Design and Evaluation Guidance for Intersection Conflict Warning Systems

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Prepared with support from:

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Introduction

Intersection crashes continue to represent a significant share of transportation fatalities and serious injuries throughout the country. The Federal Highway Administration offers a number of resources to address these crashes through their Intersection Safety Program. In addition to lighting, signing and geometric improvements, organizations are turning to Intelligent Transportation Systems as another resource for reducing intersection crashes. Over the past several years, a variety of major and minor street oriented intersection conflict warning systems have been developed and tested in states across the country. Some systems have been developed using local expertise, while others have been supported by the USDOT Cooperative Intersection Collision Avoidance Systems program. No specific guidance has been available for these systems in regard to placement, size, messaging, failsafe, etc. This has resulted in a fairly broad range of approaches and with the states' growing experience there is now an opportunity to work together in moving toward standardization.

In February 2011, FHWA released a document summarizing the state of practice for through route (or major street) activated warning systems. The document, "Stop-Controlled Intersection Safety: Through Route Activated Warning Systems (FHWA-SA-11-15)," presents the details of system deployments in the states of North Carolina and Missouri. It also presents noteworthy practices for signing, site selection, design and operation of major street oriented systems. In addition to these major street systems, there are several systems designed to provide alerts to the minor street driver. All of these systems are primarily designed to address poor site distance or gap acceptance causes by providing an alert about the presence cross traffic. However, there are still other systems designed to reduce speed on the major street under the assumption that speed is the contributing factor in crashes at some intersections.

Warning signs, in general, are used to call attention to unexpected conditions on or adjacent to a highway, street or private road open to public travel and to situations that might not be readily apparent to road users. Warning signs alert road users to conditions that might call for a reduction of speed or an action in the interest of safety and efficient traffic operations. (Federal Highway Administration, 2009) Intersection conflict warning systems offer a substantial warning to drivers and are used to provide real-time, dynamic information about intersection conditions to support driver decision and, ultimately, reduce right angle crashes.

Purpose

Bringing together organizations that have developed and deployed all types of intersection conflict warning systems, the ENTERPRISE transportation pooled fund sponsored a project to develop a consistent approach for accelerated, uniform deployment and further evaluation of these systems, and to recommend preliminary standards for the Manual of Uniform Traffic Control Devices. Developing Consistency in ITS Safety Solutions – Intersection Warning Systems, the project assembled information from the organizations list in Table 1 to better understand what types of systems have been deployed and what may be known about their effectiveness. The information gathered includes a variety of useful reference documents such as evaluation reports, plans sets, special provisions and concepts of operation. All documents are available through the project web page under Related Documents/Links.

Table 1 Sources of Intersection Conflict Warning System Information

FHWA	Florida DOT
Gwinnett County, Georgia	InterSafe (Europe)
Iowa DOT	Maine DOT
Michigan DOT	Minnesota DOT
Michigan DOT	Missouri DOT
North Carolina DOT	Pennsylvania DOT
Scott County, Minnesota	Virginia DOT
Washington DOT	Wisconsin DOT
Wright County, Minnesota	AASHTO Connected Vehicle Program

Based on the information assembled to-date about federal, state and locally sponsored experience with intersection conflict warning systems, this document provides an initial version of design and evaluation guidance to support future deployment of these systems. As defined in Part 1 of the MUTCD, "Guidance is a statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate." (Federal Highway Administration, 2009) In keeping with that definition, this design and evaluation guidance is intended to offer technical insight and recommended practice for designing and evaluating intersection conflict warning systems. It does not mandate the deployment of such systems, nor does it limit the engineering or policy discretion of the transportation agencies who may consider deploying these systems. This guidance is expected to evolve as more systems are deployed and further evaluation is conducted. It is also expected to serve as preliminary guidance for what may eventually be included in the MUTCD.

To substantiate and encourage MUTCD consideration of this guidance, ENTERPRISE engaged representatives from its pooled fund member states, other states that have deployed intersection conflict warning systems, FHWA, AASHTO's Standing Committee on Traffic Engineering, the National Committee on Uniform Traffic Control Devices and the National Association of County Engineers. These representatives participated in a webinar and two workshops which were used to share information about experiences with intersection conflict warning systems and to discuss the content of this initial design and evaluation guidance document.

The remainder of this document presents the following design and evaluation guidance for intersection conflict warning systems:

- Typical system components;
- Glossary of terms and symbols;
- Recommended layouts; and,
- Evaluation guidance.

Typical System Components

Intersection conflict warning systems may include some or all of the following components depending upon the sophistication of the warning provided to drivers. For example, some warnings may depend upon simple detection of vehicle presence and to activate a beacon on a static sign. In contrast, other warnings may require vehicle speed and traveling direction to deliver a message indicating which direction a vehicle is approaching from and how quickly it may arrive.

Detection: Used to detect vehicle presence and sometimes speed, detectors may include:

- Radar
- Pneumatic road tubes
- Light beams
- Acoustical
- Ultrasonic
- Magnetic
- Piezo-electric
- Video
- Radio frequency identification
- Probe injection technologies

Warning: Dynamically activated based on the detection of a vehicle, these components may consist of:

- Static sign
- Beacon
- Dynamic message sign
- Illuminated static sign elements

System Communication: Forms of communication used to transmit data among components – most often detection and warning – may include:

- Cellular
- Internet – Wireless Access Points
- Radio
- Landline
- Optical

Data Management: The storage of data or analysis of the data for trends, events, etc. May utilize a variety of on/off-site databases or data storage devices.

System Analysis: Analysis algorithms are designed or modified for each application of an intersection conflict warning system to fit the warning, detection and conditions of the deployment site.

System Monitoring: Failsafe and redundancies should be built into systems based upon risk assessment for system failure. Various monitoring systems or quality control testing may be utilized.

Glossary of Terms

There are many terms used in the variety of systems that have been developed to-date. Following is a list of such terms and their associated meanings. Where possible, the terms most commonly used and defined in the MUTCD (Federal Highway Administration, 2009) are suggested as the most appropriate terms of reference.

- **Actuation:** Initiation of a change in or extension of a traffic signal phase through the operation of any type of detector.
- **Beacon:** A highway traffic signal with one or more signal sections that operates in a flashing mode.
- **Detector:** A device used for determining the presence or passage of vehicles or pedestrians.
- **Engineering Judgment:** The evaluation of available pertinent information and the application of appropriate principles, provisions, and practices as contained in this Manual and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device. Engineering judgment shall be exercised by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer. Documentation of engineering judgment is not required.
- **Gap:** The space between vehicles on the major street, or the space between the vehicle on the minor street and a vehicle approaching on the major street. (Minnesota Department of Transportation, 2008)
- **Intersection Conflict Warning System**: Typically comprised of static signing, detection and dynamic elements, these systems are used to provide substantial warnings to drivers at intersections where poor site distance or gap acceptance have contributed to high crash rates. Also referred to as Collision Countermeasure System, Cooperative Intersection Collision Avoidance System, Crash Avoidance Systems, Intersection Warning System, and Traffic Actuated Warning Signs.
- **Major Street**: The street normally carrying the higher volume of vehicular traffic. Also referred to as Through Route and Mainline.
- **Minor Street**: The street normally carrying the lower volume of vehicular traffic. Also referred to as Cross Street and Stop Approach.
- **Sight Distance:** The length of roadway ahead visible to the driver. (American Association of State and Highway Transportation Officials, 1994)
- **Traffic Conflict:** A traffic event involving the interaction of two or more road users, usually motor vehicles, where one or both drivers take evasive action such as braking or swerving to avoid a collision.[1]

[1] Traffic Conflict Techniques for Safety and Operations Observer's Manual, FHWA-IP-88-027, January 1989

- **Traffic:** Pedestrians, bicyclists, ridden or herded animals, vehicles, streetcars, and other conveyances either singularly or together while using for purposes of travel on any highway or private road open to public travel.
- **Vehicle:** Every device in, upon, or by which any person or property can be transported or drawn upon a highway, except trains and light rail transit operating in exclusive or semi-exclusive alignments. Light rail transit equipment operating in a mixed-use alignment, to which other traffic is not required to yield the right-of-way by law, is a vehicle.
- **Warning Sign:** A sign that gives notice to road users of a situation that might not be readily apparent.

Recommended Layouts

Based on the information gathered about the systems deployed to-date, the next several pages present recommended layouts for intersection conflict warning systems. The layouts are presented according to which street the alert is directed at and the number of lanes at the intersection.

- ICWS 1: Minor Street Alert for 2-Lane/2-Lane (or 4-Lane) Intersection
- ICWS 2: Minor Street Alert for 2-Lane/4-Lane with Median Intersection
- ICWS 3: Major Street Alert for 2-Lane/2-Lane (or 4-Lane) Intersection
- ICWS 4: Major/Minor Street Alert for 2-Lane/2-Lane (or 4-Lane) Intersection

The layouts contained within this document are preliminary illustrations and may not represent all the intersection conflict warning systems that are or may be deployed. Systems may be combined, modified, enhanced or simplified as further deployments and evaluation are completed. These layouts offer technical insight and recommended practice for designing intersection conflict warning systems. They do not mandate the deployment of such systems, nor do they limit the engineering judgment or policy discretion of the transportation agencies who may consider deploying these systems.

These layouts are expected to evolve as more systems are deployed and further evaluation is conducted. For example, additional detail regarding conditions/warrants, most effective sign combinations and anticipated benefits will be added as information becomes available.

ICWS 1: Minor Street Alert for 2-Lane/2-Lane (or 4-Lane) Intersection

Conditions

- Crash history exhibits a higher than expected rate and/or severity.
- Major road volume may range from 3,000-10,000 AADT based on systems reviewed.
- Systems are typically used to address conditions where sight distance and/or gap acceptance are poor.

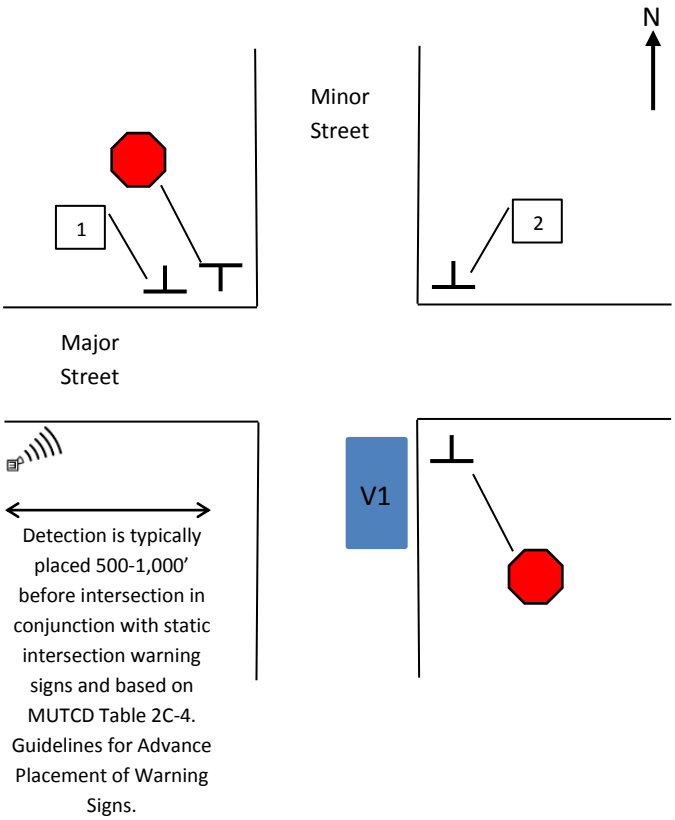
Intended Driver Use

The system provides drivers on the minor street with an additional warning of vehicle presence on the major street.

The system may also provide drivers with an indication of which direction major street traffic is approaching from.

Layout

Illustrations are not drawn to scale and are shown from the minor street, northbound vehicle (V1) perspective.



Options

Placement

Warning signs may be placed on the far-side corner (1) from STOP or far-side opposite corner (2) from STOP.

Sign combinations

Sign size should follow current standards in MUTCD Table 2C-2. Warning Sign and Plaque Sizes.

A. 

B. 

Message Sets

A. VEHICLES APPROACHING
B. CROSS TRAFFIC
C. LOOK FOR TRAFFIC
D. Vehicle symbol from left / right

Messages may also be combined with WHEN FLASHING plaque.

Notes and References

Systems have been deployed in Iowa, Missouri, Minnesota, North Carolina and Georgia on state and local roadways.

ICWS 2: Minor Street Alert for 2-Lane/4-Lane with Median Intersection

Conditions

- Crash history exhibits a higher than expected rate and/or severity.
- Major road volume may range from 10,000-18,000 AADT based on systems reviewed.
- Systems are typically used to address conditions where sight distance and/or gap acceptance are poor.

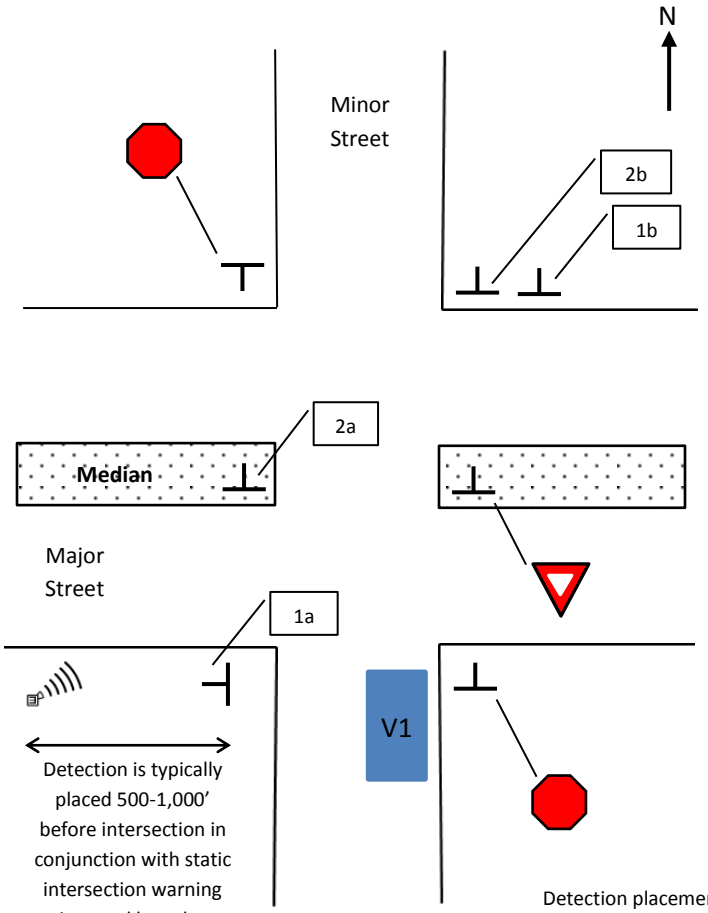
Intended Driver Use

The system provides drivers on the minor street with an additional warning of vehicle presence on the major street.

The system may also provide drivers with an indication of which direction major street traffic is approaching from and how quickly it may be approaching.

Layout

Illustrations are not drawn to scale and are shown from the minor street, northbound vehicle (V1) perspective.



Options

Placement

There is a set of two warning signs for this layout. The first sign may be placed left from STOP (1a) or on the far-side opposite corner from STOP within median (2a). The second sign may be placed on the far side corner from YIELD (1b, 2b).

Sign combinations

Sign size should follow current standards in MUTCD Table 2C-2. Warning Sign and Plaque Sizes.

A. 

B. 

Message Sets

A. VEHICLES APPROACHING
B. CROSS TRAFFIC
C. LOOK FOR TRAFFIC
D. Vehicle symbol left / right

Messages may also be combined with WHEN FLASHING plaque.

Notes and References

Systems have been deployed in Iowa, Missouri, Minnesota and Wisconsin on state and local roadways.

ICWS 3: Major Street Alert for 2-Lane/2-Lane (or 4-Lane) Intersection

Conditions

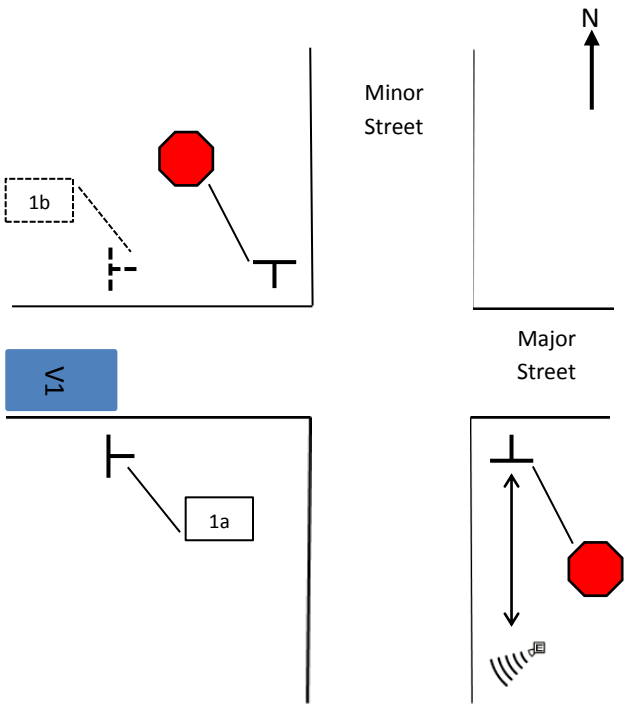
- Crash history exhibits a higher than expected rate and/or severity.
- Major street volume may range from 1,000-10,000 AADT based on systems reviewed.
- Systems are typically used to address conditions where sight distance and/or gap acceptance are poor.

Intended Driver Use

The system provides drivers on the major street with an additional warning of cross traffic presence. This may allow them to reduce speed or take defensive action.

Layout

Illustrations are not drawn to scale and are shown from the major street, eastbound vehicle (V1) perspective.



Detection placement may also be time (vs. distance) based depending on equipment selected and warning complexity.

Detection is typically placed 250-500' before intersection in conjunction with static STOP AHEAD warning signs and based on MUTCD Table 2C-4. Guidelines for Advance Placement of Warning Signs

Options

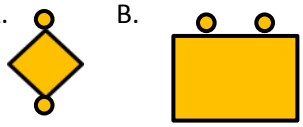
Placement

For a 2-lane major street, one sign may be placed on the right side (1a). For a 4-lane major street, an additional sign may be placed on the left side (1b).

Sign Combinations

Sign size should follow current standards in MUTCD Table 2C-2. Warning Sign and Plaque Sizes.

A. B.



Message Sets

A. VEHICLE ENTERING
B. WATCH FOR ENTERING TRAFFIC
C. CROSSING TRAFFIC

Messages may also be combined with WHEN FLASHING plaque.

Notes and References

Systems have been deployed in Minnesota, Missouri and North Carolina.

Additional information about Missouri and North Carolina systems available in FHWA-SA-11-15, "Stop-Controlled Intersection Safety: Through Route Activated Warning System."

ICWS 4: Major/Minor Street Alert for 2-Lane/2-Lane (or 4-Lane) Intersection

Conditions

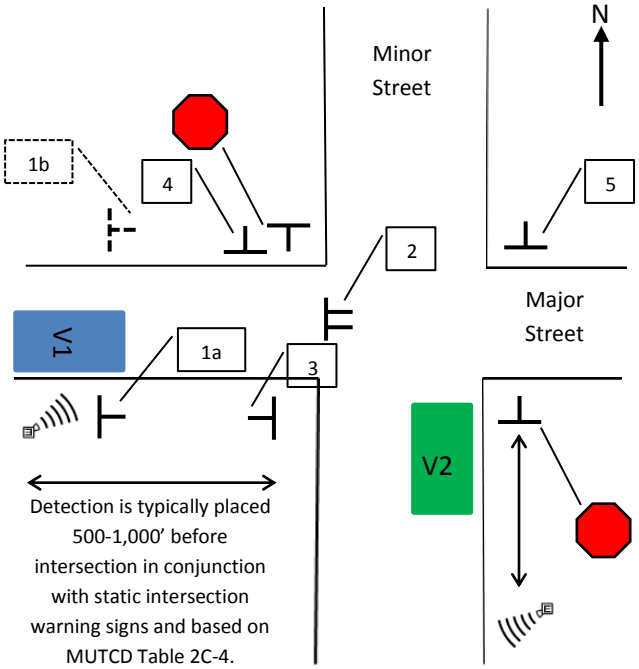
- Crash history exhibits a higher than expected rate and/or severity.
- Major road volume may range from 1,000-5,000 AADT based on systems reviewed.
- Systems are typically used to address conditions where sight distance and/or gap acceptance are poor.

Intended Driver Use

System provides drivers on the major street with additional warning of cross traffic presence. It also provides drivers on the minor street with a similar warning of vehicle presence on the major street. Combined, the system may allow major street drivers to take defensive action and provide minor street drivers with an indication of which direction and how quickly major street traffic is approaching.

Layout

Illustrations are not drawn to scale and are shown from both the major street, eastbound vehicle (V1) and the minor street, northbound vehicle (V2) perspectives.



Detection is typically placed 500-1,000' before intersection in conjunction with static intersection warning signs and based on MUTCD Table 2C-4. Guidelines for Advance Placement of Warning Signs

Detection placement may also be time (vs. distance) based depending on equipment selected and warning complexity.

Detection is typically placed 250-500' before intersection in conjunction with static STOP AHEAD warning signs and based on MUTCD Table 2C-4. Guidelines for Advance Placement of Warning Signs

Options

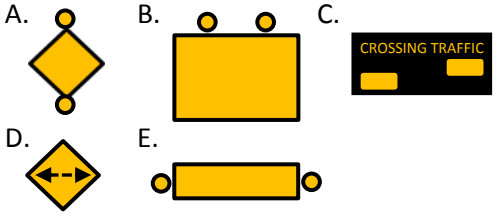
Placement

For a 2-lane *major* street, one sign may be placed on the right side (1a). For a 4-lane major street, an additional sign may be placed on the left side (1b). Signing may also be suspended above the major street (2).

Warning signs for the *minor* street may be placed left from STOP (3), on the far-side opposite corner (4) from STOP, or on the far-side corner (5) from STOP.

Sign Combinations

Sign size should follow current standards in MUTCD Table 2C-2. Warning Sign and Plaque Sizes.



Message Sets

A. VEHICLE ENTERING
B. WATCH FOR ENTERING TRAFFIC
C. CROSSING TRAFFIC
D. LOOK FOR TRAFFIC

Messages may also be combined with WHEN FLASHING plaque.

Notes and References

Systems have been deployed in Maine, Minnesota, Missouri, North Carolina and Pennsylvania.

Evaluation Guidance

THIS SECTION IS PROPOSED AND WILL BE USED FOR DISCUSSION AT SEPTEMBER 15-16 WORKSHOP.

Intersection conflict warning systems offer a substantial warning to drivers and are used to provide real-time, dynamic information about intersection conditions to support driver decision and, ultimately, reduce right angle crashes. Organizations have used a variety of approaches to evaluate the effectiveness of intersection conflict warning systems, including:

- Crash analysis. Simple before/after and long-term statistical analysis of crash history.
- Benefit cost analysis. Comparisons of the crash severity reduction benefit to the implementation/operational cost implications.
- Traffic conflict technique. Observation and measurement of traffic conflicts using rates (i.e., conflicts per 1,000 vehicles) or severity (i.e., time to collision). Higher severity scores are assigned to traffic conflicts with a low time to collision and a high risk of collision.
- Market research. Using a representative sample of road users to survey them about their perceptions of system attributes (i.e., understandability, effectiveness, etc.)
- Human factors research. Study of road user interaction with a system.

Not all organizations have formally evaluated the effectiveness of the systems deployed. The intent of this evaluation guidance is to establish a common framework that may be used to evaluate existing and future deployments of intersection conflict warning systems. Using this common evaluation framework will allow the agencies to pool and compare data from individual deployments to better understand the collective effectiveness of such systems and the potential for broader national deployment and crash reduction.

Evaluation Strategy

WHAT ARE THE MOST APPROPRIATE MEASURES OF EFFECTIVENESS? WHICH MEASURES WILL BE MOST VALUABLE FOR DETERMINING OVERALL SYSTEM EFFECTIVENESS AND FOR GUIDING THE DEVELOPMENT OF FORMAL STANDARDS?

- *Reduction in overall rate of crashes*
- *Reduction in rate of fatal crashes*
- *Reduction in rate of severe injury crashes*
- *Driver understanding/acceptance*
- *Benefit/cost*

Evaluation Plan

WHAT HYPOTHESES SHOULD BE TESTED? WHAT ARE THE BEST APPROACHES FOR TESTING THEM?

Hypothesis	*Evaluation Approach*
• *ICWS will reduce crashes by 25%*	*Crash analysis*
• *ICWS will save XX% in fatal injury costs*	*Crash analysis*
• *ICWS will reduce traffic conflicts by 25%*	*Traffic conflict technique*
•	
•	

Test Plan Parameters

WHAT TEST PLAN PARAMETERS SHOULD BE USED TO DESCRIBE HOW TESTS WILL BE CONDUCTED, RESOURCES NEEDED, PROCEDURES, SCHEDULE/TIMING, ETC?

Data Collection and Analysis

WHAT ORGANIZATION(S) WILL COLLECT AND ANALYZE DATA?

- National – ENTERPRISE, FHWA, University Centers
- State – Departments of Transportation, University Centers
- Local – Department of Transportation, University Centers

CONSIDER CRASH MITIGATION FACTOR CLEARINGHOUSE; AVAILABLE AT www.cmfclearinghouse.org; OFFERS TRANSPORTATION PROFESSIONALS A CENTRAL, WEB-BASED REPOSITORY OF CMFs AS WELL AS ADDITIONAL INFORMATION AND RESOURCES RELATED TO CMFs.

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