2019-34TS
Published August 2019

LOCAL ROAD RESEARCH BOARD

TECHNICAL SUMMARY

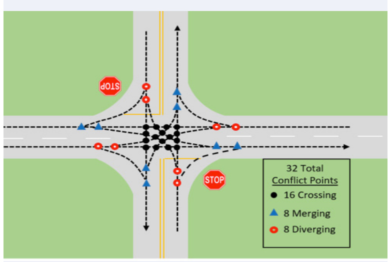
Optimal Sight Distances at Rural Intersections

Questions?
Contact research.dot@state.mn.us.

Technical Liaison:
Tracey von Bargen, MnDOT
Tracey.VonBargen@co.grant.mn.us

Principal Investigator:
Nichole Morris,
University of Minnesota

LRRB PROJECT COST:
$170,549



A typical four-leg, two-lane undivided rural intersection has 32 total conflict points.

DEPARTMENT OF TRANSPORTATION
OFFICE OF RESEARCH & INNOVATION

Using a state-of-the-art driving simulator, researchers investigated drivers' ability to judge traffic speed and gaps between cars at unsignalized intersections with varying sight distances. Researchers showed that 1,000 feet of sight distance allows drivers to make better crossing decisions.

What Was the Need?

Four-way intersections, though common and familiar to drivers, carry inherent safety risks. From 2008 to 2012, nearly 42 percent of severe crashes occurring at Minnesota intersections resulted in serious injuries and fatalities, making it an acute concern for Minnesota cities and counties.

Crashes are often more severe at unsignalized rural intersections. Drivers on minor roads seeking to cross must determine when traffic gaps are sufficient to cross and can misjudge the time to collision (TTC). Limited visibility has been associated with drivers choosing insufficient gaps and with increased stop violations.

The Local Road Research Board sought to learn the upper and lower limits of optimal sight distances at rural intersections that could maximize driver safety and behavior around rural thru-stop intersections to reduce injury and fatal crashes.

What Was Our Goal?

The project's goal was to determine the optimal sight distances at four-way intersections to promote drivers' best judgment of traffic gaps and other decisions. Beyond improved safety, optimal sight distances would reduce unnecessary clearing of trees and brush at intersections.

What Did We Do?

Researchers from the University of Minnesota HumanFIRST Laboratory conducted the investigation using a state-of-the-art driving simulator from Realtime Technologies. Consisting of a 2013 Ford Fusion cab with realistic controls and the latest generation simulation software and projection hardware, the driving simulator can generate complex environments that engage the driver's senses, creating a realistic simulated experience.

Initially, researchers conducted a literature search of studies addressing factors that cause drivers at four-way intersections to make faulty judgments, with a focus on sight distances.

Researchers developed nine simulations of existing Minnesota rural roads, incorporating wooded areas and shoulders, to examine drivers' TTC judgments for crossing. They also developed a 19-mile main line segment with 18 minor thru-stops for a rural highway intersection study.

Road simulations were rigorously tested for validity. State, county and research engineers familiar with the intersections operated the simulators and evaluated the sight estimation, representativeness rating and realism of driving the main line.

Thirty-six drivers participated in the simulator driving trials. For the TTC trial, participants waited at nine simulated intersections with varying sight distances (400, 600 or 1,000 feet) and varying speeds of oncoming vehicles (55, 65 or 75 mph). Traffic gaps varied from 3 to 12 seconds; head movements were recorded. Participants pressed the

continued

“We’ve known that sight distances were factors in rural intersection crashes. This study gave us the hard data showing how long sight distances should actually be to allow drivers sufficient time and space at rural thru-stop intersections.”

—Tracey von Bargen,
County Engineer,
Grant County

“The findings of our study may help engineers make more informed decisions about clearing trees and brush at rural intersections to improve safety by reducing the mental workload of drivers.”

—Nichole Morris,
Director, University of Minnesota HumanFIRST Laboratory

Produced by CTC & Associates for:
Minnesota Department of Transportation
Office of Research & Innovation
MS 330, First Floor
395 John Ireland Blvd.
St. Paul, MN 55155-1899
651-366-3780
www.mndot.gov/research

This view of the driving simulator shows the Ford Fusion cab facing one of the intersection creations used in the study.

gas pedal when they determined they could safely cross. For the thru-stop trial, participants drove the 19-mile main line road simulation and were presented with cars at minor road thru-stops with variable sight distances; the cars either stopped or intruded into the intersection.

After the trials, participants completed the Rating Scale Mental Effort, measuring perceived cognitive demand of the crossings.

What Did We Learn?

The literature search showed that data about drivers’ ability to judge the TTC of oncoming traffic were not definitive. Drivers under- and overestimated TTC in ways that could not be generalized to optimal sight distances.

Simulator road scenarios were improved greatly through engineers’ validity testing. Researchers adjusted the scenarios based on engineers’ test drives, ratings and comments; as a result, simulations were consistently judged as very realistic, which strongly supports the use of simulators in future studies.

The TTC and main line road simulator trials showed that 400- and 600-foot sight distances are insufficient for drivers to make good crossing decisions. The 1,000-foot sight distance and slower speeds (55 mph) allowed drivers to judge TTC more effectively, and when they drove the main line, allowed them to respond to cars at minor leg thru-stops intruding into the main line. That is, drivers could effectively respond to a car running a stop sign—often a catastrophic crash scenario. The Rating Scale Mental Effort showed drivers perceived sight distances of 400 and 600 feet as more risky, difficult and anxiety-producing.

Finally, when drivers noticed a thru-stop car closer to the intersection, they reduced speed more than for a car farther back. Thus, moving the stop bar on minor roads closer to the intersection could both increase the sight distance of the waiting driver and slow driver speeds on the main line, an inexpensive change with potentially significant benefits.

What’s Next?

Robust validation of the simulator opens its use for future studies. Agencies could use the 1,000-foot sight distance finding as a guide now or await future field studies. Because study participants were an average of 27 years old, future projects could investigate teen and over-65 drivers’ behavior. Effects of obscuring weather, skewed geometries or night driving could also be studied.

This Technical Summary pertains to Report 2019-34, “Examining Optimal Sight Distances at Rural Intersections,” published July 2019. The full report can be accessed at mndot.gov/research/reports/2019/201934.pdf.