Concept of Operations for Intersection Conflict Warning Systems (ICWS)

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Project Champion

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1. Introduction

There are over four million miles of public road in the United States ("Highway Statistics 2009", 2012). Although intersections represent a small portion of those miles, a significant share of overall crashes and fatal crashes occurs at intersections each year. In 2009, 2,210,000 crashes occurred at intersections throughout the country. This is 40 percent of the 5,505,000 total crashes that occurred that year. Those same crashes represented over 46 percent (699,000) of the total injury crashes and approximately 22 percent (6,770) of the total fatal crashes that occurred in the same year. (NHTSA, 2011)

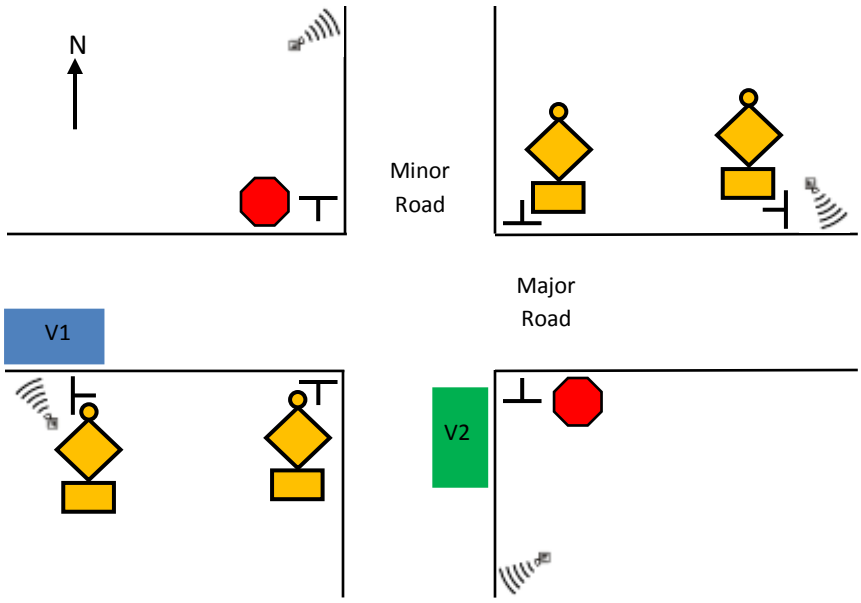
In 2010, the National Highway Traffic Safety Administration's National Center for Statistics and Analysis published a study that examined the general characteristics of crashes at intersections by analyzing the association of the critical reason for the crash with several crash factors. Using crash data between 2005 and 2007, the study reviewed 787,236 intersection-related crashes and found the critical reason cited for over 96 percent of those crashes was attributed to drivers. Of those crashes, 55.7 percent (438,194) represented drivers with recognition error (inattention, internal and external distractions, inadequate surveillance, etc.) and 29.2 percent (230,047) represented decision errors (too fast for conditions or aggressive driving, false assumption of other's actions, illegal maneuver, and misjudgment of gap or other's speed) (NHTSA, 2010).

Improving the design and operation of intersections is one of several focal points identified in the Strategic Highway Safety Plan published by the American Association of State Highway and Transportation Officials (AASHTO, 2005). One of the strategies cited in the plan calls for utilizing new technologies to improve intersection safety. Intersection conflict warning systems (ICWS) are an excellent example of how technology can be applied to address crash factors associated with driver inattention and gap selection at stop-controlled intersections in particular.

1.1 System Overview

Stop-controlled intersections often consist of a major road intersecting a minor road. The major road typically carries higher traffic volumes and the intersection approach is uncontrolled but may have advance warning signs. In comparison, the minor road usually carries lower traffic volumes and the approach is controlled by a stop sign. Traditional warning signs are used to call attention to unexpected conditions on or adjacent to a 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 (FHWA, 2009). ICWS offer a substantial warning to drivers as they provide real-time, dynamic information about intersection conditions to support driver decision and, ultimately, reduce intersections crashes. These systems address crashes at stop-controlled intersections by providing drivers – on major, minor or both roads – with a dynamic warning of other vehicles approaching the intersection. ICWS typically consist of static signing, detection and dynamic elements as illustrated in Figure 1.

Figure 1 Typical Intersection Conflict Warning System Concept



Over the past several years, a variety of major and minor road oriented ICWS have been developed and tested in many states across the country. There are over a dozen different systems that have been deployed at over 120 intersections throughout the United States. Some systems have been developed using local expertise, while others have been supported by the USDOT Cooperative Intersection Collision Avoidance Systems program. In February 2011, FHWA released a document summarizing the state of practice for through route (or major road) 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 road oriented systems.

In addition to major road oriented ICWS, there are several systems designed to provide alerts to the minor road driver. Most of these systems are primarily designed to address poor sight distance or gap acceptance by providing an alert about the presence of cross traffic. There are still others designed to reduce speed on the major road to minimize crash severity. In some locations, ICWS may also serve as a remedial step before or in place of traffic signals or geometric changes such as an interchange or roundabout. In 2011, the ENTERPRISE transportation pooled fund program completed the project, Developing Consistency in ITS Safety Solutions – Intersection Conflict Warning Systems. Bringing together organizations that have developed and deployed all types of ICWS, the project assembled design, construction and evaluation information from numerous transportation agencies to better understand what types of systems have been deployed and what may be known about their effectiveness. Design and Evaluation Guidance for Intersection Conflict Warning Systems was published by ENTERPRISE in December 2011 to offer insight on current practice among the agencies. The guidance presents typical system components, a glossary of terms and symbols, recommended layouts and evaluation guidance. It 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 Manual on Uniform Traffic Control Devices (MUCTD) and the Highway Safety Manual.

1.2 Stakeholders

The deployment and operation of ICWS will be driven by the needs of the stakeholder groups who will interact with them. Such needs have been identified for two primary groups – drivers and transportation agencies.

- ***Drivers*** of the major and minor roads at stop-controlled intersections equipped with ICWS; and
- ***Transportation agencies*** at the state, county and local level that will operate, maintain and own the ICWS.
- ***Industry*** who may design, manufacture and install ICWS for transportation agencies.
- ***Law enforcement*** who may observe operation of and driver compliance with ICWS.

As national groups like the National Committee on Uniform Traffic Control Devices consider the need for and content of ICWS standards, a concept of operations will clearly articulate the fundamental needs and concept of the systems. This concept of operations is intended to articulate the basic needs and operational concept surrounding ICWS. 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 ICWS. This document reflects stakeholder needs based on known practice nationally and should be adapted as necessary to reflect any unique or additional needs driven by individual deployments. The remainder of **this concept of operations documents the needs of the noted stakeholder groups, describes an operational concept from the stakeholder perspectives, outlines systems components and presents common operational scenarios for ICWS** that provide both major and minor road alerts.

2. Needs

This section presents system needs according to stakeholder groups. These needs will drive what the system must do and they will further define the system requirements for how ICWS must perform. Table 1 lists stakeholder needs that are identified by first describing a challenge facing one or more of the stakeholders (column 1). Then, based on each challenge, one or more needs (column 3) are described. Each need is also numbered (column 2) for identification and traceability purposes. The needs are referenced later in this document within in the operational concept and the list of proposed system components. The need identification allows each subsequent reference to be traced back to an original need and corresponding challenge.

Table 1 Stakeholder Needs for ICWS

Challenge	ID	Need
Major road drivers approaching an intersection may not see or be aware of vehicles at stop signs or yield signs on the minor road.	1	**Major road drivers** approaching an intersection equipped with ICWS **need an alert** to indicate when vehicles are approaching, at stop signs, or at yield signs on the minor road.

Challenge	ID	Need
Major road drivers approaching an intersection are typically traveling at higher speeds; limiting the physical space within which corrective action may be taken.	2	**Major road drivers** need ICWS **alerts to be visible at a distance** sufficient to allow drivers to take corrective action as needed.
Minor road drivers approaching, waiting at stop signs, or waiting at yield signs may not see vehicles on the major road.	3	**Minor road drivers** approaching, waiting at stop signs, or waiting at yield signs of an intersection equipped with ICWS **need an alert** to indicate when vehicles are approaching the intersection on the major road.
Minor road drivers waiting at stop signs or at yield signs may have difficulty judging when to enter the intersection.	4	**Minor road drivers** need ICWS **alerts to be visible** while they are waiting at the stop sign or at the yield sign to support their decision to enter or cross the major road.
Continuous alerts can diminish the credibility and value of a dynamic warning for drivers.	5	**Drivers, transportation agencies and law enforcement** need **alerts to be dynamic and not become nearly continuous** so as to lose impact.
Drivers could become confused by or misunderstand the message or intent of an alert.	6	**Drivers, transportation agencies and law enforcement** need ICWS **alerts to be easily understood**.
Drivers travel among the states and could become confused by or misunderstand the intent of an alert or signage.	7	**Drivers, transportation agencies, law enforcement and industry** need ICWS **alerts and signage to be uniform** throughout the United States, to the extent possible.
Drivers may not immediately notice the enhanced warning offered by ICWS as they approach or navigate through an intersection.	8	**Drivers** who are distracted need ICWS **alerts to be of a nature that will capture their attention**.
Driver compliance with regulatory signing must take precedence over advisory signing.	9	**Transportation agencies and law enforcement** need ICWS **alerts to provide supplemental warning** that does not contradict or override the regulatory signs at the intersection.
Drivers may become dependent upon signs to help them understand when it is inadvisable to enter the intersections.	10	**Drivers, transportation agencies and law enforcement** need ICWS to be **operational whenever vehicles approach the intersection**.
Drivers could be confused by alerts if their inactive (e.g. vehicle not detected) state is the same as their malfunctioning state.	11	**Drivers, transportation agencies, law enforcement and industry** need an ICWS **malfunction to be readily and easily differentiated** from an ICWS that is inactive due to lack of conflicting traffic.

Challenge	ID	Need
Driver views of the intersection, other vehicles and regulatory signs could be obstructed by additional signing.	12	**Drivers, transportation agencies and law enforcement** need ICWS **not to obstruct view** of intersection, other vehicles or regulatory signs.
In the event of a crash, drivers may collide with roadside equipment.	13	**Drivers, transportation agencies, law enforcement and industry** need ICWS **components to be crashworthy** in the event they are impacted by errant vehicles.
Transportation agencies are responsible for many traffic control devices and the addition of new devices requires maintenance information that allows them to set priorities for repairs.	14	**Transportation agencies** need a **maintenance process** that can be followed to repair or replace ICWS components in context with priorities for repairing all other traffic control devices.
	15	**Transportation agencies** need ICWS to **provide information regarding system performance**.
Transportation agencies may be unfamiliar with the industry installation, operational and maintenance requirements associated with ICWS.	16	**Transportation agencies and industry** need installation, operational and maintenance **documentation for ICWS.**
Transportation agencies and law enforcement aim to minimize traffic impacts during all maintenance and repair operations.	17	**Transportation agencies** need to be able to **maintain ICWS with minimal impact on traffic**.
Transportation agencies and law enforcement aim to minimize traffic impacts during maintenance and repair operations.	18	**Transportation agencies and law enforcement** need to be able to **manually activate the malfunction mode** in maintenance or repair situations.
Transportation agency operating budgets are continually reviewed and subject to reductions.	19	**Transportation agencies** need ICWS to be **cost effective**.
Transportation agencies must understand and be able to explain the safety effectiveness of ICWS to make deployment decisions, confirm effectiveness after deployment and gain public acceptance.	20	**Transportation agencies** need to **understand ICWS safety impacts** on total crash reduction, target (right angle) crash reduction and reduction in crash severity.

3. Operational Concept

The operational concept describes what is to be done and who will do it at intersections equipped with ICWS. The following concept describes a sequence of operational events and activities carried out by the each stakeholder group. The concept describes how stakeholders are expected to interact with ICWS

and references are made back to the initial stakeholder needs as a means of verifying that all needs have been anticipated.

3.1 Driver Perspective

3.1.1 **Major and minor road drivers will see an ICWS alert** as they approach the intersection. **(1) (3)**

3.1.2 If a vehicle is approaching, waiting at or entering the intersection from stop signs or yield signs on the minor road, **major road drivers will see or will have seen an ICWS alert indicating vehicles are present on the minor road**.**(1)**

3.1.3 If a vehicle is not approaching, waiting at or entering the intersection from stop signs or yield signs on the minor road, the **major road driver will see that the ICWS is not activated**. **(1)**

3.1.4 Regardless of the actions taken (e.g. decrease or maintain speed), **major road drivers will continue to see the ICWS alert as long as a vehicle is approaching, waiting at or entering** the intersection from stop signs or yield signs on the minor road. **(2)**

3.1.5 Major road drivers will **see an ICWS alert at a distance sufficient to allow them to take corrective action**. **(2)**

3.1.6 If a vehicle is approaching the intersection from any lane on the major road, **minor road drivers will see an ICWS alert indicating vehicles are present on the major road**. **(3)**

3.1.7 **Minor road drivers will continue to see the ICWS alert** as long as a vehicle is approaching the intersection from any lane on the major road. **(3)**

3.1.8 If a vehicle is not approaching the intersection from either direction on the major road, **minor road drivers will see that the ICWS is not activated**. **(3)**

3.1.9 Minor road drivers will **see an ICWS alert when they are waiting at stop signs or yield signs** to support their decision about when it is safe to enter or cross the major road. **(4)**

3.1.10 **Drivers will comply with all regulatory signs** (e.g. stopping at stop signs or yield signs) and will use the ICWS as additional information to assist their decision-making process. **(9)**

3.1.11 Drivers will not experience a situation where **ICWS alerts are displayed in a nearly continuous manner**. **(5)**

3.1.12 Drivers will **easily understand and recognize ICWS alerts** as supplemental warning information. **(6) (9)**

3.1.13 Drivers will see **uniform placement, sign combinations and message sets** in the ICWS alerts they encounter. **(7)**

3.1.14 Drivers will see **ICWS alerts that are conspicuous** enough to draw their attention, even if they are distracted. **(8)**

3.1.15 Drivers will see **operational ICWS whenever they approach** an intersection equipped with ICWS. **(10)**

3.1.16 Drivers will **understand when an ICWS is malfunctioning** by a visible indication that makes the ICWS appear different than when it is simply inactive from lack of traffic. **(11)**

3.1.17 Drivers will have an **unobstructed view of the intersection**, other vehicles, regulatory signs and ICWS. **(12)**

3.1.18 If a vehicle collides with an ICWS, damage will be minimized by the **crashworthiness of the ICWS**. **(13)**

3.2 Transportation Agency Perspective

3.2.1 Transportation agencies will not deploy ICWS where traffic volumes cause **alerts to be displayed in a nearly continuous manner**. **(5)**

3.2.2 **To facilitate driver recognition of ICWS as a warning device**, transportation agencies will deploy ICWS consistent with warning sign standards and guidance in the MUTCD. **(6)**

3.2.3 To support driver understanding of ICWS alerts across jurisdictions, transportation agencies will **deploy ICWS with uniform placement, sign combinations and alerts** throughout their jurisdiction. **(7)**

3.2.4 Transportation agencies will deploy ICWS consistent with warning sign standards and guidance in the MUTCD **to ensure that they do not contradict or override regulatory signs at the intersection**. **(9)**

3.2.5 Transportation agencies will strive to ensure ICWS operate continuously, all day, every day, year round with **minimal service interruptions**. **(10)**

3.2.6 When driving by an ICWS, transportation agencies will **clearly see when the ICWS is malfunctioning** by a visible indication that makes the ICWS appear different than when it is simply inactive from lack of traffic. **(11)**

3.2.7 Transportation agencies will locate **ICWS so that they do not obstruct** the intersection, other vehicles and other traffic control devices. **(12)**

3.2.8 Transportation agencies will see that **ICWS are crashworthy** in the event of a collision. **(13)**

3.2.9 Transportation agencies will be able to **adjust ICWS alert lag time parameters** to accommodate traffic volumes, speeds and intersection configurations when ICWS are installed and over the life of the installation as these parameters change. **(1) (3)**

3.2.10 Transportation agencies will have **training, spare parts and technical support available to support ICWS deployment, operation and maintenance** in context with priorities for repairing all other traffic control devices. **(14) (16)**

3.2.11 Transportation agencies will **understand ICWS performance** through records of system failure, activation and vehicle detection. **(15)**

3.2.12 Transportation agencies will **manage costs** through ICWS scalability and reconfiguration options to suit changing needs. **(19)**

3.2.13 Transportation agencies will maintain ICWS within public right of way and with **minimal impacts on traffic**. **(17)**

3.2.14 During maintenance or repair operations, transportation agencies can **manually activate the malfunction mode** to provide drivers with a clear indication the system is not working under normal conditions. **(18)**

3.2.15 Transportation agencies will able to **reference ICWS safety effectiveness** in determining their placement, confirming their effectiveness after deployment and gaining public acceptance. **(20)**

3.3 Industry Perspective

3.3.1 To support driver understanding of ICWS alerts across jurisdictions, industry will **design, manufacture and install ICWS with uniform placement, sign combinations and alerts** across multiple jurisdictions. **(7)**

3.3.2 When installing or responding to warranty repairs, industry will **clearly see when the ICWS is malfunctioning** by a visible indication that makes the ICWS appear different than when it is simply inactive from lack of traffic. **(11)**

3.3.3 Industry will design and manufacture **ICWS in accordance with industry standards for crashworthiness**. **(13)**

3.3.4 Industry will have **training, documentation and technical capability to support ICWS installation**. **(16)**

3.3.5 Industry will be able to **adjust ICWS alert lag time parameters** to accommodate traffic volumes, speeds and intersection configurations when ICWS are designed and installed. **(1) (3)**

3.4 Law Enforcement Perspective

3.4.1 Law enforcement will observe that ICWS **alerts are not displayed in a nearly continuous manner** that impacts driver compliance. **(5)**

3.4.2 To observe driver compliance with ICWS as a warning device, law enforcement will **observe ICWS operations in a manner consistent with warning sign standards and guidance** in the MUTCD. **(6)**

3.4.3 To observe driver understanding of ICWS alerts across jurisdictions, law enforcement will **observe uniform ICWS placement, sign combinations and alerts** throughout their jurisdiction. **(7)**

3.4.4 Law enforcement will observe ICWS operating in a manner consistent with warning sign standards and guidance in the MUTCD **to ensure that ICWS do not contradict or override regulatory signs at the intersection**. **(9)**

3.4.5 Law enforcement will observe ICWS operating continuously, all day, every day, year round with **minimal service interruptions**. **(10)**

3.4.6 When driving by an ICWS, law enforcement will **clearly see when the ICWS is malfunctioning** by a visible indication that makes the ICWS appear different than when it is simply inactive from lack of traffic. Malfunctions will be reported to the transportation agency. **(11)**

3.4.7 Law enforcement will observe that **ICWS do not obstruct** the intersection, other vehicles and regulatory signs. **(12)**

3.4.8 Law enforcement will see that **ICWS are crashworthy** in the event of a collision. **(13)**

3.4.9 During repair situations such as those that may follow a collision impacting ICWS, law enforcement can **manually activate the malfunction mode** to provide drivers with a clear indication the system is not working under normal conditions. **(18)**

4. System Components

Intersection conflict warning system components include all the physical parts of the system that, working together, create the complete system to provide major and/or minor road alerts to drivers. Following is an overview of typical system components for ICWS, depending on its level of sophistication.

- Detection: Used to detect vehicle presence and sometimes speed. Detection may include a range of technologies such as radar or inductive loops.
- Warning: Dynamically activated based on the presence of a vehicle, these components may consist of static signing, flashing beacons, dynamic message signs or illuminated static sign alerts.
- System Communication: This component manages communication used to transmit data among other components (e.g. detection and warning) and may include cellular, radio or other landline and wireless forms.
- Data Management: This component is used to store system performance data and may be accomplished with a variety of on/off-site databases or data storage devices.
- System Monitoring: System logical components may be used to operate, detect and report fluctuations in system performance.
- Power: Operation of the detection, warning and system communication require power and the most common sources are grid, battery and solar.

4.1 System Component Support and Responsible Parties

Each ICWS deployed will consist of the system components that address the needs identified in Section 2 and operational concept described in Section 3. Each component will require deployment, operations and maintenance activities to support their function. This section defines the deployment, operations and maintenance activities that transportation agencies or industry will be required to perform. It is important to note that some of these activities could be performed by one or multiple transportation agencies, particularly when a system is installed at the intersection of two roads with separate jurisdiction. Some activities could also be performed by industry depending on transportation agencies'

staff expertise and availability. For each support activity, references are made back to the operational concept and fundamental needs driving it.

Table 2 Activities Required for ICWS Components

Component	Support Required
Overall ICWS	Determine where ICWS should be installed based on traffic volumes, speeds and intersection design characteristics for maximum safety effectiveness. **(3.2.1) (3.2.12) (3.2.14) (3.3.5)**
	Design and deploy ICWS in accordance with relevant standards. **(3.2.2) (3.2.3) (3.2.4) (3.2.7) (3.2.8) (3.2.9) (3.3.1) (3.3.3)**
	Incorporate routine inspection and maintenance of ICWS into the agencies standard practices. **(3.2.5) (3.2.6) (3.2.10) (3.2.11)**
	Maintain ICWS on routine basis and as needed to repair malfunctions. **(3.2.10) (3.2.11) (3.2.13)**
Detection	Install detection equipment and connect to power. **(3.2.10) (3.3.4)**
	Install and integrate detection with system communication to connect detection to the warning, data management and system monitoring. **(3.2.10) (3.3.4)**
	Conduct periodic inspections to determine if detection is functioning properly. **(3.2.6) (3.2.10) (3.2.13)**
	If detection is not functioning, follow procedures to troubleshoot and restore functionality. **(3.2.6) (3.2.10) (3.2.13)**
Warning	Install warning equipment and connect to power and other ICWS components. **(3.2.10) (3.3.4)**
	Conduct periodic inspections to determine if warning is functioning properly. **(3.2.6) (3.2.10) (3.2.13)**
	If warning is not functioning, follow procedures to troubleshoot and restore functionality. **(3.2.6) (3.2.10) (3.2.13)**
System Communication	Install and connect system communication equipment with other ICWS components. **(3.2.10) (3.3.4)**
	Conduct periodic inspections to determine if communication is functioning properly. **(3.2.6) (3.2.10) (3.2.13)**
	If system communication is not functioning, follow of procedures to troubleshoot and restore functionality. **(3.2.6) (3.2.10) (3.2.13)**
Data Management	Install and connect data management equipment to other ICWS components. **(3.2.10) (3.3.4)**
	Periodically download data from storage device following procedures. **(3.2.10) (3.2.11) (3.2.13)**
	Conduct periodic inspections to determine if data management is functioning properly. **(3.2.10) (3.2.13)**
	If system communication is not functioning, follow of procedures to troubleshoot and restore functionality. **(3.2.10) (3.2.13)**
System Monitoring	Install system monitoring equipment and connect to other ICWS components. **(3.2.10) (3.3.4)**
	Conduct periodic inspections to determine if system monitoring is functioning properly. **(3.2.10) (3.2.13)**

Component	Support Required
	If system monitoring is not functioning, follow procedures to troubleshoot and restore functionality. **(3.2.10) (3.2.13)**
Power	If AC power is desired and is not at selected site, arrange power installation with termination at a location close enough to the intersection to operate ICWS. **(3.2.10) (3.3.4)**
	Connect ICWS components to power supply following the rules and procedures of the local power company. **(3.2.10) (3.3.4)**
	If solar or other auxiliary power is specified, install equipment and connect to other ICWS components. **(3.2.10) (3.3.4)**
	If commercial AC power supply is not functioning (power outage), contact the power company to report the failure and arrange for restoration. **(3.2.6) (3.2.10) (3.2.13)**
	Maintain an account with AC power supply company for continuous service, including paying all power bills. **(3.2.10)**

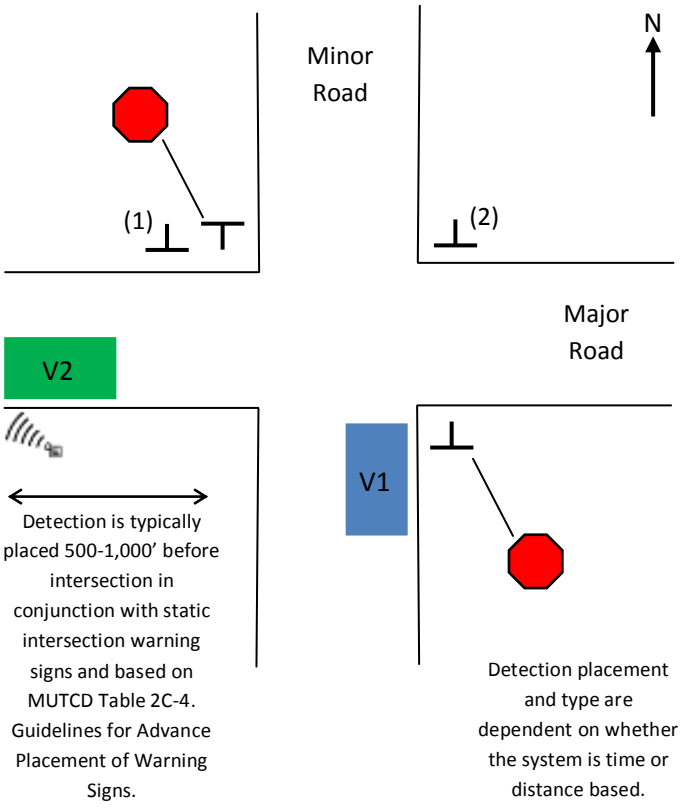
5. Operational Scenarios

The operational scenarios presented on the following pages describe some of the most common situations that will require activation of an ICWS, identifying such things as detection, actions and response of the stakeholders.

5.1 Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection

As the minor road driver (V1) approaches the intersection they will see the STOP and corresponding ICWS. If the ICWS detects a vehicle on the major road (V2), the system will display a dynamic warning to alert the minor road driver that a vehicle is approaching the intersection on the major road. The alert may also indicate the direction of travel for the approaching major road vehicle. The alert will remain active as long as vehicles are detected on the major road, indicating that it may be inadvisable for the minor road driver to proceed. The minor road driver will watch the ICWS, in conjunction with approaching vehicles and other traffic control devices, to determine when it is safe to navigate the intersection. As illustrated in Figure 2, warning signs may be placed on the far-side opposite corner (1) from STOP or far-side corner (2) from STOP. A third placement – suspended above the minor road in the intersection – has been used but has since been found ineffective through a safety effectiveness evaluation conducted by the North Carolina Department of Transportation.

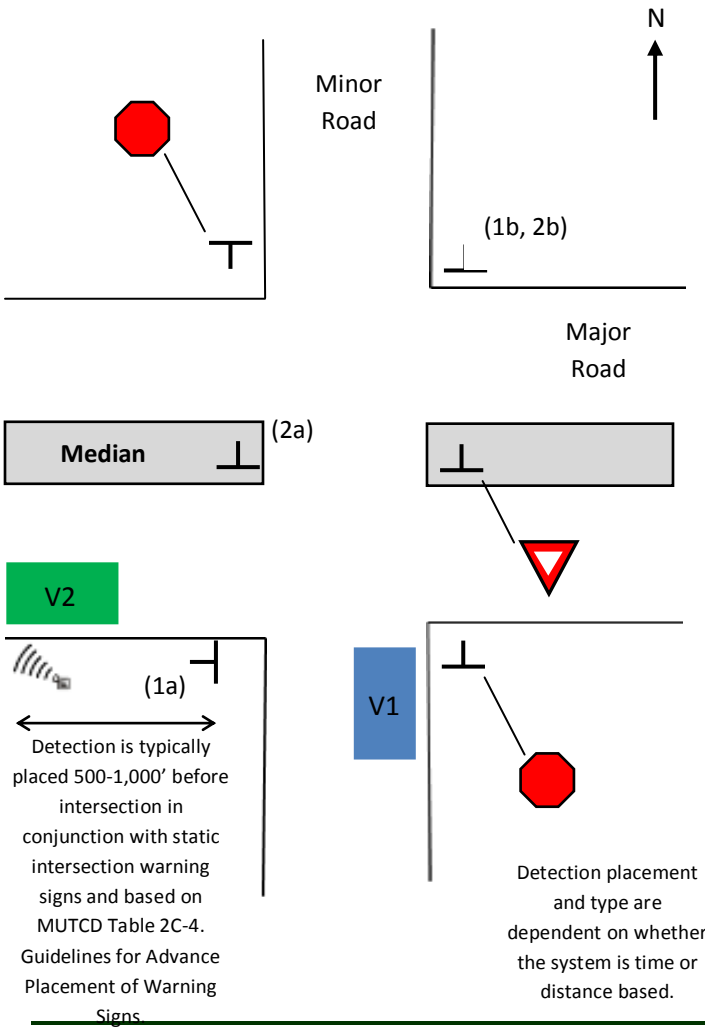
Figure 2 Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection



5.2 Minor Road Alert for 2-Lane/Multi-Lane Median Separated Intersection

As the minor road driver (V1) approaches the intersection they will see a near-side STOP and corresponding ICWS. If the ICWS detects a vehicle in the near-side lanes of the major road (V2), the system will display a dynamic warning to alert the minor road driver that a vehicle is approaching the intersection in the near-side lanes of the major road. Once the minor road driver has crossed the near-side lanes of the major road, they may see a median YIELD and they will see the far-side STOP and corresponding ICWS. Again, if the ICWS detects a vehicle in the far-side lanes of the major road, the system will display a dynamic warning to alert the minor road driver that a vehicle is approaching the intersection in the far-side lanes of the major road. The alerts may also indicate the direction of travel for approaching major road vehicles. The alerts will remain active as long as vehicles are detected on the major road, indicating that it may be inadvisable for the minor road driver to proceed. The minor road driver will watch the ICWS, in conjunction with approaching vehicles and other traffic control devices, to determine when it is safe to navigate the intersection. As illustrated in Figure 3, there is a set of two warning signs for this intersection configuration. The first sign may be placed left from STOP (1a) or on the far-side opposite corner from STOP within the median (2a). The second sign may be placed on the far side corner from YIELD (1b, 2b). Signing has also been suspended above the minor road in the intersection but has since been found ineffective through a safety effectiveness evaluation conducted by the North Carolina Department of Transportation.

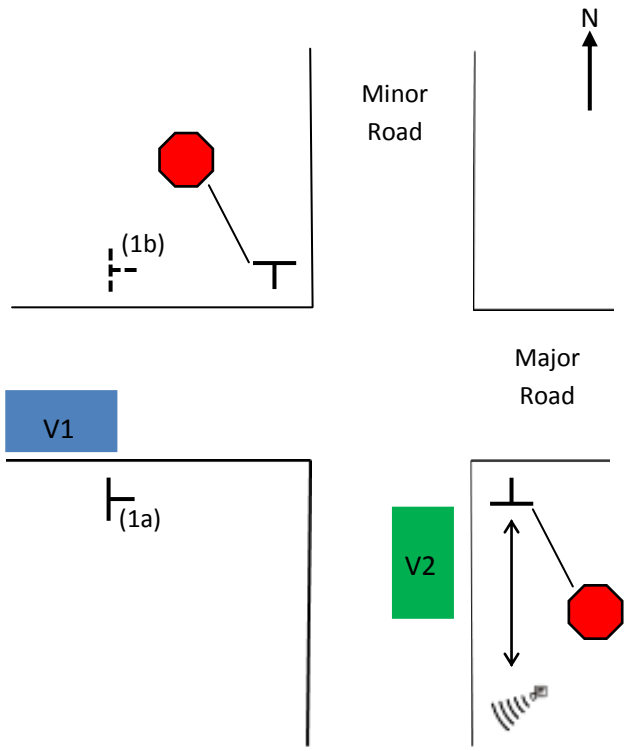
Figure 3 Minor Road Alert for 2-Lane/Multi-Lane Median Separated Intersection



5.3 Major Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection

As the major road driver (V1) approaches the intersection they will see a corresponding ICWS. If the ICWS detects a vehicle on the minor road (V2), the major road driver will see or will have seen a dynamic warning to alert them that a vehicle is approaching the intersection or waiting at the STOP (or median YIELD) on the minor road. The alert may also indicate the direction of travel for the approaching minor road vehicle. The alert will remain active as long as vehicles are detected on the minor road, indicating a supplemental warning for the major road driver to be aware. The major road driver will watch the ICWS, in conjunction with traffic and other traffic control devices, to determine if evasive action may be needed. As illustrated in Figure 4, for a 2-lane major road, one sign may be placed on the right side (1a). For a multi-lane major road, an additional sign may be placed on the left side (1b). Signing has also been suspended above the major road in the intersection but has since been found ineffective through a safety effectiveness evaluation conducted by the North Carolina Department of Transportation.

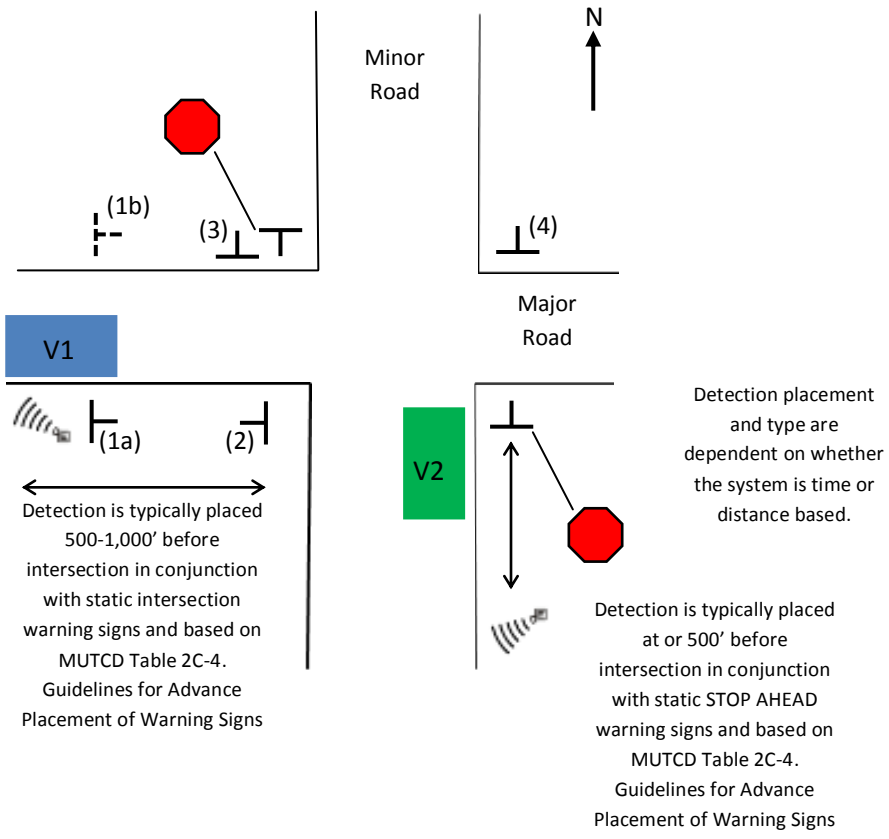
Figure 4 Major Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection



5.4 Major and Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection

Two alerts are delivered simultaneously in this ICWS configuration. As the major road driver (V1) approaches the intersection they will see a corresponding ICWS. If the ICWS detects a vehicle on the minor road (V2), the major road driver will see or will have seen a dynamic warning to alert them that a vehicle is approaching the intersection or waiting at the STOP (or median YIELD) on the minor road. Simultaneously, as the minor road driver approaches the intersection they will see the STOP and corresponding ICWS. If the ICWS detects a vehicle on the major road, the system will display a dynamic warning to alert the minor road driver that a vehicle is approaching the intersection on the major road. Both the major and minor road alerts may also indicate the direction of travel for the approaching vehicle. The alerts will remain active as long as vehicles are detected on the opposing roads. The major road driver will watch the ICWS, in conjunction with traffic and other traffic control devices, to determine if evasive action may be needed. At the same time, the minor road driver will watch the ICWS, in conjunction with approaching vehicles and other traffic control devices, to determine when it may be safe to navigate the intersection. As illustrated in Figure 5, for a 2-lane major road, one sign may be placed on the right side (1a). For a multi-lane major road, an additional sign may be placed on the left side (1b). Warning signs for the minor road may be placed left from STOP (2), on the far-side opposite corner (3) from STOP, OR on the far-side corner (4) from STOP. Signing has also been suspended above the in the intersection but has since been found ineffective through a safety effectiveness evaluation conducted by the North Carolina Department of Transportation.

Figure 5 Major and Minor Road Alert for 2-Lane/2-Lane (or Multi-Lane) Intersection



References

AASHTO. (2005). *AASHTO Strategic Highway Safety Plan.* Washington DC: American Association of State Highway and Transportation Officials. Retrieved from http://safety.transportation.org/doc/Safety-StrategicHighwaySafetyPlan.pdf

FHWA. (2009). *Manual on Uniform Traffic Control Devices.* Washington DC: Federal Highway Administration.

NHTSA. (2010). *Crash Factors in Intersection-Related Crashes: An On-Scene Perspective.* National Center for Statistics and Analysis. Washington DC: National Highway Traffic Safety Administration. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/811366.pdf

NHTSA. (2011). *Traffic Safety Facts 2009.* Washington DC: National Highway Traffic Safety Administration. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/811402.pdf

USDOT. (2009). *Highway Statistics 2009; Table HM-10 Public Road Length 2009 Miles by Ownership*. Retrieved August 10, 2012, from Federal Highway Administration: http://www.fhwa.dot.gov/policyinformation/statistics/2009/hm10.cfm