



Executive Summary

In Minnesota, 70 percent of all intersection-related fatal crashes for the period of 2006 to 2008 occurred at rural, through/stop intersections [1]. The Minnesota Department of Transportation identified improving the design and operation of intersections as a critical emphasis area in the Minnesota Comprehensive Highway Safety Plan [2]. At these intersections, sight restrictions caused by vertical and horizontal curves negatively affect a driver's ability to safely accept a gap in the traffic stream.

This report presents the results of a two-year study on the development and evaluation of a new intersection warning system referred to as an Advanced Light-Emitting Diode (LED) Warning System (ALWS). The ALWS was developed to replace the static warning signs that are commonly used to address the sight restrictions at rural through/stop intersections, which have been shown to be ineffective [3-5]. The ALWS consists of vehicle detectors that detect approaching or stopped vehicles and LED warning signs that blink according to the received messages from the detectors. For easy installation, all signs and detectors are powered by solar panels and rechargeable batteries. All message communications between the detectors and warning signs are performed through wireless transceivers. Wireless communication avoids potential problems associated with buried wires, i.e., wire breakages, short circuits, difficulty of replacement, and monthly power bills.

In order to evaluate this new sign technology, the intersection of West Tischer Road and Eagle Lake Road in Duluth, Minnesota was chosen. West Tischer Road is the main road with a through condition while Eagle Lake Road is the minor road with a stop condition. The Annual Average Daily Traffic (AADT) for West Tischer Road is 980 vehicles per day. The AADT for Eagle Lake Road is 550 vehicles per day. The number of daily entering vehicles is 760 vehicles per day [6]. This intersection was selected because of a severe vertical curve on the east approach of West Tischer Road. This vertical curve significantly reduces the available intersection sight distance for vehicles stopped on either the north or south approaches of Eagle Lake Road thereby requiring these vehicles to blindly accept gaps in the westbound traffic stream. Conversely, vehicles traveling westbound on West Tischer Road cannot see cross traffic at the intersection until they are nearly in the intersection.

The ALWS for this intersection consists of three blinker signs and four vehicle detectors. The blinker sign for the main approach displays the message “CROSS TRAFFIC WHEN FLASHING” for westbound traffic. There are two radar detectors on Eagle Lake Road installed on the top of the stop signs. These detectors detect vehicles stopped at the stop signs. When a vehicle is detected at either stop sign, a wireless signal is transmitted to the blinker sign and it flashes. The blinker signs for the minor approaches displays the message “VEHICLE APPROACHING WHEN FLASHING” for northbound or southbound traffic. These signs were installed on the northeast and southwest quadrants of the intersection. Two Passive Infrared (PIR) detectors are located on West Tischer Road. One detector is located east of the intersection and detects vehicles traveling westbound on West Tischer Road. The other detector is located west of the intersection and detects vehicles traveling eastbound on West Tischer Road. When a vehicle is detected by either PIR sensor, a wireless signal is transmitted to both blinker signs and they flash. These blinker signs provide an advanced warning to vehicles stopped at either stop sign that a vehicle is approaching the intersection from the east or west on West Tischer Road. Video data was collected through an on-site video monitoring system consisting of a digital video recorder (DVR) and two video cameras. The first camera records video of vehicles traveling toward the intersection through the vertical curve. The second camera records vehicles traveling through the intersection. Video data collection occurred in two phases: before (Phase I) and after (Phase II) the installation of the ALWS. Phase I data was collected for a time period of 48 days and Phase II data for 204 days. Speed markers were painted on the roadway to measure the speed of vehicles with 1 mph accuracy. Analysis of the video data before and after the installation of the ALWS included vehicle speeds on the main approach, intersection wait time, and intersection roll-throughs. In addition to the analysis of the video data, mail-in and on-site surveys were conducted. The findings based on the video data analysis are summarized below:

- The average vehicle speed on the main approach decreased during the nighttime after installation of the ALWS while no changes were observed during the daytime.
- When a vehicle enters the intersection from the minor approach, the average speed on the main approach decreased after installation of the ALWS.
- The average intersection wait time from the minor approach was significantly increased (5.4 seconds) when the warning signs were flashing.
- Number of intersection roll-throughs decreased to zero when the warning signs on the minor approaches were flashing.
- Number of intersection roll-throughs increased when the warning signs in the minor approach were not flashing.

Overall, the ALWS was effective at reducing vehicle speeds on the main approach, and increasing the wait time and altogether stopping roll-throughs for vehicles on the minor approaches when a conflict exists at the intersection. However, an increase in roll-throughs when no conflict exists at the intersection is a concern that must be addressed in the future design of the ALWS. According to the mail-in and on-site survey results, 86 percent of respondents believed that the warning system is effective. However, they also raised a concern that the drivers might start ignoring the stop signs and/or not look for oncoming traffic, thus completely relying on the warning signs. This is a cause for concern if the electronics in the warning system fail. If these concerns are addressed, the researchers believe that the ALWS can be an effective system for reducing crashes in rural stop/through intersections.