Cooperative Intersection Collision Avoidance System: Stop Sign Assist - Field Operational Test

Mn/DOT and ITS Institute, University of Minnesota
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Intersection Crashes

- Represents 40% of all 5.811 million police reported crashes.
- In the US, 7,421 of 34,017 (22%) of fatal crashes were intersection related:
  - 34% occurred at signalized intersections
  - 66% occurred at unsignalized intersections (stop sign, no controls, other sign)

NHTSA, Traffic Safety Facts 2008 Table 29 Chapter 2
## Minnesota Fatal Crashes: Rural Intersections

### Fatal Crashes

<table>
<thead>
<tr>
<th>Fatal Crashes</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural (R), Non-Signalized (NS), Intersection-Related (IR)</td>
<td>118</td>
<td>127</td>
<td>98</td>
<td>96</td>
<td>117</td>
<td>93</td>
</tr>
<tr>
<td>All Fatal Crashes</td>
<td>583</td>
<td>520</td>
<td>500</td>
<td>456</td>
<td>463</td>
<td>420</td>
</tr>
<tr>
<td>R, NS, IR as % of All Fatal Crashes</td>
<td>20%</td>
<td>24%</td>
<td>20%</td>
<td>21%</td>
<td>25%</td>
<td>22%</td>
</tr>
</tbody>
</table>

### Fatal Crashes (Rural as % of Total)

<table>
<thead>
<tr>
<th>Fatal Crashes</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>401</td>
<td>366</td>
<td>349</td>
<td>308</td>
<td>326</td>
<td>283</td>
</tr>
<tr>
<td>Total</td>
<td>583</td>
<td>520</td>
<td>500</td>
<td>456</td>
<td>463</td>
<td>420</td>
</tr>
<tr>
<td>Rural as % of Total</td>
<td>69%</td>
<td>70%</td>
<td>70%</td>
<td>68%</td>
<td>70%</td>
<td>67%</td>
</tr>
</tbody>
</table>
Intersection Crashes: Driver Error

- In study of over 100 straight crossing path crashes at thru-STOP intersections, Chovan et al. (1994) found that the primary causal factors for drivers that stopped before entering the intersection was:
  - Driver looked but did not see other vehicle (62.1%)
  - Driver misjudged the gap (lag) size or velocity of approaching vehicles (19.6%),
  - Driver had obstructed view (14.0%), or
  - Roads were ice-covered (4.4%)
- Of these 4 driver error types, the first 3 can be described as either problems with gap (lag) detection or selection.
Focus on Driver Error Causal Factors

- Deploy where the fatalities/crashes warrant deployment
- Assist driver with *judging gap intervals, clearance and timing*
- Reduce rural expressway intersection crashes *without adversely affecting mainline traffic flow*
- Develop solution to rural intersection crash problem
  - Traditional traffic engineering countermeasures have proven ineffective
  - Stop sign recognition/violation is typically **NOT** the problem
- **Prohibitive frame:** Provide information regarding *unsafe* lags.
- **Cost:** Same order of magnitude as rural *signalized* intersection
Gap vs. Lag

Definition from:
Harwood, D.W., Mason, J.M., Brydia, R.E., Pietrucha, M.T., Gittings, G.L.
“Intersection Sight Distance”
Intersection gap, lead, lag, left gap, and right gap definitions

“A”

“B”

“C”

“D”
1st Test Intersection: MnDOT District 6
US52 & CSAH9, Goodhue County, MN

Sensors (1st gen) installed in Summer, 2004

Over 3 year period (2006-8), there were 23 crashes (14 rt angle) which included: 2 fatal, 3 Type A, 6 Type B crashes
Sensors (for measuring gaps and lags)

Power, Communication, Local Processor

Radar Sensor
Mainline Sensor Performance

◆ 2200 feet of coverage
◆ Individual sensor detection rate: 99.998%
  (Multiple sensors drive this higher)
◆ Longitudinal lane position error
  – Mean: -10 ft. Standard deviation of 8.9 ft
◆ Lateral lane position error:
  – Mean: -0.4 feet. Standard deviation: 2.5 ft (only lane assignment ambiguity during lane changes)
◆ Speed estimation error
  – Standard deviation: 0.73 MPH
Other sensors used in experiments

Pan-tilt Cameras for Crossroad Surveillance

Used for Vehicle Classification

LIDAR

Used for Crossroad Surveillance
Pooled Fund Study: Evaluated Driver Gap Behavior

• Goals:
  – Characterize rural intersection crashes across U.S.
  – Identify regional differences in driver gap decision-making behavior
  – Use information to design nationally deployable system

• Key Results:
  – Data collected in pooled fund partner states showed that driver behavior is similar.
  – Data substantiated claim that a Stop Sign Assist system could work throughout the U.S.
Final sensor-driven active LED “icon” based SSA sign

Alert!

Warning!!
Initial warning time selected based on Safety Margin - Definitions
Warning time adjusted based on Validation Pilot Study

- Instrumented vehicle & intersection:
  - Behavior & location of participant driver
  - Approaching traffic location & speed

- Completed in early 2009
  - Car drivers, equal number of:
    • Young (19-26 yrs)
    • Middle (35-50 yrs)
    • Older (60-72 yrs)
  - Heavy truck drivers (Mn/DOT & Goodhue County)

- All drivers experience sign on & off
  - Right, left, & crossing maneuvers
  - Gap safety margins, movement time, & rejected gaps
  - Eye glance behavior towards sign & traffic
  - Subjective measures from random gap simulation study
View of the installed near-side sign
Mainline traffic approaching from the left is at least 7 secs (“warning”),
but less than 11 secs away (“alert”).
Mainline traffic approaching from the right is less than 7 secs away.
Radar Sensors

Original experiments:
Eaton EVT-300
- Range: 350ft
- FOV: 11°
- Track up to 8 vehicles
- Range rate accuracy: 1% ± 0.2 mph

Deployed in FOT:
Delphi ESR
- Range: 575 ft
- FOV: 20°
- Track up to 64 vehicles
- Range rate accuracy: ±0.27 mph
Redesigned system for FOT:
“Minimal” sensor suite
- Main line (“Expressway”)

◆ Originally 1800 ft of coverage upstream of intersection (6 radar, each direction)
  ❖ 300 ft coverage/unit

◆ New design: 1500 ft of coverage (3 radar), of which 1200 ft is upstream of intersection.
  ❖ 500 ft coverage/unit
Stop Sign Assist requires NO sensors on minor leg. For analysis/eval, FOT uses additional instrumentation as follows:

- **US52 & Cty9 (8mi S of Cannon Falls)**
  - Vehicle position at stop bar determined from 2 Ibeo Lux lidar units. Vehicle position in median determined from Ibeo Alasca lidar.

- **US53 & Cty77 (Minong, WI)**
  - Timing (to determine when vehicle leaves the stop bar) from Banner adjustable field radar sensor (R-Gage) used as presence detector (1 each at 4 stop bars; there is a stop bar in median – deeper than other intersections)

- **MN23 & Cty7 (Marshal, MN)**
  - RFID reader to determine when instrumented vehicles approach intersection for additional planned experiments

- **US169 & Cty11 (Milaca, MN)**: No additional sensors
SSA deployed at 2nd intersection as part of successful WisDOT RSIP proposal

US53 and County Hwy 77, Minong, WI
Radar Sensors

Radar Sensor Field Of View

Mainline Vehicles

Vehicle waiting to enter traffic stream

Vehicle waiting at the crossroad

Minor road

Lidar Sensor for Vehicle Position and Length Measurement

Lidar Sensor for Vehicle Height Measurement

Original sensor layout at Minong (during pooled fund study)
3 Year Field Operational Test Began January 20, 2010

- Sensors were upgraded and SSA turned on for all at US52 & Cty9 intersection.
- SSA at Minong, WI intersection turned on: April, 2010.
- Two additional MN intersections will be instrumented & SSA turned on: Fall, 2010.
- 30 instrumented cars (from population that uses intersection) will be used to determine effect of SSA on driver behavior (1 year) at Marshall, MN location.
- In next phase, the roadside unit at US52&Cty9 will wirelessly communicate to test vehicles; a DVI will be designed and tested (IntelliDrive)
MN Intersection #2 for SSA deployment

MNTH 23 & CSAH 7, Lyon County (just outside Marshall, MN)  
MnDOT District 8

Over 3 year period (2006-8), there were 14 crashes (8 rt angle) which included: 1 fatal, 1 Type A, 4 Type B crashes
MN Intersection #3 for SSA deployment

USTH 169 & CSAH 11, Mille Lacs County (4mi N of Milaca, MN)
MnDOT District 3

Over 3 year period (2006-8), there were 21 crashes (15 rt angle) which included: 1 fatal, 0 Type A, 6 Type B crashes
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Live view of intersection at US52 & Goodhue Cty9:
  http://idsweb.me.umn.edu/minnesota/