Outline

Problem
- Rural stop-controlled intersections

Human Factors
- Driver Tasks
- Driver Errors
- High-risk drivers

IDS Design Concepts
- Preliminary Evaluation
- Simulator evaluation

Conclusions
Rural Stop-Controlled Intersections
The Problem

Rural Crashes More Severe

- 70% of All Crashes are Urban
- 70% of Fatal Crashes are Rural
- 25% of Fatal Crashes at Intersections
Assessing the Human Factors of Intersection Negotiation

Task analysis
- What do drivers do at rural stop-controlled intersections?

Driver errors
- What errors do drivers make at rural stop-controlled intersections?
- Which errors lead to crashes (particularly serious crashes)?

Which drivers are at the highest risk?
Tasks

A. Detect intersection
B. Decelerate
C. Enter correct lane (if required)
D. Signal if intending to turn
E. Detect traffic control device
F. Interpret traffic control device
G. Monitor lead vehicle (if present)
H. Detect approaching vehicles and gaps
I. Perceive gaps
J. Accept gap
K. Complete Maneuver
Errors Leading to Serious Crashes

A. Failure to detect intersection
E. Failure to detect traffic control device
H. Failure to detect approaching vehicles and gaps
I. Failure to perceive gaps
J. Failure to accept gaps appropriately
Common Driver Errors

In Minnesota, most drivers stop before proceeding (Preston & Storm, 2003)

- 57% stopped in 2296 rural thru-STOP accidents
- 87% of right angle crashes at US 52 and CSAH 9 occurred after the driver stopped (test site)
Errors Reflected in Crash Data

H. Failure to detect approaching vehicles and gaps
I. Failure to perceive gaps
J. Failure to accept gaps appropriately
Older Drivers & Intersections

Over-represented in all intersection crashes

Gap perception
- Difficulty determining speed and location of oncoming vehicles
- Vision decrements, especially at night

Reaction time
- Safety margin decreases the longer it takes to begin movement into intersection

Decision making
- Working memory deficits
- Impatience
- Inattention
Intersection Decision Support

Goal

- To prevent serious crashes at intersections due to problems with detecting, perceiving and accepting (judging) gaps using an infrastructure-based solution.
## IDS Primary Information Requirements

<table>
<thead>
<tr>
<th>Task</th>
<th>Info Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. Detect approaching vehicles &amp; gaps</td>
<td>H1. Presence of major road vehicles</td>
</tr>
<tr>
<td></td>
<td>H2. Presence of gaps</td>
</tr>
<tr>
<td>I. Perceive gaps</td>
<td>I1. Speed, distance, &amp; arrival time of major road vehicles</td>
</tr>
<tr>
<td></td>
<td>I2. Size of available gaps</td>
</tr>
<tr>
<td></td>
<td>I3. Monitor changes in gap size</td>
</tr>
<tr>
<td>J. Accept gap</td>
<td>J1. Evaluate whether gap is acceptable</td>
</tr>
<tr>
<td></td>
<td>J2. Determine when to initiate maneuver</td>
</tr>
</tbody>
</table>
Additional Issues

- Must be technically feasible
- Must use a prohibitive framework
  - i.e., convey when it is not safe to go
- Assumes the minor-road driver stops
- Apply to all stop-controlled intersections, regardless of specific geometry
- Gaps are calculated from the minor-road driver to the next closest vehicle on the road
Preliminary Evaluation

Involved subject matter experts from various DOTs and traffic engineers

Presented with nine design concepts

- A dynamic sign at the intersection best suited the goal of deployment at multiple sites

3 preliminary designs were re-designed and a 4th created
IDS system can inform, warn or advise drivers about gaps.
What is a safe gap?

Many factors determine gap safety
- e.g., driver’s age, number of lanes, maneuver type, road conditions, size of driver’s vehicle/approaching vehicle

As a non-cooperative system, these sign concepts do not have a “preview” of all these factors

System must therefore make assumptions about the driver

Sign concepts account for worst-case scenario
- Left turns + older drivers
Minimum Safe Gaps for Design

2-stage crossing strategy
- Driver stops in median

1-stage crossing strategy
- Driver does not stop in median

System accounts for worst-case scenario of an older driver making a left turn.

Information Content

Inform → Warn → Advise
Hazard Sign (1 stage)

12.5 s
7.5 s
12.5 s
7.5 s
12.5 s
7.5 s
12.5 s
7.5 s
12.5 s
7.5 s
Countdown Sign (1 then 2 stage)

12.5 s

7.5 s

12.5 s

7.5 s

12.5 s

7.5 s

12.5 s

7.5 s
Icon Sign (1 then 2 stage)

- 7.5 s
- 12.5 s
- 7.5 s
- 12.5 s
- 7.5 s
- 12.5 s
- 7.5 s
- 12.5 s
Map Sign (1 and 2 stage)

12.5 s  7.5 s
8.0 s  12.5 s
7.5 s  7.5 s
12.5 s  7.5 s
8.0 s  12.5 s
7.5 s  7.5 s
8.0 s  12.5 s
12.5 s  7.5 s
8.0 s  8.0 s
12.5 s  12.5 s
8.0 s  8.0 s
12.5 s  12.5 s
8.0 s  12.5 s
12.5 s  12.5 s
8.0 s  8.0 s
12.5 s  12.5 s
8.0 s  8.0 s
12.5 s  12.5 s
Concept Evaluation

What function is effective?
- Warn
- Inform
- Advise

What level of complexity can drivers handle?
- Single piece of information
- Multiple pieces of information
Virtual Environment for Surface Transportation Research

- 8 channels
- 3D surround sound
- Car body vibration
- Force feedback steering
- Power-assist feel on the brakes
- 3-axis electric motion system

- Ability to model precise reproductions of geo-specific locations
- Resolution = 2.5 arc-minutes per pixel
Methods

- Exact simulation of actual test site
- 5 sign conditions
  - Within-subjects
- 2 age groups
  - 24 young; 24 old
- 2 light conditions
  - Day vs. night
- 12 participants per group/condition

Include nighttime: (1) high risk factor, (2) impoverished environment, (3) suboptimal viewing conditions.
Driver Tasks

- Drive 2 trials for each sign concept
- Straight crossing path (not worse case)
- Drive as they normally would and...
  - Look at the sign and see if they comprehend it
  - Use it if they think it is useful
- Random order of sign presentation
- One gap pattern
  - Examine 2 and 1 stage crossings
  - Force “waiting”
  - Determine acceptable gap threshold
Accepted Gap (near side)

Size of gap driver accepted (as defined in traffic model)
## Compliance (near side)

Percentage of participants relative to 7.5 s safe gap.

<table>
<thead>
<tr>
<th></th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 7.5 s</td>
<td>&gt; 7.5 s</td>
</tr>
<tr>
<td>Baseline</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Hazard</td>
<td>91.67</td>
<td>8.33</td>
</tr>
<tr>
<td>Map</td>
<td>79.17</td>
<td>20.83</td>
</tr>
<tr>
<td>Countdown</td>
<td>91.67</td>
<td>8.33</td>
</tr>
<tr>
<td>Icon</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>
Did you use information provided by the sign to help make your crossing decision?

<table>
<thead>
<tr>
<th>Percent answering</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young</td>
<td>Old</td>
</tr>
<tr>
<td>Hazard</td>
<td>41%</td>
<td>58%</td>
</tr>
<tr>
<td>Map</td>
<td>58%</td>
<td>25%</td>
</tr>
<tr>
<td>Count-down</td>
<td>67%</td>
<td>50%</td>
</tr>
<tr>
<td>Icon</td>
<td>58%</td>
<td>25%</td>
</tr>
</tbody>
</table>
Initial Time-to-Collision (near side)

Time to oncoming vehicle when driver begins crossing maneuver
Safety Margin (near side)

Time to oncoming vehicle when driver is in middle of southbound lanes (maximum exposure)
# Collisions – Night Only

<table>
<thead>
<tr>
<th>Sign Condition</th>
<th>Young</th>
<th>Old*</th>
<th>Young</th>
<th>Old*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hazard</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Map*</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Countdown</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Icon</td>
<td>1</td>
<td>2 (0)</td>
<td>0</td>
<td>4 (3)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4</td>
<td>5 (3)</td>
<td>2</td>
<td>11 (10)</td>
</tr>
</tbody>
</table>

* 4 of 7 crashes occurred on first trial.

+ 7 of 16 old crashes with two drivers.
Performance Summary

Compared to baseline, which concept is effective?

Baseline vs. Warn

Baseline vs. Inform / Advise

Conclusion: Informing function more effective (and higher compliance 🌟).
Performance Summary

What level of information complexity can be communicated effectively?

Similar result
- Countdown preferred and used more often for decision-making.

Largest gap with most complexity
- Possibly due in part to time taken to interpret sign. However, largest gaps were observed for drivers who were not confused.

Conclusion: Complex information can be effective.
Summary

All sign concepts resulted in safer gap performance
  - However, threshold was perceived as too conservative (not individuated)

Compliance with sign advice increased with perceived task difficulty
  - i.e., old drivers in night condition

Dynamic aspects of signs aided with comprehension process (Map and Countdown)
  - Opportunity to learn / associate sign features with information in context

Some “education” is probably necessary to support comprehension and acceptance.
Conclusion

Explore format (MUTCD and MnDOT compliance), for most preferred sign concepts.

- Retain inform, warn, advise
- Support 1 and 2 stage

![Traffic signs](images/traffic_signs.png)
These numbers count down time until northbound traffic will cross the intersection. When t<7, the background turns from black to red (advisory to warning).

Graphic presents general information:

- Caution
- Do Not Enter
- No Left Turn
- No Crossing Maneuver