# INCIDENT CAPACITY REDUCTION ON FOUR-LANE FREEWAYS USING REAL WORLD DATA PART 2: MULTILANE CLOSURES

Golnush Masghati Amoli
Bahar Zarin
Kaveh Farokhi Sadabadi
Mark Franz

**Submitted for Presentation and Publication to:**
**94th Annual Meeting**
**Transportation Research Board**
**Washington, D.C., 2015**

# Introduction

- Why are we concerned about quantifying capacity reductions during incident?

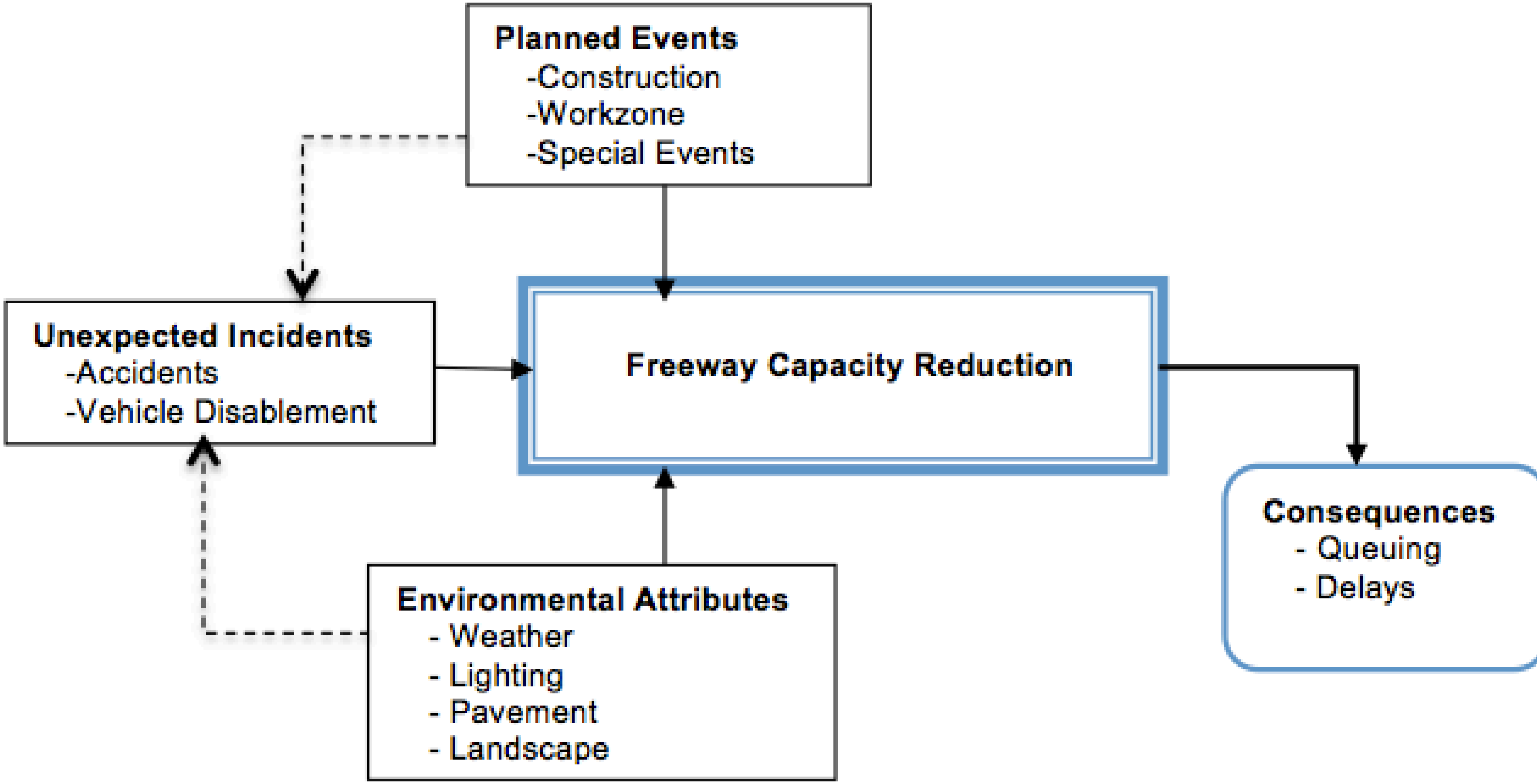
- Incident-induced capacity $\neq$ physical reduction in roadway space caused by the incident

- Capacity Reduction during incidents ➔ Delay and Queuing.

- 1 minute freeway travel lane closure during peak use $\cong$ 4 minutes of delay after the incident is cleared ➔ 4.2 billion hours per year in delays.

- Americans burn more than 2.8 billion gallons of gasoline every year while stuck in incident-related traffic.

# Conceptual Framework



# Background

| Author | Year | Data | Methodology | |
|---|---|---|---|---|
| | | | Incident Capacity | Non-incident Capacity |
| Goolsby, M. | 1971 | Three-lane Freeway Video Recordings | Queue discharge rate during incident | Max flow during peak hour |
| Smith, B.L., Qin, L., and R. Venkatanarayana. | 2003 | Three-lane Freeway Detector Data | Min of 10 minute moving average of bottleneck discharge flow rate | free flow capacity (Absolute peak) |
| Knoop, V., Hoogendoorn, S., and K. Adams | 2008 | Two-lane Freeway Video Recording | Average Discharge Flow | standard lane capacities in Netherland's |
| Knoop, V., Hoogendoorn, S., and K. Adams | 2009 | Three-lane Freeway Detector Data | median of the discharge flow rate | queue discharge rate measured under normal conditions |
| Lu, C., and L. Elefteriadou. | 2013 | Two-lane Freeway Detector Data | moving average of downstream flow with 10-minute lag | average flow over 10 minutes before breakdown |

# Background

**TABLE 1 Comparison of Percent Freeway Capacity Available under Incident Conditions from Different Studies**

| Number of Lanes (One Direction) | Shoulder Disablement | Shoulder Accident | One Lane Blocked | Two Lanes Blocked | Three Lanes Blocked |
|---|---|---|---|---|---|
| 2 | **0.95** | **0.81**<br><br>0.68-0.77 | **0.35**<br>0.47-0.50<br>0.46-0.50 | **0.00**<br>0.13-0.14 | **N/A** |
| 3 | **0.99**<br>0.52 | **0.83**<br>0.74<br>0.72 | **0.49**<br>0.50<br>0.36<br>0.37<br>0.40-0.43 | **0.17**<br>0.21<br>0.18<br>0.23<br>0.29-0.32 | **0.00** |
| 4 | **0.99** | **0.85** | **0.58** | **0.25** | **0.13** |
| 5 | **0.99** | **0.87** | **0.65** | **0.40** | **0.20** |
| 6 | **0.99** | **0.89** | **0.71** | **0.50** | **0.26** |
| 7 | **0.99** | **0.91** | **0.75** | **0.57** | **0.36** |
| 8 | **0.99** | **0.93** | **0.78** | **0.63** | **0.41** |

# Objectives

1. Develop a new methodology to measure sustainable flow rates during incidents using real world data.
2. Measure Available Capacity Ratio during incidents on four-lane freeways.

- More than 80% of US Interstate System mileage is allocated to Four-lane freeways!!!
- No published work on four-lane highways except HCM

# Methodology

## Incident Selection

| Check for the Proximity to Upstream/Downstream Detectors | Check for the Presence of Bottleneck |
|---|---|

↓

## Incident Capacity Estimation

| Cumulative Count Curve | Finding the best-fitted Breakpoints | Slope Calculation |
|---|---|---|

↓

## Non-incident Capacity Estimation

| Cumulative Count Curves | OR | 15% Reduction from Max Observed Flow |
|---|---|---|

↓

## Capacity Reduction Estimation

Calculate the Percentage of Available capacity During Incidents based on the Results from Step 2 & 3

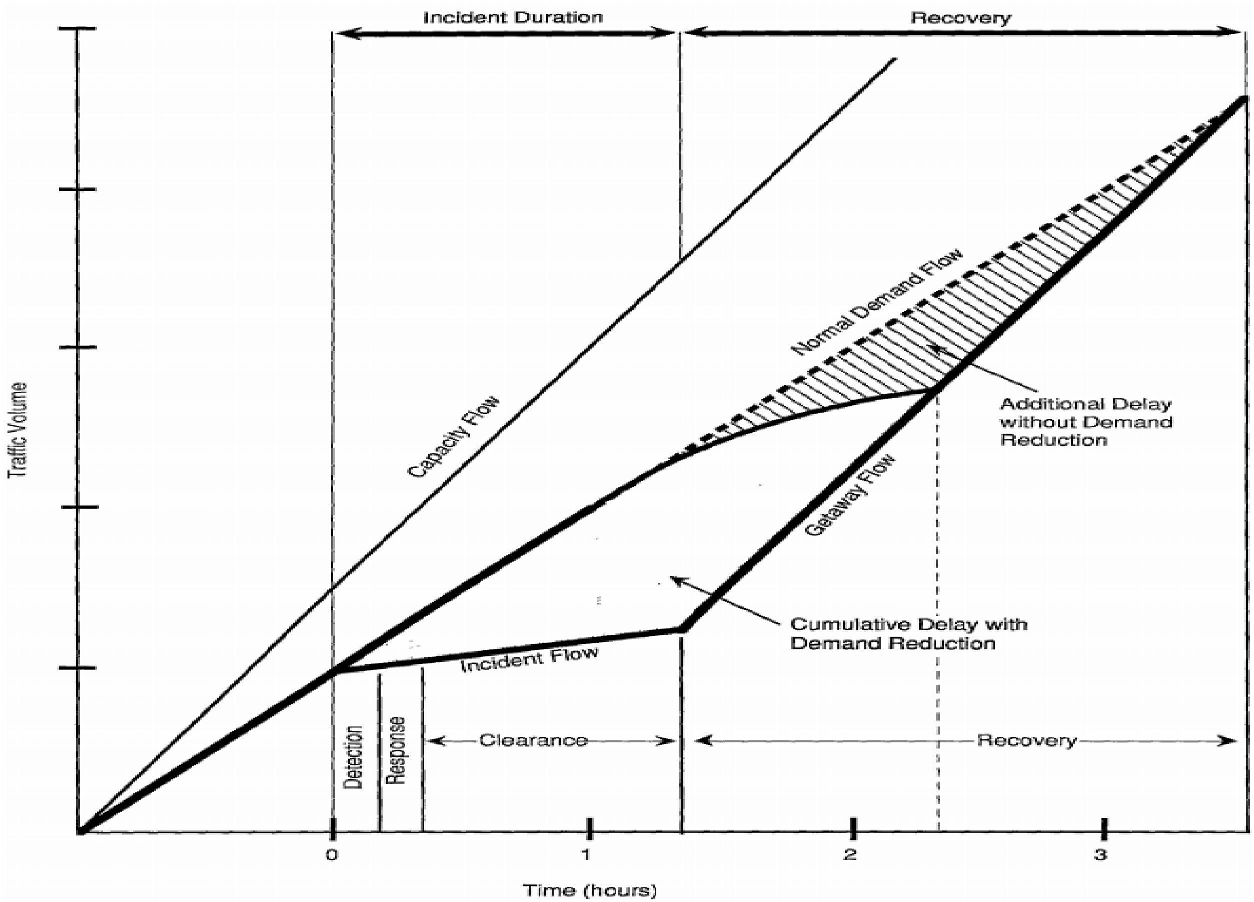
# Incident Selection

- Proximity to Traffic Detectors
  - Only incidents within maximum one-mile distance from upstream and downstream detectors (without any on-ramp or off-ramp in between) were considered for analysis.
- Active Bottlenecks
  - Incidents were checked for the existence of an active bottleneck formed as a result of lane closures.

# Incident Capacity Estimation

## Cumulative Counts Concept

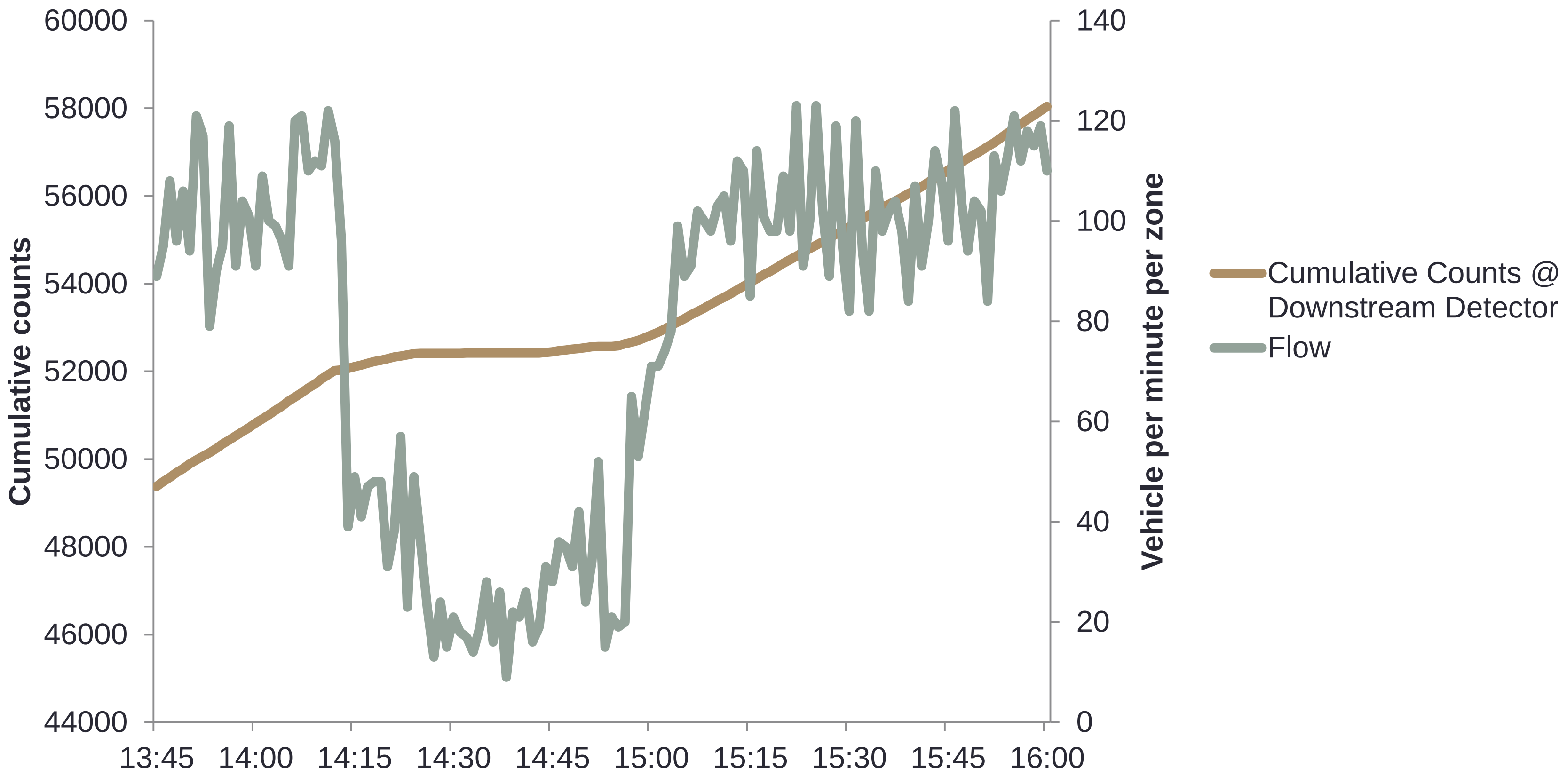
- To avoid difficulties in dealing with random variations in vehicle counts, incident capacity was estimated as the slope of the downstream detector's cumulative counts.



# Incident Capacity Estimation

## Cumulative Counts Concept

- Smooth out random variations in flow
- Challenge???? identify the best-fitted breakpoints



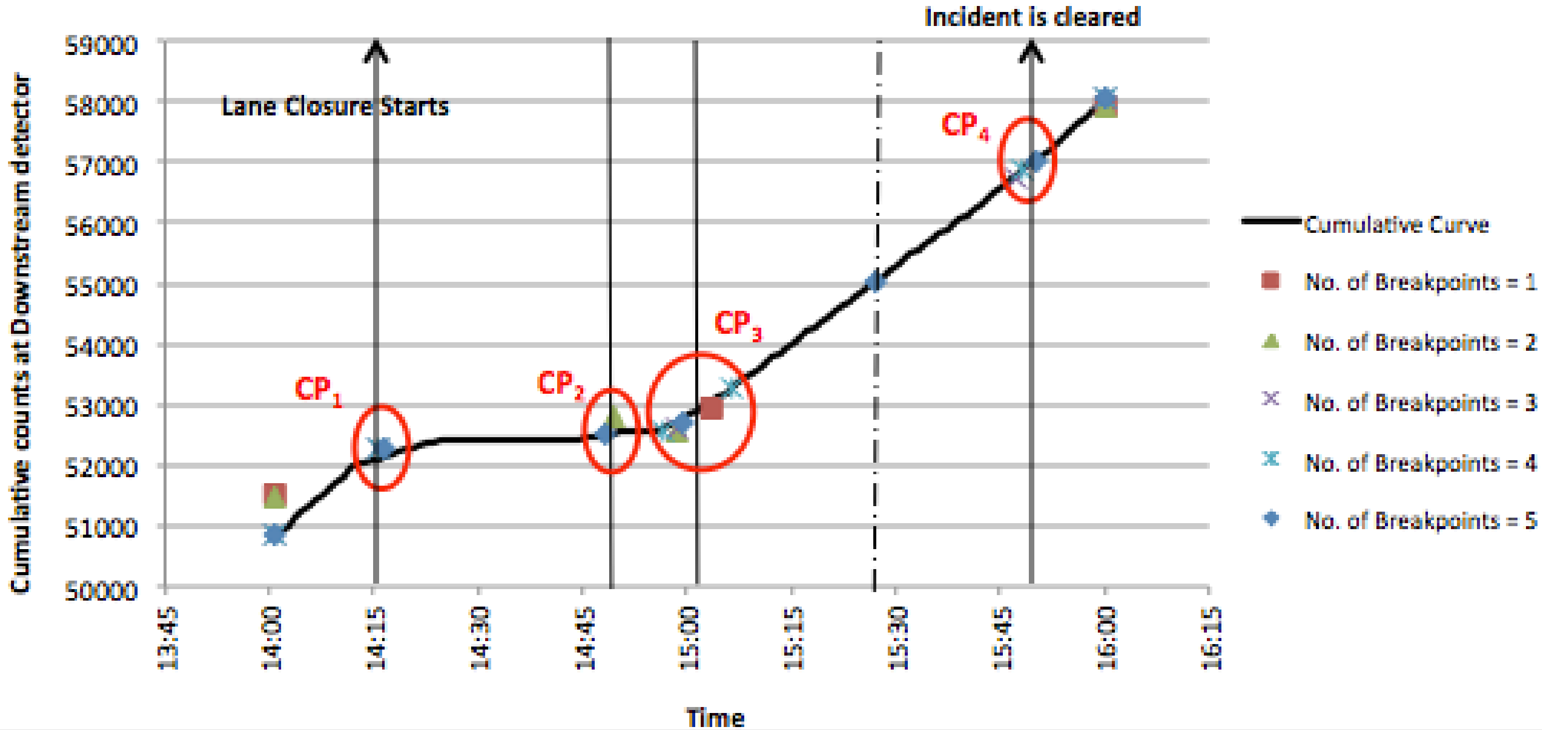
# Incident Capacity Estimation

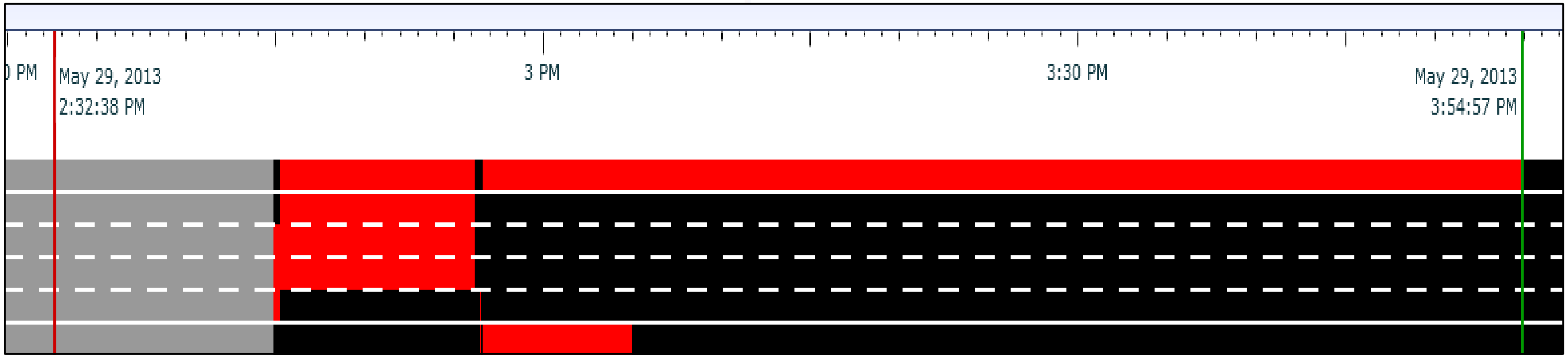
## Fitting Breakpoints

- The best-fitted breakpoints on the cumulative counts curve were found by fitting a *Broken Stick Piecewise Regression Optimization Model* to the downstream count data.
- Model input:
  1. Vehicle cumulative counts $y_i$ together with their corresponding time stamps $x_i$ in the form of a set of ordered pair $(x_i, y_i)$ points, $i=1,\ldots,m$,
  2. Desired number of breakpoints $p$
- Model output
  1. Coordinates of the best-fitted breakpoints $(X_k, f_k)$, $k = 1, \ldots, p$
  2. Slopes, $b_k$, of each fitted segment of the piecewise line

# Incident Capacity Estimation

## Fitting Breakpoints Algorithm



# Incident Capacity Estimation

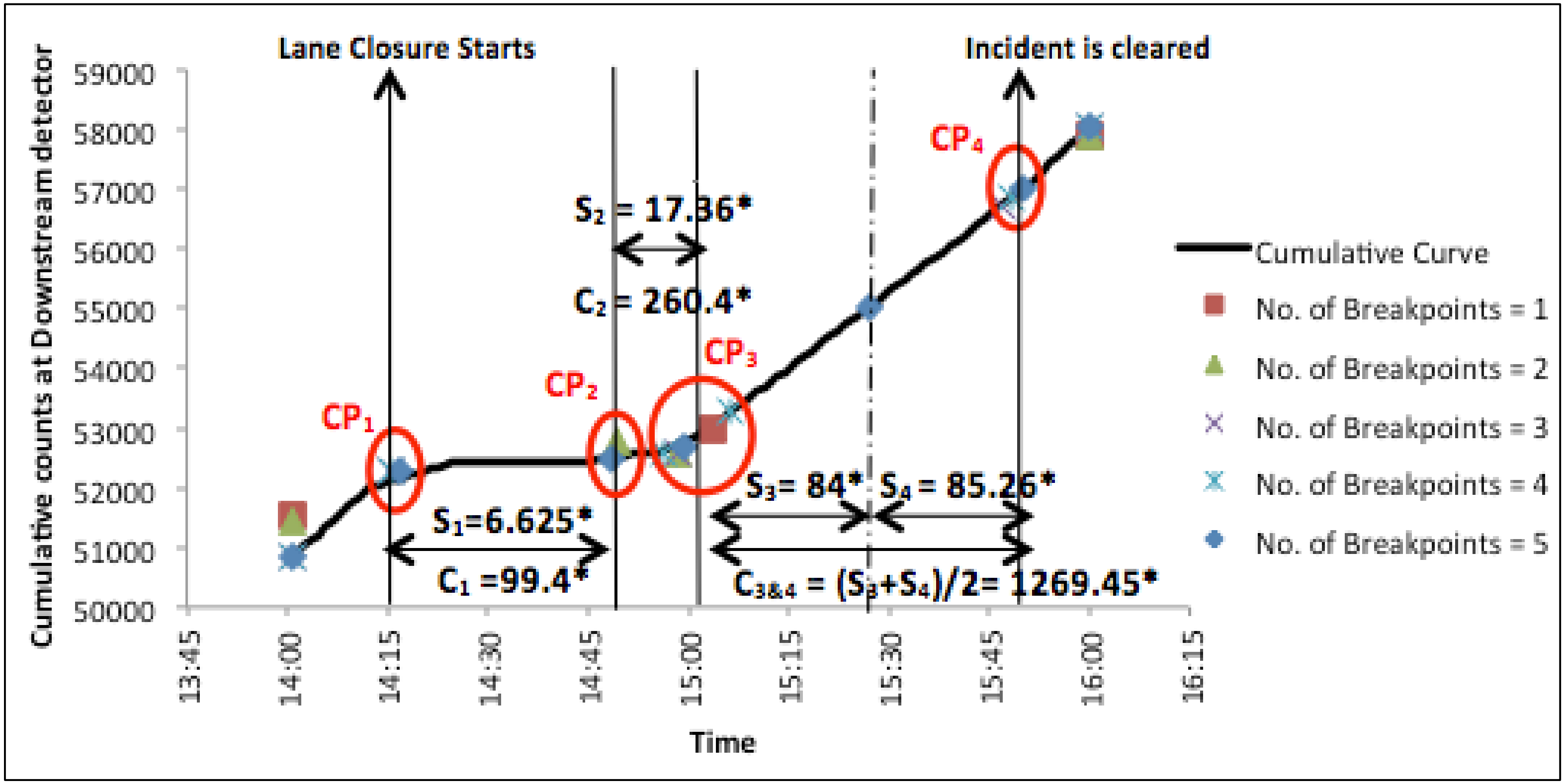
## Slope Calculation Algorithm

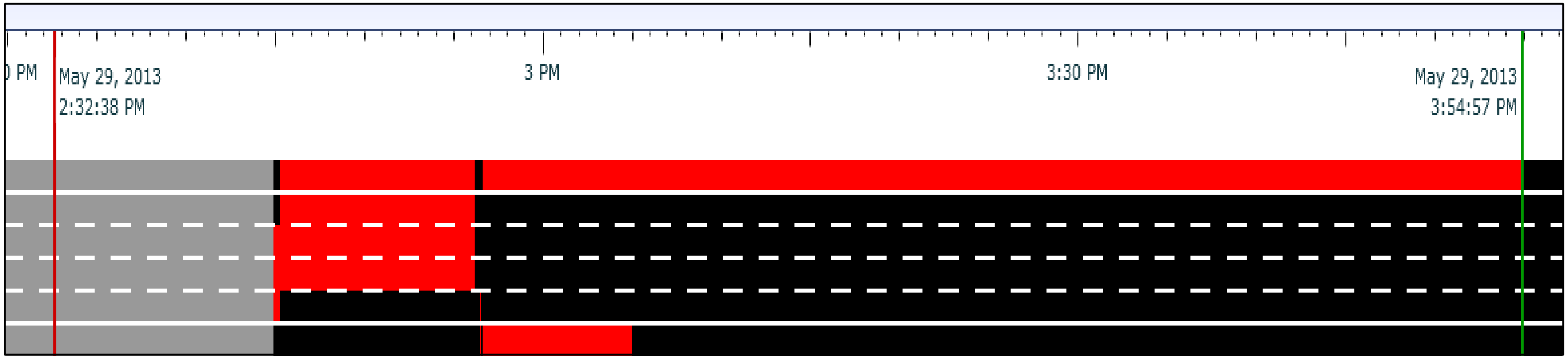
1) If time difference between any two consecutive breakpoint is less than 10 minutes, disregard the slope, unless both of them are found to be critical points

2) If there is a point between any two consecutive critical points dividing the segments between them to two segments, test if the slope of these segments are significantly different

# Incident Capacity Estimation

## Slope Calculation Algorithm



# Non-Incident Capacity Estimation

- Two different approaches:

1. The slope of the cumulative counts curve of the flow at the downstream detector, if bottleneck still existed after the incident was cleared
2. Subtracting 15% from the maximum observed flow at downstream detector over a week before and a week after the incident, otherwise.

# Available Capacity Ratio & Efficiency Ratio

$$ACR = \frac{C_{incident}}{C_{non-incident}}$$

- $C_{incident}$ = Roadway capacity during incident
- $C_{non\text{-}incident}$ = Roadway Capacity during normal conditions

$$\gamma = \frac{ACR}{\frac{n_{incident}}{n_{non-incident}}}$$

- $n_{incident}$ = Number of open lanes during incidents
- $n_{non\text{-}incident}$ = Number of open lanes under normal condition, which is four in his study

# Data

- Incident Data
  - Obtained from the Coordinated Highways Action Response Team (CHART) for a period of six years from January 2008 to May 2014.
  - Only incidents during peak hours were considered.
  - Only focused on two of Maryland major four-lane interstate freeways: Capital Beltway (I-495), and the I-95 corridor between Washington, D.C. and Baltimore.
  - In total 32 incidents was selected from five different locations.

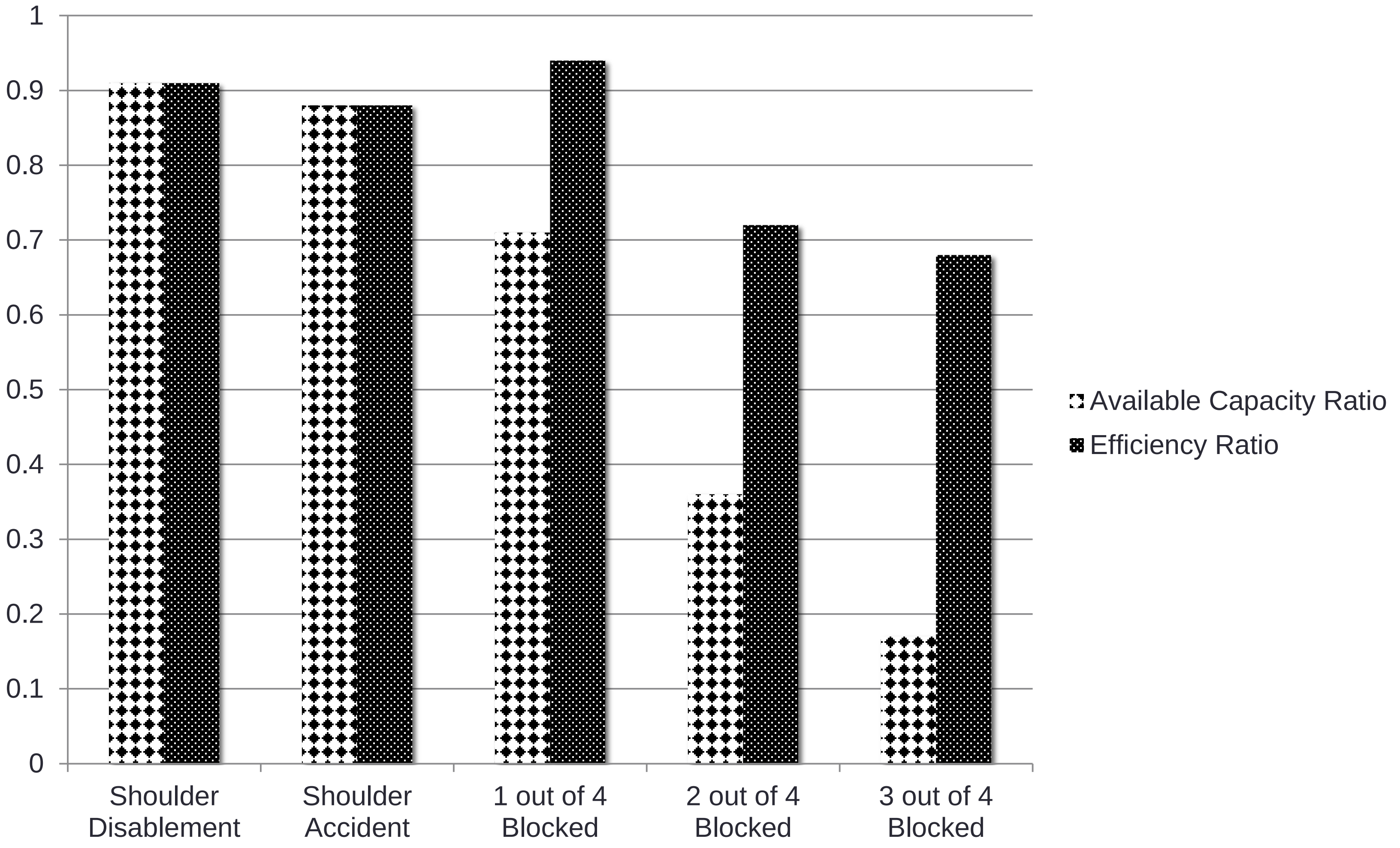
- Traffic Data
  - Downstream detector data was accessed through detector query tools in RITIS.
  - Occupancy, speed, and vehicle count data was avilable at one-minute time intervals on both lane-by-lane and overall zone basis.

# Result

| Type of Blocking | | Shoulder Disablement | Shoulder Accident | 1 out of 4 | 2 out of 4 | 3 out of 4 |
|---|---|---|---|---|---|---|
| Mean($C_{non\text{-}incident}$) | | 1800 vphpl | 1800 vphpl | 1800 vphpl | 1800 vphpl | 1950 vphpl |
| Mean($C_{incident}$) | | 1550 vphpl | 1450 vphpl | 1300 vphpl | 650 vphpl | 350 vphpl |
| ACR | Mean | 0.91 | 0.88 | 0.71 | 0.36 | 0.17 |
| | Std. Dev. | 0.046 | 0.065 | 0.054 | 0.057 | 0.05 |
| | HCM (1) | 0.99 | 0.85 | 0.58 | 0.25 | 0.13 |
| Efficiency Ratio | | 0.[illegible] | [illegible] | 0.94 | 0.72 | 0.68 |
| Number of Cases | | [illegible] | [illegible] | 13 | 5 | 4 |
| Target Sample Size | | 3 | 6 | 4 | 4 | 4 |
| Z Value | | -3.012 | 1.221 | 8.680 | 4.315 | 2.162 |
| Test Result on Null Hypothesis* | | Is Rejected | Is Accepted | Is Rejected | Is Rejected | Is Rejected |

$$N = \left(\frac{Z_{\alpha/2} \times \sigma}{E}\right)^2$$

# Result



1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Shoulder Disablement
Shoulder Accident
1 out of 4 Blocked
2 out of 4 Blocked
3 out of 4 Blocked
Available Capacity Ratio
Efficiency Ratio

# Conclusion

- Estimated available capacity ratio during incidents were significantly different from HCM, except for shoulder closure scenarios.

- Capacity reduction during incidents were found to be not only because of the less number of available lanes but also due to a change in driving behavior.

- The efficiency of the road being used during shoulder and one lane closure incident cases is the same at 95% level of confidence which is conflicting with Knoop's findings.

- The same efficiency factor for two lanes blocked and three lanes blocked scenarios indicates that they both lead to similar impacts on behavior of traffic→ result in a smaller relative drop in capacity where two lanes blocked is changed to three lanes blocked.

# Contribution

- With the new developed algorithm the challenges in dealing with random variation in vehicle counts was solved and sustainable discharge flow rates were measured using real world traffic data.

- The first study investigating the effect of incidents on four-lane freeways using real world data.

- Accurate information on the available road capacity during incident can be used by authorities in their incident management decisions.

- This may include decisions on rerouting the traffic or potentially changing the road closure patterns to provide maximum possible capacity of the roadway under prevailing traffic conditions.

- The reduced capacity estimates can also be used in delay calculations which in turn can be used to inform the travelers about the delay they should anticipate as a result of a particular incident with known number of lanes closed.

# Thank You!