. (Courtesy of Charlotte DOT).



**Figure 96.** Close-up of crossing and median refuge island. (Courtesy of Charlotte DOT).



**Figure 97.** Close up of larger concrete landing in one corner. (Courtesy of Charlotte DOT).

## CHAPTER 7. ENFORCEMENT PRACTICES AND EDUCATIONAL PROGRAMS

This chapter addresses several items identified during the tour that pertain to enforcement and driver and pedestrian education.

### Enforcement Practices

There were several enforcement practices that were identified by host agencies and noted by the tour team. Specifically, so-called “rat lights,” automated red light running enforcement systems, and automated speed enforcement were topics that warrant brief discussion.

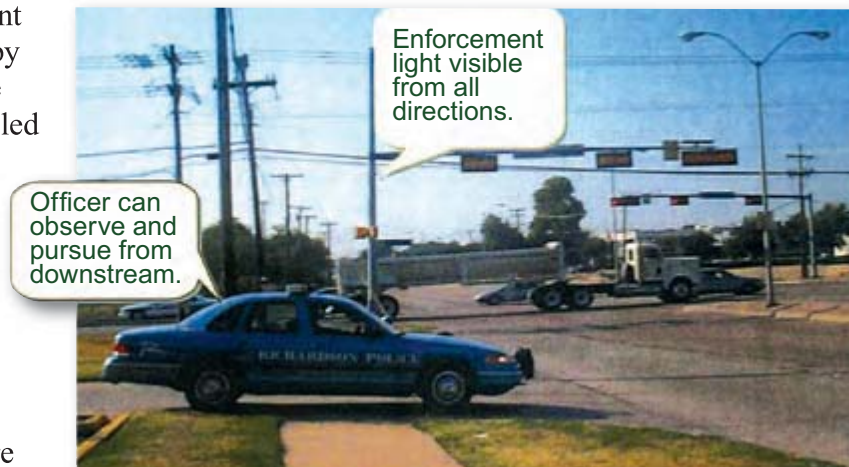
#### “Red Signal Indicator Lights.”

Almost all of the agencies were familiar with “red signal indicator lights” that have other commonly understood names, such as “rat lights.” Several had implemented

some or were in the process of implementing them. They are devices typically wired to signals and located so that they can be seen downstream of the signalized intersections. “Rat lights” are typically wired so that when the signal indication for traffic entering the upstream side of the intersection is red, the “rat light” is illuminated. This system allows a police officer to position their police vehicle downstream and watch the “rat light” and entering vehicles. If a vehicle enters the intersection while the “rat light” is illuminated, then the enforcement officer



**Figure 99. Another detailed view of “rat light.”**  
(Courtesy of the City of Richardson).



**Figure 98. View of signal-controlled intersection equipped with “rat lights” in Richardson, Texas.**  
(Courtesy of the City of Richardson).

knows that the motorist entering the intersection has illegally entered on red. The officer can proceed to stop the subject vehicle for a red light violation, as shown in figure 98. Since the officer is positioned downstream of the intersection, the officer is in a much safer position to initiate his pursuit. Without the “rat light,” as shown in figure 99, officers would need to be upstream of the intersection. In order to pursue the alleged violating motorist, the officer would also have to violate the red light indication by following the motorist through the intersection. Of course, some police agencies eliminate the risk that would result from chasing the violator through a red signal by using a pair of officers in separate vehicles to coordinate and issue citations to red light violators. But the disadvantage to this approach is that more police resources would have to be devoted to red light running enforcement, which potentially makes this effort more costly to the police agency.



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Automated Red Light Running Enforcement Systems. Similarly, there were several agencies that implemented or are in the process of implementing red light running systems in their jurisdictions. Figure 100 depicts the advance sign for a red light running camera system in Portland. The camera is shown in figure 101, and the strobe light at the intersection is shown in figure 102. For completeness sake, figure 103 presents a view of the loops at the stop bar.



**Figure 100.** View of advance sign for a red light running automated enforcement system in Portland.



**Figure 101.** View of camera for a red light running automated enforcement system.



**Figure 102.** View of strobe light at the intersection for a red light running automated enforcement system in Portland.



◀ **Figure 103**  
View of inductive loops at stop line for a red light running automated enforcement system in Portland.



◀ **Figure 104.**  
View of advance  
sign for a red  
light running  
automated  
enforcement  
system in  
Charlotte.

Although it is a slightly different system, figures 104 and 105 show the advance sign and a view of the camera, respectively, for a red light running automated enforcement system in Charlotte. There are several issues that continue to plague red light running automated enforcement systems. The issues include a person's right to privacy and the amount of the fine. There are also legal issues about who owns the vehicle and can the owner be forced to pay the fine. Then there are issues over whether the system has been implemented for ostensibly safety reasons or whether it was implemented solely to raise revenue for the local jurisdiction. With regard to the safety effects, the most recent and comprehensive study of the crash and economic effects by Council et al.<sup>(9)</sup> concluded that, in general, automated red light systems reduce the more severe angle crashes with a lesser amount of increase in rear-end, less severe crashes.

Automated Speed Enforcement. Charlotte, North Carolina, instituted a speed enforcement program that employs mobile technology



**Figure 105.** View of camera for a red light running automated enforcement system in Charlotte.

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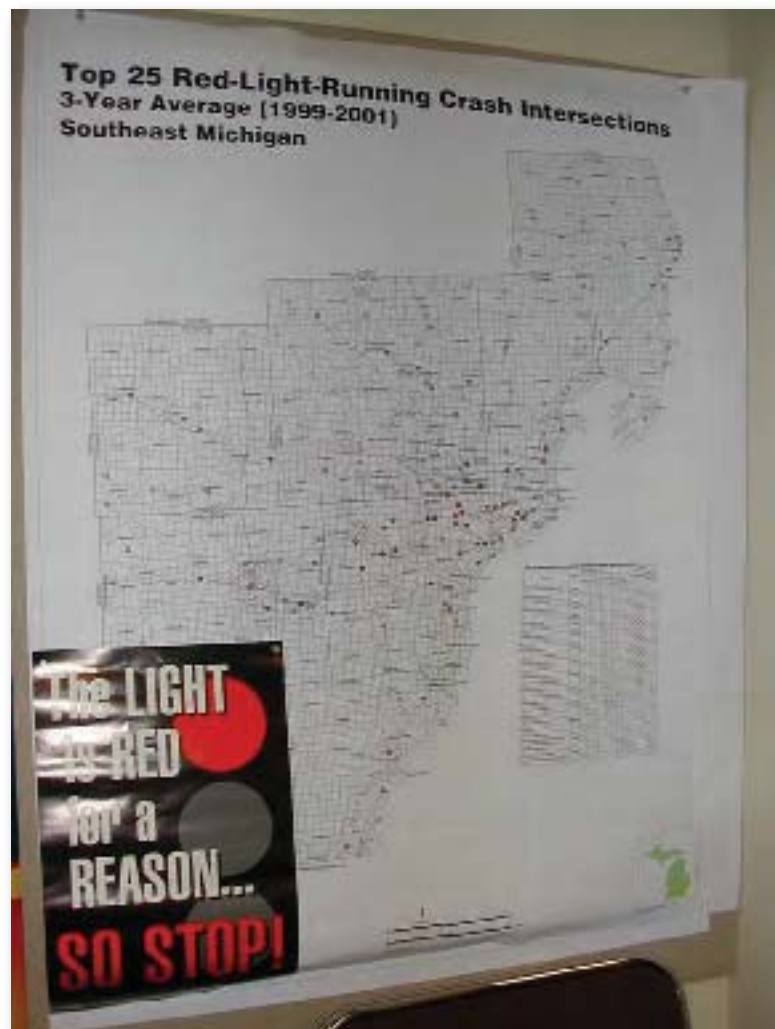
that resides in a specially equipped van, which allows speeding vehicles to be captured after they have passed the van. A vendor operates the system for the city, but the local law requires a trained police officer to be present at the site whenever enforcement activity is underway. Although the program has targeted certain areas, it was considered too early in time because this program was initiated to assess the relative effectiveness of the program within the community. Portland also had an automated speed enforcement program.

### **Educational Programs**

There were two items related to educational programs that are discussed below. The first deals with safety awareness campaigns. The second deals with multilingual formats.

#### Safety Awareness Programs.

During the scan, it was noted that of the agencies visited during the tour, several locations, including Portland, Oregon transportation officials, the Michigan State Police, and the Southeast Michigan Council of Governments (SEMCOG), have developed and implemented safety awareness educational programs geared toward intersection safety. For example, figure 106 presents a large display and promotional poster about SEMCOG's red light running program. The key aspects of educational programs that promote intersection safety are: (1) what is the message that needs to be communicated; and (2) how best can that message be communicated. To many traffic engineers and highway safety professionals, intersections are extremely complex situations, which are not fully understood especially when it comes to causal relationships. However, to be effective promotional campaigns, there is a need to simplify the information so that the public can not only understand, but also embrace it as well.



**Figure 106. SEMCOG's program to reduce red light running.**



**Multilingual Programs.** Earlier in this report, a pedestrian push button regulatory sign in Spanish was discussed. Within the field of driver and pedestrian education, there is a growing recognition of the informational needs of people who do not speak English and those for whom English is a second language. Several cities visited have significant Hispanic populations. Consequently, some have taken steps toward accommodating the needs of drivers and pedestrians who only speak Spanish. Figures 107 and 108 are scanned images of selected pages of a walking promotional document. When folded, it is six pages in length. Three of the pages are in English and three are in Spanish. While the message is only minimally geared toward intersection safety, there are obvious benefits when the content of the safety programs can be communicated to large segments of the local community.

HERE'S A HABIT WORTH FORMING!

SO THAT'S WHAT THESE ARE FOR!

OH! I GET IT!

**Take purposeful walks**  
 Include friends & family to nearby...

- work - school
- restaurants
- retail stores
- groceries
- library
- places of worship
- playgrounds - parks
- post office - medical services
- bus stop - rail station

**Safety Tips**

- On streets or sidewalks - always walk facing traffic.
- On trails, slower traffic stays right - faster traffic passes on the left.
- Let someone know your route and when you will be back. Take a cell phone if you have one.
- Drink plenty of water - before, during and after walking.
- Check with your doctor if you have any health concerns or medical conditions.

**Walking Gear Tips**

- Wear comfortable clothes and walking shoes.
- Dress in layers in cool weather.
- Stuff wet shoes with newspaper and allow to dry naturally.

**Figure 107. English version of brochure on the benefits of walking.** (Source: Courtesy of NCTCOG).

¡QUÉ BUENA COSTUMBRE PARA EMPEZAR!

¡AH, BASTA SE USA PARA ESO!

¡AH, YA ENTENDO!

**Camina con un propósito definido**  
 Incluye a los amigos y parientes en las cercanías de

- trabajo - escuela
- restaurantes
- tiendas
- supermercados
- biblioteca
- iglesias
- campos de deporte - parques
- oficina de correos - servicios médicos
- paradas de autobús - estación de tren

**Consejos sobre seguridad**

- En las calles o aceras - Camina siempre en dirección contraria al tráfico.
- En los senderos, el tráfico lento permanece a la derecha - el tráfico rápido pasa por la izquierda.
- Hazle saber a alguien tu recorrida y hora de regreso. Si tienes teléfono celular, llévalo contigo.
- Bebe mucha agua - antes, durante, y después de la caminata.
- Consulta con tu médico si tienes alguna inquietud con respecto a tu salud o problemas médicos.

**Consejos sobre el atuendo para caminar**

- Lleva ropa cómoda y zapatos para caminar.
- Lleva suficientes prendas de ropa en tiempo frío.
- Rellena los zapatos húmedos con papel periódico y déjalas secar naturalmente.

**Figure 108. Spanish version of brochure on the benefits of walking.** (Source: Courtesy of NCTCOG).

## **CHAPTER 8. CONCLUSIONS**

**T**his chapter summarizes the key findings of the scan. Due to the scope of the scan, it was possible to only visit a limited number of areas in the United States, and not possible to identify all innovative intersection safety treatments and comprehensive intersection safety practices that have been and are being implemented in the United States today. However, many of the practices and treatments implemented by the host agencies are noteworthy and have the potential to affect a positive improvement in intersection safety.

### **Intersection Safety Management**

Several host agencies agreed that the first step toward achieving significant improvements in intersection safety is to create a culture of safety within the organization. These organizations found that by assigning a greater prominence to safety in transportation investment decisions, they were able to produce significant reductions in crashes. Before this could happen, it was understood that the agencies had to raise the awareness and importance of highway safety throughout all branches of the state, county, city, and municipal government transportation departments. This required the development and implementation of processes and procedures to monitor the performance of the highway system in measurable safety criteria, including crash frequency, rates, and severity.

Safety management that is truly performance-based was judged to be the cornerstone. The greatest gains were experienced by those agencies that had established formal numerical goals and measurable objectives with respect to crash experience. Finally, several of the host agencies also pointed to public-private partnerships as a means of improving intersection safety. The project completed by the cities of Detroit and Grand Rapids, in association with AAA Michigan, was cited as a notable case study. Since AAA Michigan is somewhat unique in that it is an insurance provider as well, other business models could be applied to better fit the constraints and opportunities that exist throughout the United States.

### **Intersection and Safety Data**

Repeatedly, host agencies indicated that it was not possible to do a reasonable job in intersection safety unless accurate crash data was matched to the correct intersection. Similarly, the host agencies voiced many concerns attributable to highly suspect crash data. All levels of government must assume a commitment to improving the quality of crash data, as well as supporting intersection inventory data and traffic data. Without a set of clearly defined numerical goals and established performance standards, operating agencies will continue to wait excessively long periods until crash data becomes available for their use.

Most host agencies also indicated that better access to crash data is needed to further enhance intersection safety. Specifically, they desired to have quickly-generated spatial data displays. Agencies with access to tools that allow generating Geographic Information Systems (GIS) pin maps and other displays, such as those that can be generated from the SEMCOG Web site, felt empowered.



Several of the host agencies also discussed a need for a flow of safety-related information from the state's central agency. The scan revealed that there are multiple benefits to the two-way exchange of crash and intersection-related data. Certainly, many benefits accrue when data can be transported up from local police departments and the state patrol to the appropriate headquarters agency tasked with the responsibility for the central crash records system. However, the benefits are also large when the data is reduced, subjected to quality control checks and summarized in meaningful formats, and returned to the police departments and transportation agencies at the local government level.

### **Intersection Safety Research**

A few of the host agencies conducted rigorous before and after evaluations of the effects of these implemented treatments on crash experience. Therefore, there is still knowledge to be learned about many of the treatments cited in this report. Limited sample size and limited post-treatment durations restrict the evaluator's ability to generate strong conclusions on the effectiveness of these treatments.

In addition, there is a need to develop and maintain an accurate knowledge base of the effects of projects, including those with multiple treatments, on crash experience. Safety effectiveness estimates are especially needed for flashing yellow left arrow signal indications, pedestrian detection systems that seek to extend pedestrian clearance intervals, and treatments that delay the onset of the yellow interval, among the treatments encountered during the scan.

### **Traffic Control Devices at Intersections**

Within the area of traffic control devices at intersections, many of the host agencies implemented innovative treatments, including street name signs with larger lettering in Clearview font at signalized intersections and advance street name signs that were placed at locations on the major approaches upstream of the intersection. There were also numerous pedestrian treatments, including pedestrian countdown devices, more pronounced crosswalk markings, audible pedestrian signal heads, and pedestrian push buttons and signs designed for mobility-challenged pedestrians. Some have implemented activated, in-pavement lights for crosswalks and activated pedestrian crossing warning devices-systems that alert drivers of possible conflicts.

With respect to pavement markings, several host agencies made innovative use of dashed markings, which are frequently called "cat tracks" or "puppy tracks" text on pavement surfaces at locations where supplemental directional information is needed, and messages (e.g., "LOOK LEFT") in the pavement where there is a greater need to communicate to pedestrians, such as a roundabout.

Some agencies installed internally illuminated traffic sign boxes, which are continuously lit at night that featured permanent regulatory restrictions, such as "NO LEFT TURN" and "STOP." Other agencies installed internally illuminated "PEDESTRIAN CROSSING" signs at mid-block crossings that are illuminated in response to actuations of pedestrian push buttons. Fiber-

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optic and other dynamic regulatory signs (e.g., “NO TURN ON RED” to communicate time-dependent regulations) were effectively used by some host agencies.

### **Traffic Operations at Intersections**

Virtually every host agency identified traffic operations strategies and techniques that most would consider conventional practices. These included yellow and red clearance intervals for phases at signalized intersections that meet national guidelines/practices, the provision of additional crossing time for older pedestrians and at intersections where conditions warrant (e.g., high numbers of elderly pedestrians and/or school children), and protected left-turn phases that can be called back into service during the same cycle under certain conditions.

Many of the host agencies also described their experiences with innovative practices. In addition to the “Dallas Phase” sequence for left-turn movements at intersections operating with lead-lag left turn phasing, the city of Dallas cited an innovative treatment that allows for longer pedestrian walk and pedestrian clearance intervals to be subsequently provided in response to continuously depressing the pedestrian push button for five seconds or more. The cities of Portland and Richardson have experimented with systems that delay the onset of the yellow interval or extend red clearance intervals, respectively. While it is common practice to vary the duration of green intervals in response to congestion conditions, it is hoped that in the future systems, processes, practices and/or procedures can be devised that would allow for the dynamic variation of yellow, red clearance, pedestrian walk and pedestrian clearance intervals in response to monitored conditions in an attempt to reduce safety risks.

Other innovative treatments implemented included delaying the onset of the yellow interval based on detection of vehicles beyond the stop line at wide intersections, implementing longer pedestrian walk and pedestrian clearance intervals at different times of the day when students are present at intersections near schools, time-of-day phasing in which left-turn phasing sequencing can be varied by time of day and day of week, and flashing yellow left turn arrows.

### **Intersection Geometric Design**

Innovative, non-traditional geometric design treatments, which were implemented by the host agencies, included the Michigan Indirect Left Turn treatment, the New Jersey “jug-handle” treatment, roundabouts, mini-roundabouts, and the Michigan “Loon,” which facilitate U-turns by large trucks at intersection sites with narrow medians and less than three opposing travel lanes. Several host agencies also implemented road diet projects that converted four-lane cross sections to three-lane cross sections. Median island treatments were constructed on several intersection approaches to limit the effects of nearby driveways and other access by eliminating crossing maneuvers from minor access points. Other treatments include intersection bulb-outs and offsetting left turn lanes to improve sight distance at intersections with opposing left turn lanes and permitted left turn signal phasing.

Several of the host agencies had installed unique crosswalks, which included brick crosswalks,

blue bike lanes, raised crosswalks, and novel intersection designs, such as raised intersections that are similar to speed tables. At a few downtown intersections where some of these treatments were constructed, the corner curbing was concurrently removed to make the corner landing flush with the roadway. Although these geometric treatments are clearly innovative, there is a healthy debate on their appropriateness by road, functional classification, area context, vehicle speeds, and volume.

### **Intersection Safety-Oriented Enforcement and Education**

Although enforcement and driver education were not the focus of this scan, several notable programs were identified by host cities. Enforcement treatments implemented by the host agencies pertained to the vigilant enforcement of unsafe driving behavior at intersections. These included so-called “rat lights,” which assist police agencies to identify drivers that violate red signal indications at intersections, and photo enforcement systems.

Other enforcement programs featured enforcement target maps, which have been developed by traffic engineering agencies to pinpoint the clustering of selected crash types for given “targets,” such as red-light running, speeding, and aggressive driving, among others. Driver education treatments for intersection safety included multi-jurisdictional education campaigns aimed at red light running and widely distributed brochures in Spanish that explain traffic control devices at intersections.

Other innovative education programs included a mobile truck simulator for truck driver training and portable, radar-based dynamic speed signs. Innovative traffic control or geometric design treatments should not be implemented without advance public information. Wherever new treatments, especially those that are non-intuitive, are to be implemented, consideration should be given to developing and conducting a comprehensive public education program prior to deployment and updating driver training materials to ensure that the message is communicated to new drivers.

Readers of this scan report are encouraged to contact the individuals in Appendix B to learn more about the treatment and processes that are described. It is hoped that better and more effective intersection safety treatments can be developed and implemented by others as a result of this search for innovative ideas.

### **Summary**

Like many of the states, counties, cities and municipalities throughout the United States, the host agencies that participated in this scan are endeavoring to improve safety at intersections. The treatments they have developed and implemented are not applicable to all intersections and may not be appropriate for a given municipality or state. In the interest of information dissemination, these treatments were documented in this report. Readers are encouraged to contact the individuals in Appendix B to learn more. It is hoped that better and more effective intersection

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safety treatments can be developed and implemented by others as a result of this search for innovative ideas.

### **Disclaimer**

Some of the traffic control devices or applications described in this report are not in compliance with the *Manual on Uniform Traffic Control Devices (MUTCD)* and are considered experimental. Any jurisdiction wishing to use a non-compliant device or application on a road open to public travel must request and receive approval from the Federal Highway Administration for experimentation. Please refer to Section 1A.10 of the *MUTCD* (<http://mutcd.fhwa.dot.gov>) for procedures regarding experimentation.”



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# APPENDIX A

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**Shyuan-Ren (Clayton) Chen, Ph.D.**, is a Highway Traffic Engineer of the Office of Safety Programs for the Federal Highway Administration in Washington, D.C. His emphasis includes developing FHWA's safety program in geometric design, intersection/interchange safety, intersection roadmap, and supporting road safety audit, access management, pavement safety policy, and cooperative intersection collision avoidance systems programs. Chen has a Ph.D. degree major in Transportation and Urban Engineering from the University of Connecticut. He is a licensed professional engineer in Virginia and a certified professional traffic operations engineer.

**Warren E. Hughes, P.E., PTOE**, is a Principal of BMI-SG; a VHB company affiliated with Vanasse-Hangen-Brustlin, Inc, in their Vienna, VA, office. He has been continuously active in highway safety research projects since 1981. In addition, he has extensive experience in traffic engineering, traffic signal design and modification projects, traffic operations analyses, transportation corridor improvement studies, highway location and design projects, transportation planning studies, intersection design projects, crash analyses, and traffic simulation. He graduated magna cum laude with a BSCE from the University of Notre Dame and received his MSCE from the University of Maryland.

**Eugene Calvert, P.E., PTOE**, is the Interim Director of the Transportation Engineering & Construction Management Department for the Collier County Transportation Services Division in Naples, Florida. Mr. Calvert is responsible for the administration and project management of the capital road and bridge improvement program for the Collier County. He has been involved in the construction and management of highway improvement projects on the local level for 27 years. Mr. Calvert is an active member of the National Association of County Engineers (NACE) and has been affiliated with the National Local Technical Assistance Program (LTAP). Mr. Calvert holds a bachelor's and a master's degree in civil engineering from the University of Wyoming. He is the recipient of the *Eldon J. Yoder Award* for the Transportation Research Board (TRB) Eighth International Conference on Low-Volume Roads and a recipient of the *California Transportation Foundation TRANNY Award* for the Outstanding Highway Management Program for 2003. He is a licensed professional engineer in four states and a registered land surveyor in two. Mr. Calvert is a certified Professional Traffic Operations Engineer (PTOE) and is an active committee member of TRB.



**Douglas W. Harwood, P.E.**, manages the transportation engineering section of the Applied Engineering Division at Midwest Research Institute in Kansas City, Missouri. Mr. Harwood has more than 30 years of research experience for federal, state and local agencies, and he has served as principal investigator of numerous FHWA and NCHRP research projects concerning traffic safety, highway geometric design, and traffic operations. He has had a key role in the development of guides to assist highway agencies in implementing the AASHTO Strategic Highway Safety Plan; in particular, he was the lead author of a guide on improving safety at unsignalized intersections that has been published in the *NCHRP Report 500* series. He is a civil engineering graduate of Clarkson College and has a master's degree in transportation engineering from Purdue University in Indiana. He is a licensed professional engineer in Missouri and Montana. Harwood is also a member of the Transportation Research Board's Task Force on the Development of the Highway Safety Manual and, until recently, served as chair of the TRB Committee on Operational Effects of Geometrics.

**Loren Hill, P.E.**, began his career at the Minnesota Department of Transportation (Mn/DOT) in 1973. He is the Mendota State Traffic Safety Engineer. His unit is responsible for crash analysis and speed limit issues statewide. He was the project manager of the Minnesota Comprehensive Highway Safety Plan (CHSP). Hill is a graduate of the University of Minnesota, with postgraduate work at University of Texas and at the University of Nevada-Reno. He is a licensed engineer in Minnesota. He has been a member of the expert panel on the *Model Minimum Uniform Crash Criteria Guideline* manual, was involved in the safety analyst development, and was a panel member on the *NCHRP Report 500* series.

**Stanley F. Polanis** began his transportation career as a Human Factors Researcher with the Highway Safety Foundation in 1971. He worked for the Pennsylvania Department of Transportation from 1974 through 1979. In late 1979 he joined the City of Winston-Salem's Traffic Engineering staff and was named Assistant Director of Transportation in 1993 and Director of Transportation in December of 2002. As Director, he is responsible for management of a transportation department with more than an \$11 million budget that includes 65 employees and is the lead planning agency for the Winston-Salem Urban Area Metropolitan Planning Organization (MPO). The Department also oversees the Winston-Salem Transit Authority. Mr. Polanis received his undergraduate degree from Ashland College in Ohio and is a 1976 graduate of the Bureau of Highway Traffic at Pennsylvania State. He is a member of Institute of Transportation Engineers (ITE), the Transportation Research Board (TRB) and the International Parking Institute. Mr. Polanis has published papers dealing with traffic safety and authored the ITE's Traffic Safety Toolbox. He has also authored papers on parking issues and traffic signal timing and fuel economy.

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**Publication Number FHWA-SA-06-016**

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