Analysis of the SHRP 2 Naturalistic Driving Study Data:
Evaluation of Offset Left-Turn Lanes
Project Team

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Research Objectives

Answer the following questions:

– Do offset left-turn lanes affect turn behavior and gap acceptance?

– What effect does the presence of a vehicle in the opposing left-turn lane have?

Can we answer these questions effectively and efficiently using the NDS data?
Where Our Study Fits Into Project S08

• Studies should address one of the three components of roadway safety
  1. **Driver behavior**
  2. Vehicle design and operation
  3. **Roadway infrastructure design and operations**

• Studies should fall into one of the four priority areas
  1. Roadway departure
  2. **Intersection crashes**
  3. **Driver characteristics, behavior and performance**
  4. Driver interaction with advanced technology

8.5% of all traffic fatalities involve left-turn collisions

-FARS 2009
What is an Offset Left-Turn Lane?

- Positive Offset
- No Offset
- Negative Offset
Left-Turn Lanes and Sight Distance
Detecting Intersections and Left-Turn Maneuvers of Interest

• Use left-turn movements to find intersections
  – Use of left-turn signal
  – Speed data
  – GPS data

• Follow up with Google Earth or other mapping software
  – Is the intersection signalized?
  – Does the intersection have left-turn lanes?
  – What is the offset of the left-turn lanes?
## Data Needs for Site Selection

<table>
<thead>
<tr>
<th>In-Vehicle DAS</th>
<th>Airphotos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude, longitude</td>
<td>Intersection configuration</td>
</tr>
<tr>
<td></td>
<td>(number of legs, number of lanes, turn lanes, medians, etc.)</td>
</tr>
<tr>
<td>Left-turn signal indication</td>
<td>Offset between opposing left-turn lanes</td>
</tr>
<tr>
<td>Yaw angle</td>
<td>Intersection traffic control</td>
</tr>
<tr>
<td>Forward and lateral acceleration and speed</td>
<td>(signal or STOP sign, signal phasing)</td>
</tr>
</tbody>
</table>
Data Needs for Gap Acceptance Analysis

<table>
<thead>
<tr>
<th>Data Element</th>
<th>Data Stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Videos showing intersection movements with time stamp to obtain:</td>
<td>Extracts from DAS forward view and rear view imagery plus related in-vehicle DAS data</td>
</tr>
<tr>
<td>- time left-turning vehicle becomes first in queue at stop line</td>
<td></td>
</tr>
<tr>
<td>- presence of opposing left-turn vehicle</td>
<td></td>
</tr>
<tr>
<td>- time left-turning vehicle began turning maneuver</td>
<td></td>
</tr>
<tr>
<td>- time each opposing through vehicle reached the intersection</td>
<td></td>
</tr>
<tr>
<td>Latitude, longitude</td>
<td>In-vehicle DAS</td>
</tr>
<tr>
<td>Yaw angle</td>
<td>In-vehicle DAS</td>
</tr>
<tr>
<td>Forward and lateral acceleration and speed</td>
<td>In-vehicle DAS</td>
</tr>
<tr>
<td>Acceleration pedal inputs</td>
<td>In-vehicle DAS</td>
</tr>
<tr>
<td>Brake pedal inputs</td>
<td>In-vehicle DAS</td>
</tr>
<tr>
<td>Brake light indication</td>
<td>In-vehicle DAS</td>
</tr>
<tr>
<td>Left-turn signal indication</td>
<td>In-vehicle DAS</td>
</tr>
<tr>
<td>Vehicle type of subject vehicle</td>
<td>Driver questionnaire</td>
</tr>
<tr>
<td>Vehicle type of opposing left-turn vehicle (if present)</td>
<td>DAS forward view video</td>
</tr>
</tbody>
</table>
Data Elements
Camera Views of Left-Turning Vehicles
Automating Data Capture

• Identifying left-turn maneuvers (vehicle data)
• Capturing the time of specific events (video data)
  – Left-turning vehicle reaching stop bar
  – Left-turning vehicle initiating turn
  – Left-turning vehicle passing through center of intersection
  – Opposing through vehicle passing through center of intersection
Surrogate Safety Measures

• Gap acceptance will be used as a surrogate for crash risk
  – For accepted gaps, crash risk is represented by the duration of the accepted lag
  – For rejected gaps, crash risk is represented by the duration of the rejected gap
  – For left-turners that arrive at the intersection or become first in queue in the middle of a gap, the lag is the remaining gap time
Data Analysis Approach

• Gap acceptance analysis
  – Estimate the effect of left-turn offset distance on drivers’ gap acceptance/rejection behavior

• Measures of crash risk/driver risk taking:
  – Critical gaps, $t_c$ or $t_{50}$
  – Percentage of drivers accepting lags of specific durations less than $t_c$ or $t_{50}$
  – Rate of occurrence of erratic maneuvers during left turns
Logistic Regression Analysis for Gap Acceptance

• Develop a logit model

\[
\text{logit}(P) = \ln \left( \frac{P}{1 - P} \right) = \beta_0 + \beta_1 X + \beta_i I_i + \text{fct}(\text{Intersection, Driver, } X)
\]

- \( P \) = probability of accepting gap of length \( X \)
- \( I_i \) = indicator variable for the categorical **offset** parameter
  → based on categories of left-turn lane offset distances
- \( \beta_i \) = offset regression coefficients
- \( \text{fct}(\text{Intersection, Driver, } X) \) = function of intersection, driver, gap length (\( X \)), and their interaction, whose coefficients will be estimated
Regression Analysis Objective

• Does the left-turn lane offset have an overall significant effect on the probability of gap acceptance?
  – If yes, then compare the various offset categories to each other by estimating odds ratios
Logistic Regression Inference

• Estimate odds ratios, and show, for example, that:
  – The odds of a driver accepting a gap of a specific length at an intersection with an offset in the range of +6 ft is $x$ times as high as that of accepting that same gap at an intersection with a -6 ft offset
Estimate Effect of Offset on Rate of Erratic Maneuvers

• Statistical approach is similar to that for previous gap acceptance analysis with two exceptions:
  – Only look a those drivers who accepted a gap
  – Dependent variable = Yes/No whether drivers made erratic maneuver
Estimate Effect of Presence of Opposing Left-Turners on Gap Acceptance Behavior

• Statistical approach is similar to that for previous gap acceptance analysis with one exception:
  – Include an additional factor to the logit model that indicates the presence/absence of vehicles in the opposing left-turn lane

• Consider the interaction of that factor with offset

• Test whether the effect of presence of vehicles in opposing left-turn lane on gap acceptance behavior varies by offset distances
Limitations

• Are there enough intersections of interest with a variety of left-turn offsets?
• Are there enough recorded left-turn maneuvers at these intersections?
• Will we have enough independent observations (i.e., not the same vehicle going through the same intersection each day)?
• Can we capture left-turn movements made by non-instrumented vehicles when the opposing through vehicle is instrumented?
Project Outcomes

• Phase 1--Preliminary Proof-of-Concept Analysis
  – Familiarity with NDS data
  – Method for identifying intersections and maneuvers of interest
  – Methods for automating data reduction
  – Statistical methods for evaluating gap acceptance behavior
  – Work Plan for Phase 2

• Phase 2--Full Analysis
  – Answers to research questions
  – Recommendations for left-turn design guidance