

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

Gary A. Davis, Jingru Gao, John Hourdos
November 2nd, 2017

UNIVERSITY OF MINNESOTA

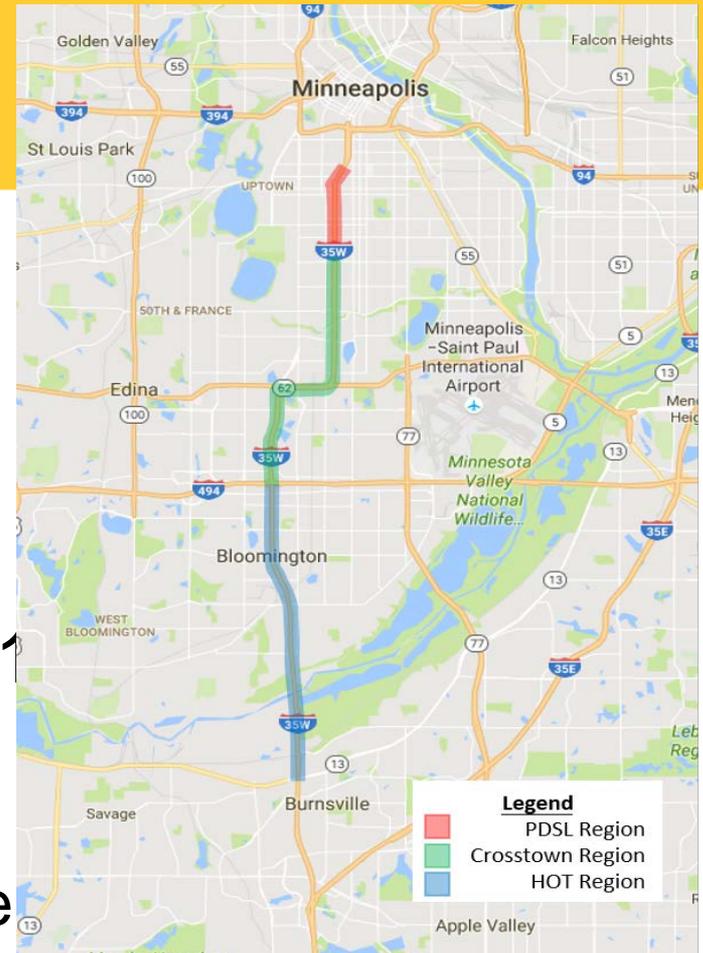
Outline

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

Introduction

Minnesota's UPA Project

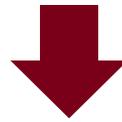
- Scope: I-35W corridor
- Time: May 2009-November 2011
- Major Improvements:
 - High-Occupancy Toll (HOT) Lane
 - Crosstown Commons Reconstruction
 - Priced Dynamic Shoulder Lane (PDSL)



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

	2006-2008 (Before UPA Project)	2011-2013 (After UPA Project)
Number of Lanes	4	5
Number of Rear-end Crashes	151	389

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

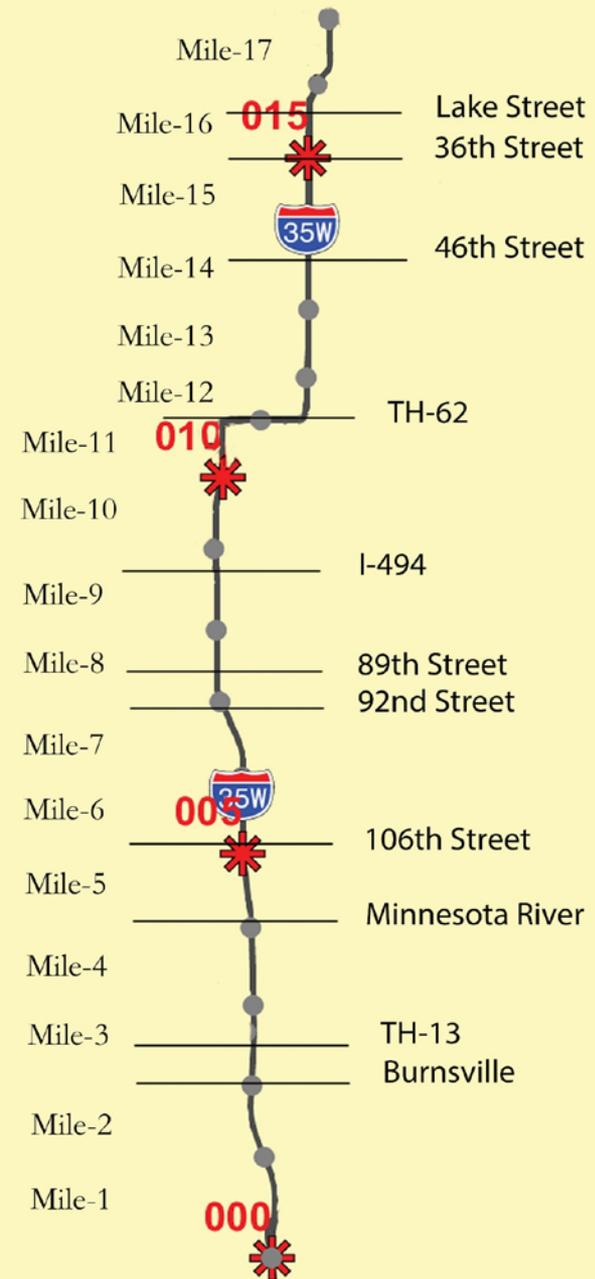
Objective (more specific):

Estimate change in crash risk:

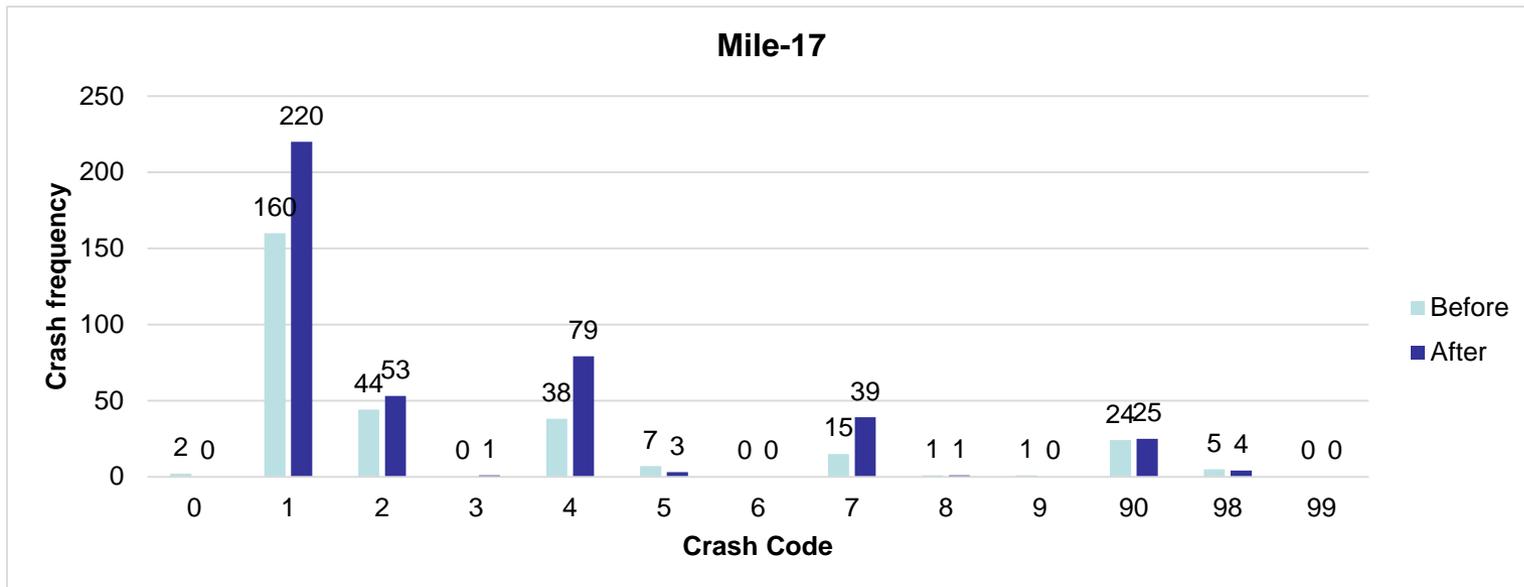
- Before (2006-2008) vs. After UPA (2011-2013)
- In different sections of I-35W
- Controlling for
 - Changes in traffic conditions
 - Weather

Preliminary Analysis

- I-35W from start to I-94 divided
- Crash data
 - Before period: 2006-2008
 - After period: 2011-2013
 - Source: Minnesota Crash Mapping
- Crash frequencies tabulated by section



Preliminary Analysis



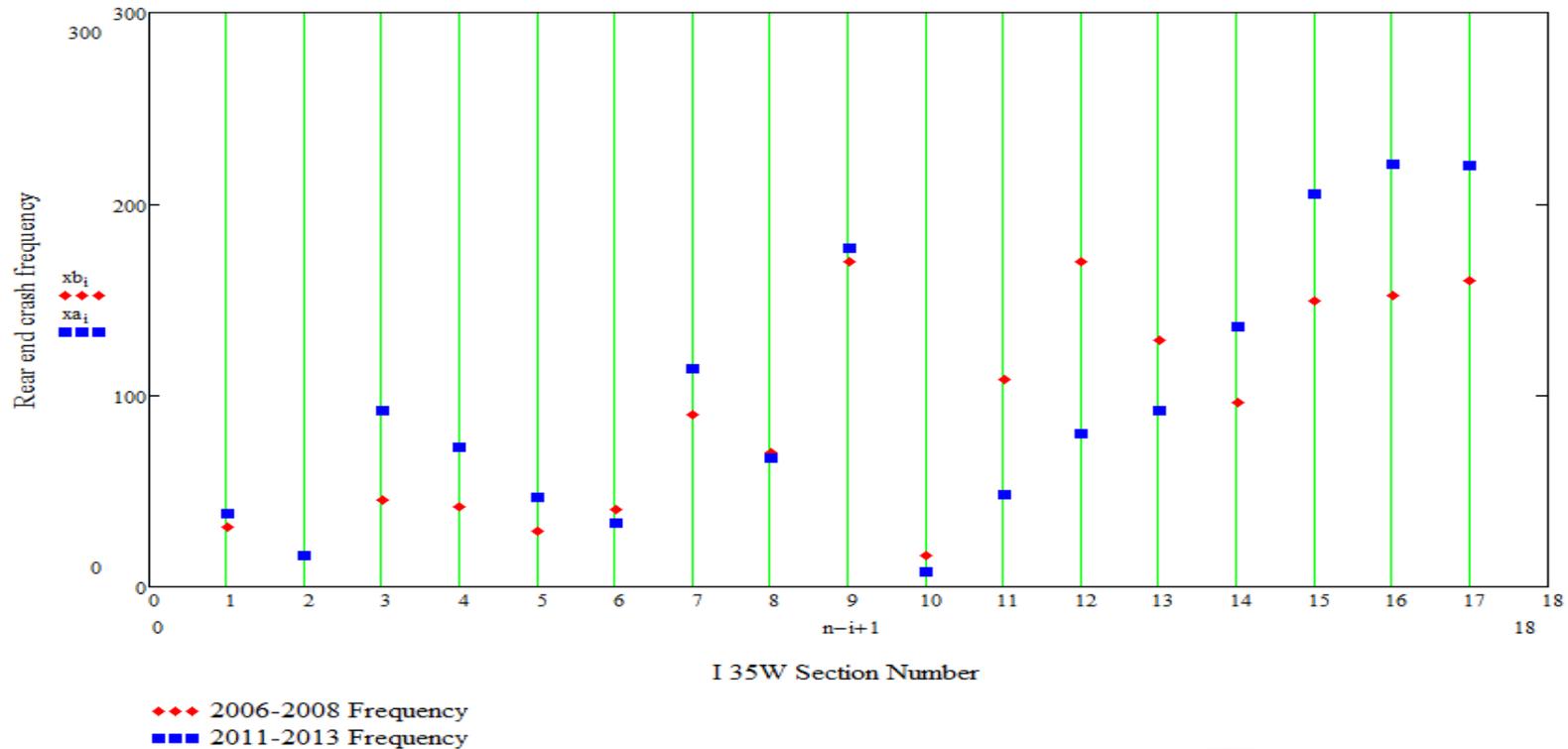
Crash Codes

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

Most frequent crash type: Rear-end (Priority)

Preliminary Analysis

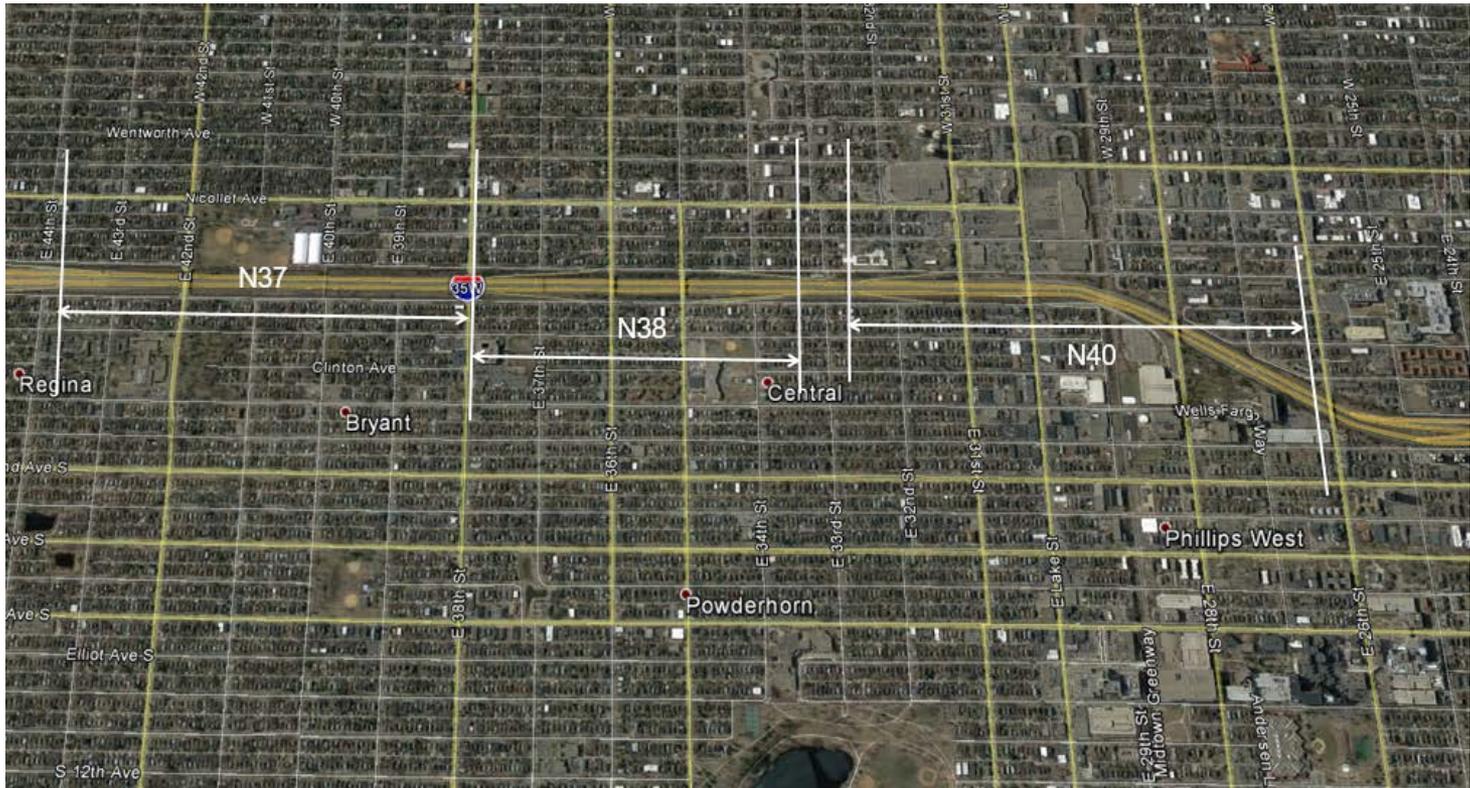
Before and After Rear-end Crash Frequencies



Analysis Regions: HOT & PDSL Region

Data Preparation

PDSL Region: 3 Analysis Sections



Data Preparation

Crash Data

B/A UPA rear-end crashes

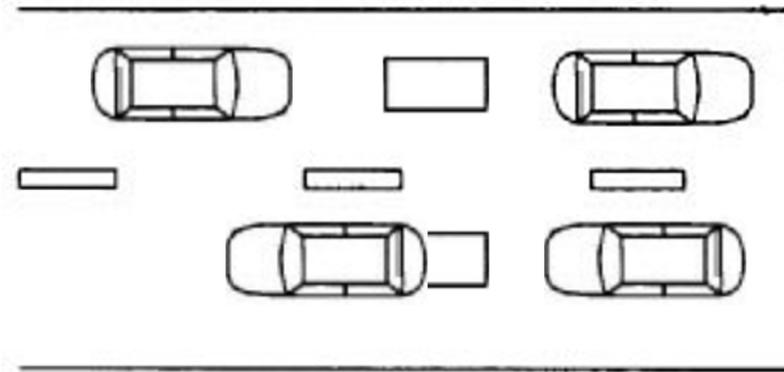
- Source:
 - MNCMAT
 - DOT/OTS Accident Report
- Checked for:
 - Crash type accuracy
 - Time accuracy
 - Location accuracy

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

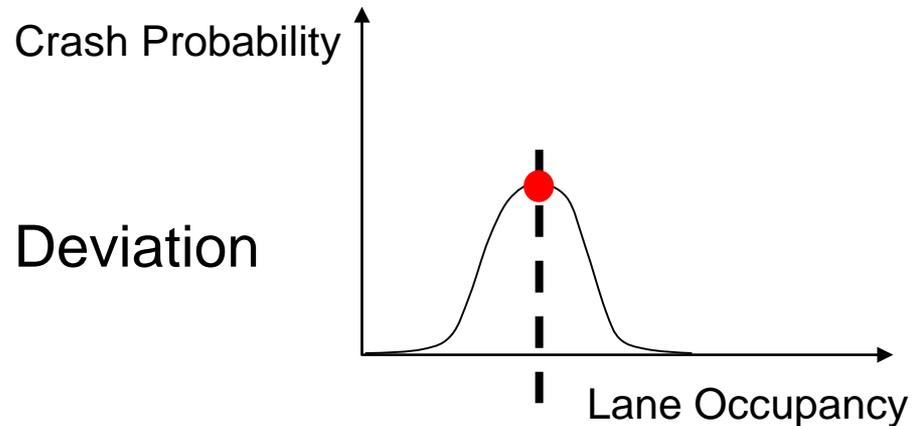
Proportions of the duration of each PDSL activation status in each hour

- 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 Occupancy²
- Lane Occupancy Standard Deviation
- Rainy Condition
- Snowy Condition
- PDSL Open
- PDSL Closed
- Sign Dark
- VSA



Statistical Analysis

Logistic Regression Model

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

π_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 ,
- **In(flow)** during hour i ,
- **centered average lane occupancy** during hour i ,
- **centered average lane occupancy²**,
- **centered lane occupancy SD** during hour i .

Section No.	Variable	Estimate	Std. Error	z value	Pr (> z)	Signif. codes
N37	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				H-L = 7.8064, p-value = 0.4526	
Residual deviance = 832.88				AIC: 854.88		

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

Statistical Analysis

Section No.	Variable	Estimate	Std. Error	z value	Pr (> z)	Signif. codes	
N37	Constant	-7.791773	0.267902	-29.084	< 2E-16	***	
	Lane Occupancy	0.444544	0.051367	8.654	< 2E-16	***	
	Lane Occupancy ²	-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)

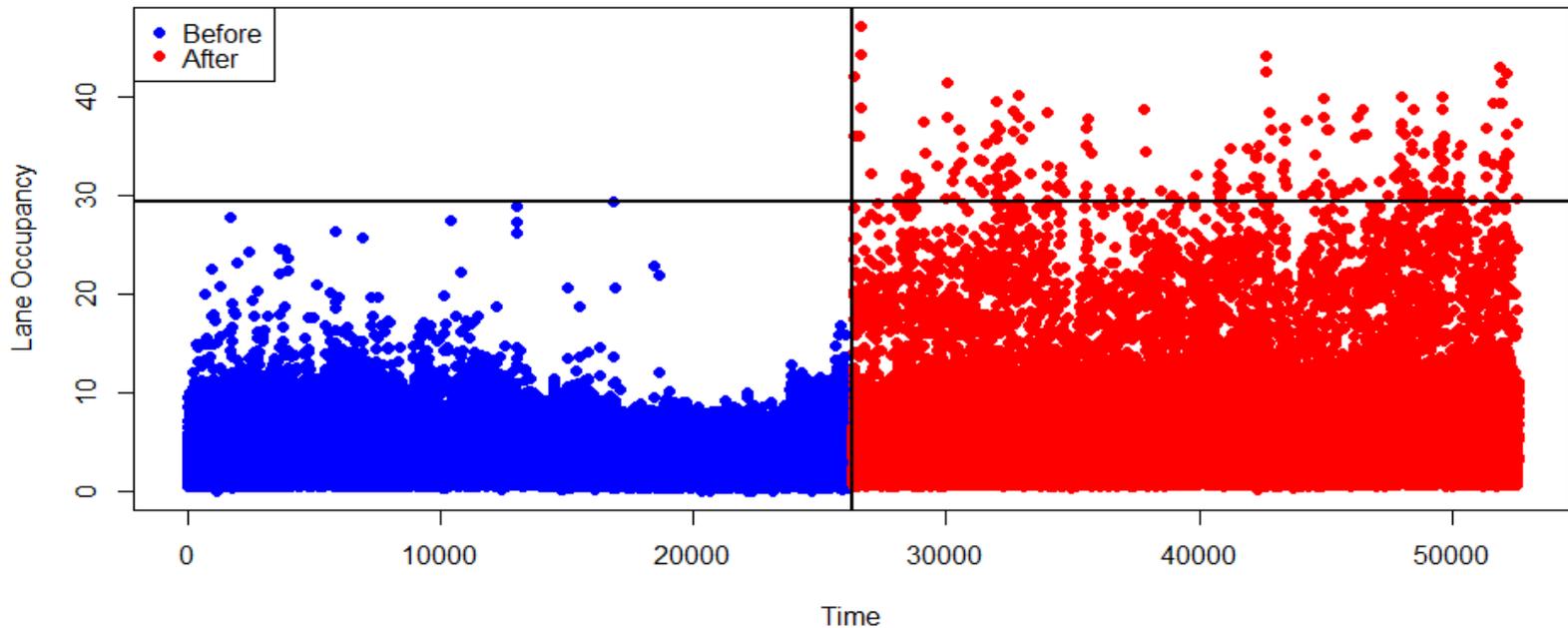
Statistical Analysis

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

$$\text{N37: } o_{max} \approx \bar{o} - \frac{\widehat{\beta}_1}{2\widehat{\beta}_2} = 6.22 - \frac{0.444544}{2(-.009567)} = 29.45$$

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
N38	Constant	-7.769015	0.258508	-30.053	< 2E-16	
	Lane Occupancy	0.374028	0.045492	8.222	< 2E-16	***
	Lane Occupancy ²	-0.008324	0.001766	-4.714	2.43E-06	***
	Null deviance = 1178.50			H-L = 10.235, p-value = 0.2489		
	Residual deviance = 949.32			AIC: 955.32		

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

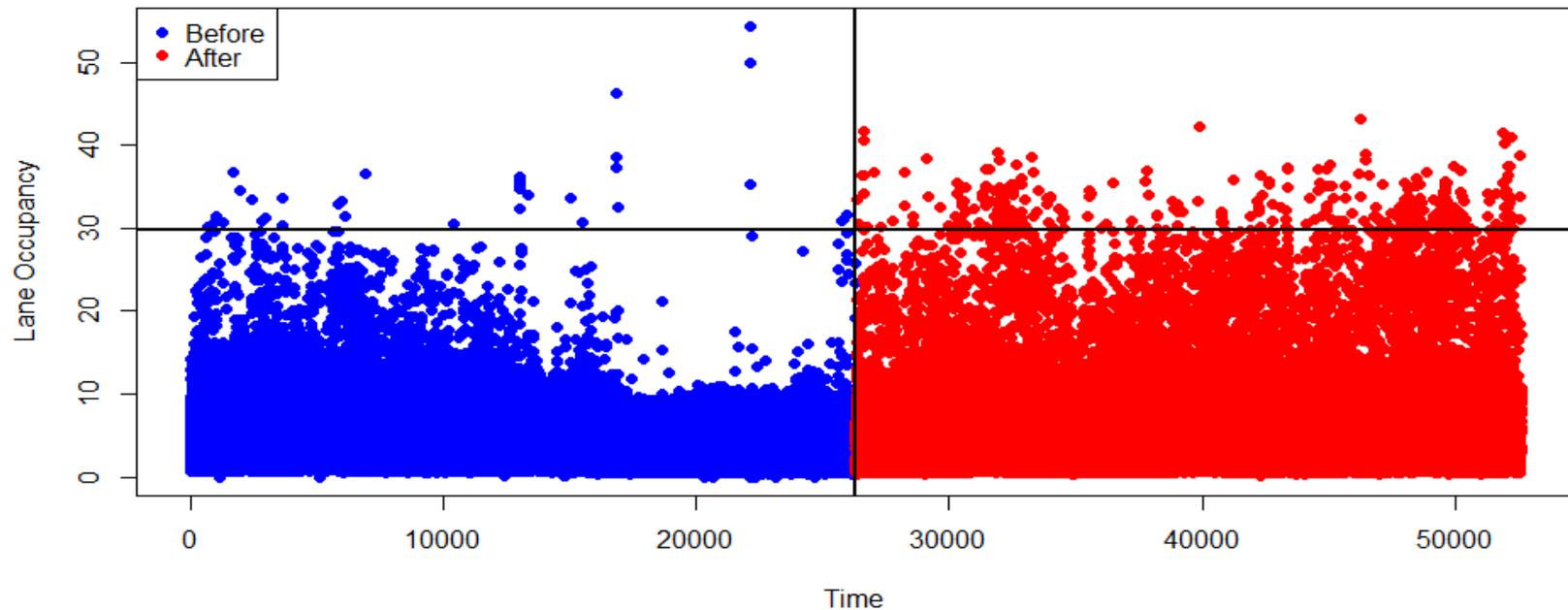
Statistical Analysis

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

$$\text{N38: } o_{max} \approx \bar{o} - \frac{\hat{\beta}_1}{2\hat{\beta}_2} = 7.26 - \frac{0.374028}{2(-0.008324)} = 29.73$$

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	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 Occupancy ²	-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)

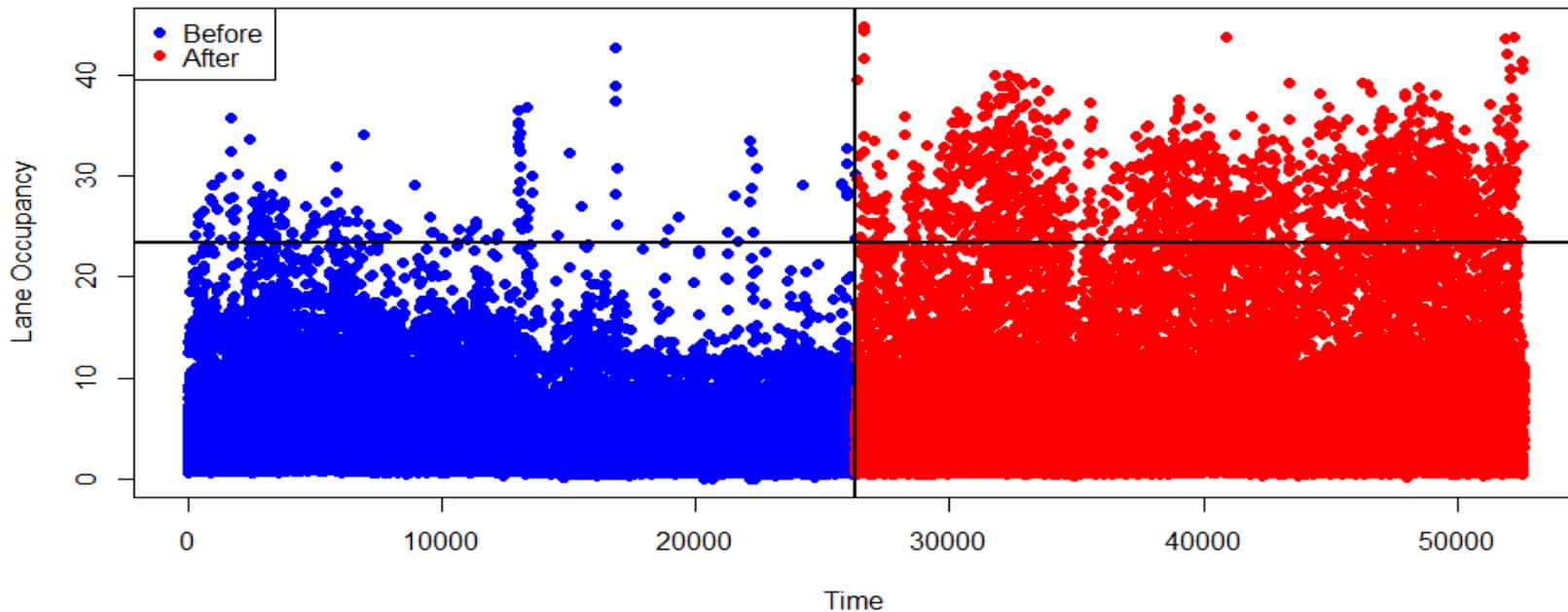
Statistical Analysis

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

$$\text{N40: } o_{max} \approx \bar{o} - \frac{\widehat{\beta}_1}{2\widehat{\beta}_2} = 7.43 - \frac{0.256277}{2(-0.008003)} = 23.44$$

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!