A STUDY OF LOCAL GAP ACCEPTANCE BEHAVIOR USING DRONE VIDEOGRAPHY

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June 29, 2020
About Me

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Education
B.S. Civil Engineering (2011; University of Wyoming)
M.S. Civil Engineering (2013; University of Wyoming)

Experience
HDR Inc. (2013 - 2015)
DOWL (2015 - 2016)
City of Laramie (2016 - Present)

Licenses
Professional Engineer (2016)
Introduction

- On-street parking around TWSC intersections is a common safety concern in Laramie.
- A typical sight triangle analysis in Laramie can remove three to five spots on each corner of the intersection.
  - Removing parking produces negative feedback from local residents and business owners who rely on public parking.
How can we minimize the impact of sight triangles on local on-street parking while maintaining a safe and efficient intersection?

Three factors that contribute to sight triangle dimensions:
- Vehicle speed on the major leg
- Location of stopped vehicle on the minor leg
- **Gap acceptance of the stopped vehicle on the minor leg**

![Diagram showing sight triangles and decision points](image)

**Table 9.7: Design Intersection Sight Distance—Case B1, Left Turn from Stop**

<table>
<thead>
<tr>
<th>U.S. Customary</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Speed (mph)</strong></td>
<td><strong>Stopping Sight Distance (ft)</strong></td>
</tr>
<tr>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>25</td>
<td>40</td>
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<td>30</td>
<td>50</td>
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<td>35</td>
<td>60</td>
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<td>45</td>
<td>80</td>
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<td>55</td>
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<td>60</td>
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<td>75</td>
<td>140</td>
</tr>
<tr>
<td>80</td>
<td>150</td>
</tr>
</tbody>
</table>

*Note: Intersection sight distance shown is for a stopped passenger car to turn left onto a two-lane highway with no median and grades 3 percent or less. For other conditions, the time gap should be adjusted and the sight distance recalculated.*
NCHRP Report 383 Intersection Sight Distance

- Acceleration-Deceleration ISD Model (Green Book pre-1996)
- Gap Acceptance Model
  - Proposed by report for future sight distance calculations
  - Easier calculation

\[ ISD = 1.47 \times V \times G \]

- Two methods to determine critical gap “G”
  - Raff Method
  - Logistic Regression
Raff Method

- Comparing the cumulative distribution of accepted gaps and rejected gaps.
- The critical gap is considered the point where the two graphs intersect.

The Raff Method for Right Turning Vehicles (Harwood, Mason, Brydia, Pietrucha, & Gittings, 1996)
Logistic Regression Method

A logistic regression equation is created from the “accept” and reject”

\[
\ln \left( \frac{p}{1 - p} \right) = -4.75 + 0.730X
\]

The critical gap is measured at 50% probability of gap acceptance.
Laramie Study Intersections

1) 4th Street and Clark Street
2) 9th Street and Spring Creek Drive
3) 17th Street and Spring Creek Drive
4) 22nd Street and Reynolds Street
5) 22nd Street and Sheridan Street
Drone Video Collection

DJI Phantom 4 Pro

- 1080p and 60 frames per second.
- 10 to 15 minute battery life.
- Advantages: Inconspicuous and easy to measure gap acceptance.
- Disadvantages: Continuous video collection limitations and constant pilot observation.

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Dates</th>
<th>Recording Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th Street and Clark Street</td>
<td>4/16/2019; 10/21/2019</td>
<td>1 Hour 16 Minutes</td>
</tr>
<tr>
<td>9th Street and Spring Creek Drive</td>
<td>10/24/2019</td>
<td>1 Hour 8 Minutes</td>
</tr>
<tr>
<td>17th Street and Spring Creek Drive</td>
<td>11/13/2019; 11/15/2019</td>
<td>1 Hour 7 Minutes</td>
</tr>
<tr>
<td>22nd Street and Reynolds Street</td>
<td>10/25/2019</td>
<td>1 Hour 26 Minutes</td>
</tr>
<tr>
<td>22nd Street and Sheridan Street</td>
<td>11/4/2019; 11/5/2019</td>
<td>1 Hour 36 Minutes</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>6 Hours 33 Minutes</strong></td>
</tr>
</tbody>
</table>
Video Analysis

- Four types of gaps measured (gap accept, gap reject, lag accept, lag reject)
- Time stamps recorded when a minor street vehicle approaches the stop sign
Raff Method Results

Left Turn from Stop

Right Turn from Stop

Crossing from Stop

$t_c = 7.7 \text{ s}$

$t_c = 7.3 \text{ s}$

$t_c = 7.5 \text{ s}$
Raff Method Results

![Graph showing cumulative percent of gaps accepted and rejected over gap time (s). The graph indicates that at a gap time of 7.7 s, there is a significant drop in the cumulative percent of gaps accepted, with a corresponding increase in the cumulative percent of gaps rejected.](image)
Logistic Regression Method Results

Left Turn from Stop

\[ \ln \left( \frac{P}{1-P} \right) = -5.9590 + 0.8537X \]

Crossing from Stop

\[ \ln \left( \frac{P}{1-P} \right) = -6.3969 + 0.8645X \]

Right Turn from Stop

\[ \ln \left( \frac{P}{1-P} \right) = -4.4070 + 0.62484X \]
Results

- Typical left turning vehicle gap acceptance for Laramie closely matches Green Book Recommendations.

- Typical right turning gap acceptance for Laramie is 0.6 seconds longer than Green Book recommendations.

- Although it is important to take note of it, crossing sight distance is not as critical for intersection sight distance.
  - Green Book 7th Edition: “The departure sight triangles for left and right turns onto the major road...will also provide adequate sight distance for minor road vehicles to cross the major road”

<table>
<thead>
<tr>
<th></th>
<th>Green Book 7th Edition (s)</th>
<th>Raff Method Laramie (s)</th>
<th>Logistic Regression Laramie (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Turn</td>
<td>7.5</td>
<td>7.7</td>
<td>7.3</td>
</tr>
<tr>
<td>Crossing</td>
<td>6.5</td>
<td>7.5</td>
<td>7.4</td>
</tr>
<tr>
<td>Right Turn</td>
<td>6.5</td>
<td>7.3</td>
<td>7.1</td>
</tr>
</tbody>
</table>
Applying Observed Gap Acceptance
Conclusion

- Using a drone to collect intersection data is a great way to discreetly observe driver behavior, although the man hours requirement and battery life restrictions are limiting.

- The City engineering division will continue to use the Green Book recommendations with added confidence that the amount of parking removed is at a minimum while still maintaining the national standard for safe and efficient two-way stop-controlled intersection.
Thank You!

References