Safety Study of I-35W Improvements
Done Under Minnesota’s Urban Partnership Agreements (UPA) Project

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Outline

• Introduction
• Study Objective
• Preliminary Analysis
• Data Preparation
• Statistical Analysis
• Conclusions
Introduction

Minnesota’s UPA Project

• Scope: I-35W corridor

• Time: May 2009-November 201

• Major Improvements:
  - High-Occupancy Toll (HOT) Lane
  - Crosstown Commons Reconstruction
  - Priced Dynamic Shoulder Lane (PDSL)
Introduction

MnDOT Problem Statement NS-329:

Interest in extending interventions to other corridors

Estimation of their safety effects is needed!
Introduction

Example: PDSL Region

Table  PDSL Section Changes Before vs. After UPA Project

<table>
<thead>
<tr>
<th></th>
<th>2006-2008 (Before UPA Project)</th>
<th>2011-2013 (After UPA Project)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Lanes</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Number of Rear-end Crashes</td>
<td>151</td>
<td>389</td>
</tr>
</tbody>
</table>

An increase in crash frequencies have been observed in PDSL region, but is it due to *UPA intervention* or increased *traffic congestion* resulting from the removal of TH-62 I-35W bottleneck?
Research Objective

**Objective:**

To untangle the indirect safety effects due to changes in traffic conditions from the direct effects, if any, due to the UPA improvements.
Research Objective

Objective (more specific):

Estimate change in crash risk:

- In different sections of I-35W
- Controlling for
  - Changes in traffic conditions
  - Weather
Preliminary Analysis

• I-35W from start to I-94 divided into 17 1-mile sections
• Crash data
  ➢ Before period: 2006-2008
  ➢ After period: 2011-2013
  ➢ Source: Minnesota Crash Mapping Analysis Tool (MNCMAT)
• Crash frequencies tabulated by crash type for each section
Preliminary Analysis

Most frequent crash type: Rear-end (Priority)

Crash Codes
1 - Rear end
2 - Sideswipe same
3 - Left turn
4 - Run off left
5 - Right angle
6 - Right turn
7 - Run off right
8 - Head on
9 - Sideswipe opposing

Mile-17

Crash frequency
Crash Code
0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
2  0  220 160 44 53 38 79 7 3 0 0 15 39 1 1 1 0 2425 5 4 0 0

Before
After
Preliminary Analysis

Before and After Rear-end Crash Frequencies

Analysis Regions: HOT & PDSL Region
Data Preparation

PDSL Region: 3 Analysis Sections
Data Preparation

Crash Data
B/A UPA rear-end crashes

- Source:
  - MNCMAT
  - DOT/OTS Accident Report

- Checked for:
  - Crash type accuracy
  - Time accuracy
  - Location accuracy
Data Preparation

Traffic Conditions

30-second Loop Detector Data

• Source:
  - All Detector Report (ADR)
  - DataExtract tool

• Processed:
  (after data screening)
  - Traffic flow
  - Average lane occupancy
  - Lane occupancy standard deviation

(For crash hours: 30-s traffic condition data 30 minutes prior to crash were used)
Data Preparation

PDSL Operation Historical Data
Proportions of the duration of each PDSL activation status in each hour

- Source:
  - MnDOT’s log of Intelligent Lane Control Signal (ILCS)

- Processed:
  - Data Screening
  - Proportions of the duration in each hour:
    - PDSL Open
    - PDSL Closed
    - Sign Dark
    - VSA (Variable speed advisory displayed)
Statistical Analysis

Predictors:

- Traffic Flow
- Lane Occupancy
- Lane Occupancy^2
- Lane Occupancy Standard Deviation
- Rainy Condition
- Snowy Condition
- PDSL Open
- PDSL Closed
- Sign Dark
- VSA
Logistic Regression Model

\[ E \left\{ \log \frac{\pi_i}{1 - \pi_i} \right\} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{ki} \]

\( \pi_i \) - the probability of getting at least one rear-end crash during hour i

\( x_{ki} \) - predictors:

- **Hourly proportion of different** PDSL status during hour i;
- **Rainy** (0/1) during hour i,
- **Snowy** (0/1) during hour i,
- ln(flow) during hour i,
- centered average lane occupancy during hour i,
- centered average lane occupancy^2,
- centered lane occupancy SD during hour i.
| Section No. | Variable               | Estimate | Std. Error | z value | Pr (>|z|) | Signif. codes |
|------------|------------------------|----------|------------|---------|----------|---------------|
|            | Constant               | -5.993853| 4.975980   | -1.205  | 0.2284   |               |
|            | Rainy                  | 0.068005 | 0.354964   | 0.192   | 0.8481   |               |
|            | Snowy                  | -0.023336| 0.479197   | -0.049  | 0.9612   |               |
|            | ln(flow)               | -0.203466| 0.598580   | -0.340  | 0.7339   |               |
|            | Lane Occupancy         | 0.459360 | 0.086809   | 5.292   | 1.21E-07 | ***           |
|            | Lane Occupancy^2       | -0.009862| 0.002374   | -4.155  | 3.25E-05 | ***           |
|            | Occupancy Standard Deviation | -0.010092 | 0.071139 | -0.142  | 0.8872   |               |
|            | PDSL Closed            | -0.3042  | 0.5364     | -0.567  | 0.5706   |               |
|            | PDSL Open              | -0.7873  | 0.3813     | -2.065  | 0.0389   | *             |
|            | Sign Dark              | -0.3658  | 1.148      | -0.319  | 0.7500   |               |
|            | VSA                    | -0.8552  | 1.568      | -0.545  | 0.5855   |               |

Null deviance = 1075.53
Residual deviance = 832.88

(Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1)
## Statistical Analysis

### Table: Model Summary

| Section No. | Variable            | Estimate | Std. Error | z value | Pr (>|z|)  | Signif. codes |
|-------------|---------------------|----------|------------|---------|-----------|---------------|
| N37         | Constant            | -7.791773| 0.267902   | -29.084 | < 2E-16   | ***           |
| N37         | Lane Occupancy      | 0.444544 | 0.051367   | 8.654   | < 2E-16   | ***           |
| N37         | Lane Occupancy²     | -0.009567| 0.001802   | -5.309  | 1.1E-07   | ***           |
|             | PDSL Open           | -0.635194| 0.319932   | -1.985  | 0.0471    | *             |

**Null deviance = 1075.53**  
**H-L = 7.0154, p-value = 0.535**

**Residual deviance = 833.74**  
**AIC: 841.74**

(Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1)
Approximate value of average lane occupancy when rear-end crash risk is maximal:

\[ N37: \sigma_{max} \approx \bar{o} - \frac{\bar{\beta}_1}{2\bar{\beta}_2} = 6.22 - \frac{0.444544}{2(-.009567)} = 29.45 \]
Statistical Analysis

Section N37: Maximum Rear-end Crash Risk at Occupancy = 29.45%

Vertical lines: the Before/After change points.
Horizontal lines: approximate value of average lane occupancy where rear-end crash risk is maximal.
## Statistical Analysis

### Section No. Variable Estimate Std. Error z value Pr (>|z|) Signif. codes

<table>
<thead>
<tr>
<th>N38</th>
<th>Constant</th>
<th>-7.769015</th>
<th>0.258508</th>
<th>-30.053</th>
<th>&lt; 2E-16</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lane Occupancy</td>
<td>0.374028</td>
<td>0.045492</td>
<td>8.222</td>
<td>&lt; 2E-16</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>Lane Occupancy$^2$</td>
<td>-0.008324</td>
<td>0.001766</td>
<td>-4.714</td>
<td>2.43E-06</td>
<td>***</td>
</tr>
</tbody>
</table>

Null deviance = 1178.50
Residual deviance = 949.32

H-L = 10.235, p-value = 0.2489
AIC: 955.32

(Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1)
Statistical Analysis

Approximate value of average lane occupancy when rear-end crash risk is maximal:

\[ o_{max} \approx \bar{\delta} - \frac{\bar{\beta}_1}{2\bar{\beta}_2} = 7.26 - \frac{0.374028}{2(-0.008324)} = 29.73 \]
Statistical Analysis

Section N38: Maximum Rear-end Crash Risk at Occupancy = 29.73%

Vertical lines: the Before/After change points.
Horizontal lines: approximate value of average lane occupancy where rear-end crash risk is maximal.
### Statistical Analysis

#### Section No. Variable

| Section No. | Variable                  | Estimate | Std. Error | z value | Pr (>|z|)   | Signif. codes |
|-------------|---------------------------|----------|------------|---------|------------|---------------|
| N40         | Constant                  | -6.489315| 0.142749   | -45.460 | < 2E-16    | ***           |
|             | Lane Occupancy            | 0.256277 | 0.036566   | 7.009   | 2.41E-12   | ***           |
|             | Lane Occupancy²           | -0.008003| 0.001134   | -7.054  | 1.74E-12   | ***           |
|             | Occupancy Standard Deviation| 0.108783 | 0.030181   | 3.604   | 0.000313   | ***           |

Null deviance = 2437.0

H-L = 11.553, p-value = 0.1723

(Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1)
Approximate value of average lane occupancy when rear-end crash risk is maximal:

\[ N_{40} : o_{max} \approx \bar{o} - \frac{\beta_1}{2\beta_2} = 7.43 - \frac{0.256277}{2(-0.008003)} = 23.44 \]
Statistical Analysis

Section N40: Maximum Rear-end Crash Risk at Occupancy = 23.44%

**Vertical lines:** the Before/After change points.

**Horizontal lines:** approximate value of average lane occupancy where rear-end crash risk is maximal.
Conclusions

PDSL Region

• All 3 analyzed sections showed substantial increases in lane occupancy following UPA.
• Observed increases in rear-end crash frequency can be explained by increases in hours showing higher-risk traffic conditions.
• Increase in higher-risk traffic conditions is most likely due to removal of TH 62 I-35W bottleneck.
Conclusion

• There is a nonlinear relationship between lane occupancy and the probability a rear-end crash occurs during an hour, controlling for traffic volume, weather, and geometry.

• Rear-end crashes were most likely when lane occupancies were approximately 20%-30%.
Thanks!