Crashes at rural thru-Stop intersections arise primarily from a driver, after stopping, attempting to either cross or enter the mainline traffic stream after failing to recognize an unsafe gap condition. The driver proceeds into the approaching traffic, and is hit by a vehicle travelling at high speed. Unfortunately, because of the high speeds involved, these crashes often produce serious injuries or fatalities.

Because the primary cause of these crashes is not failure to stop, but failure to recognize an unsafe condition, the United States Department of Transportation Federal Highway Administration (US DOT FHWA), the Minnesota Department of Transportation (Mn/DOT) and the University of Minnesota Intelligent Transportation Systems ITS Institute initiated three programs designed to address crashes at thru-Stop rural intersections:

The **Intersection Decision Support (IDS)** program developed an analysis technique to determine which rural thru-Stop intersections are most at risk, developed an intersection surveillance system, which would determine the dynamic “state” of the intersection, including identifying and tracking gaps on the major road, and developed infrastructure-based dynamic signs designed to alert and warn drivers of dangerous conditions.

The **Pooled Fund Study TPF-5(086)**, “Reducing Crashes at Rural Intersections: Toward a Multi-State Consensus on Rural Intersection Decision Support” program developed a mobile intersection surveillance system which was used to collect driver gap acceptance and rejection data at problematic intersections in seven different states throughout the United States.

The **Cooperative Intersection Collision Avoidance System – Stop Sign Assist (CICAS-SSA)** analyzed the driver gap acceptance and rejection data from the Pooled fund study, and implemented the alert and warning timing at actual experimental intersections sites. The system used sensing technology, a computer processor and algorithms to determine unsafe conditions, and a driver interface to provide timely alerts and warnings, which were designed to reduce the frequency of crashes at rural expressway intersections.

Gap rejection behavior was addressed from the macroscopic point of view. Conditions examined include effects due to maneuver type, time of day, average length of gap available to a waiting driver, time spent waiting for an acceptable gap, departure zone, and vehicle classification.
Three important findings arose from the state pooled fund macroscopic study. First, drivers are consistent in gap rejection behavior, both in terms of geographic location and in terms of conditions associated with those gap rejection decisions.

Second, drivers do not appear to change their gap acceptance behavior in response to the time that drivers are required to wait for an acceptable gap. This indicates that if the alert and warning timing is on the conservative side (i.e., warnings provided earlier to give drivers more time to comprehend the sign and react accordingly), the frustration level of the driver is unlikely to increase to the point where the alerts and warnings are no longer obeyed.

Third, and most surprising, is the finding that gap rejection is essentially independent of vehicle classification (i.e., size). The prevalent hypothesis prior to this analysis was that drivers of heavy and/or large vehicles will exhibit a higher gap rejection threshold when compared to drivers of lighter, faster vehicles because of the additional time required by heavy and long vehicles to clear an intersection. However, this hypothesis was found to be incorrect; drivers of heavy trucks reject gaps in a manner very consistent with drivers of smaller, faster vehicles. This finding has significant impact on the costs to deploy CICAS-SSA systems: the expensive vehicle classification equipment used on the minor road approaches is likely unnecessary.

We in particular call your attention to the report, “Macroscopic Review of Driver Gap Acceptance and Rejection Behavior at Rural Thru-Stop Intersections in the U.S. – Data Collection Results in Eight States: CICAS-SSA Report #3” which analyzed driver behavior at Median-Separated Expressway intersections, Median-Separated Expressway “T” Intersections, Two Lane Rural Thru-Stop intersections and Four lane, non-median separated intersections w/left turn lanes in eight states.

Because of the consistency of gap rejection behavior between conditions and between states, the use of a standard alert and warning timing was feasible. Alerts were determined to be required in the 7.5-to-11 second gap/lag range; Alerts turn to warnings at the 7.5-second epoch.

A three-year Field Operational Test was conducted at three sites (US52 and Goodhue CSAH9, US169 and Mille Lacs CSAH11, and MN23 and Lyon CSAH7) during which time the CICAS-SSA system was activated using the above timing thresholds. The limited time period of the study and the number of sites was not sufficient to provide a statistically significant change in crash behavior at these sites. However, the Mn/DOT sponsored Rural Intersection Collision Warning System (RICWS) that is being deployed at approximately 50

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sites across the state uses similar timing thresholds (warning duration can be adjusted between 4 and 9 seconds with most sites using a 6.5 second warning duration), and could yield more statistically relevant data on the effectiveness of a CICAS-SSA system, or what might be better characterized as a Stop Sign Gap Assist (SSGA) system as defined by the Connected Vehicles Reference Implementation Architecture (CIVRIA).²

Additionally, a connected Vehicle To Infrastructure (V2I) application was developed and tested at the US169 site. The Road Side Equipment (RSE) implemented the GID and SpaT messages (using SAE J2735), and could broadcast this information to vehicles approaching on the minor road. The connected minor road vehicle would process this information and provide relevant in-vehicle alerts and warnings to the driver via a smartphone connected to the DSRC radio mounted in the vehicle.

At the completion of this project, the CICAS-SSA systems were removed from all three sites. The US169 and MN23 sites will have the lower cost RICWS systems installed in their place, while the US52 CSAH9 intersection in Goodhue County was replaced by a grade separated overpass in 2014.

![TH52/CASH9 quadrant interchange in Goodhue County completed in 2014](image)

Updates on the deployment of RICWS can be found at:
[http://www.dot.state.mn.us/trafficeng/signals/conflictwarning.html](http://www.dot.state.mn.us/trafficeng/signals/conflictwarning.html)

² [http://www.iteris.com/cvria/html/applications/app70.html#tab-3](http://www.iteris.com/cvria/html/applications/app70.html#tab-3)