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

Golnush Masghati Amoli[1], Bahar Zarin[1], Kaveh Farokhi Sadabadi[1], Mark Franz[1]

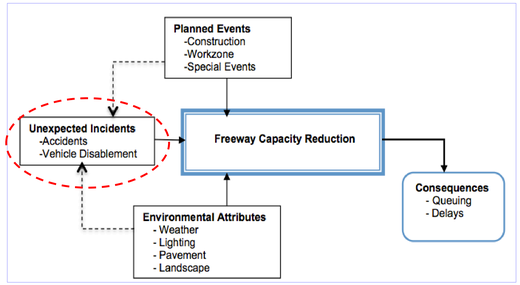
[1]Civil and Environmental Engineering Department , University of Maryland, College Park, MD 20742, USA

Abstract

One of the main goals in incident management is to reduce delay and queuing caused by an incident. Delay and queuing are among other things dependent on the road capacity, so an accurate estimate of the capacity reduction can potentially lead to improved efficiency of incident management and delay reduction. In this study a new method based on the slope of the cumulative counts is proposed to estimate capacity reductions at the incident site. The method is applied to real world incident scenarios on four lane freeways in Maryland and Northern Virginia. Thirty-two incidents from Maryland and nineteen cases from Northern Virginia meet the requirements to apply the proposed methodology. Results indicate that except for shoulder accident cases, the estimated available capacity ratios during incidents are significantly different from those reported in HCM. It is found that in cases where one driving lane is blocked, the available capacity reduces to 70%. This value reduces to 36% and 17% for two lanes closure and three lanes closure scenarios, respectively. Moreover, it is found that besides less available number of lanes, less efficient use of driving lanes due to changes in driver behavior and distractions is another contributing factor to capacity reduction.

Introduction

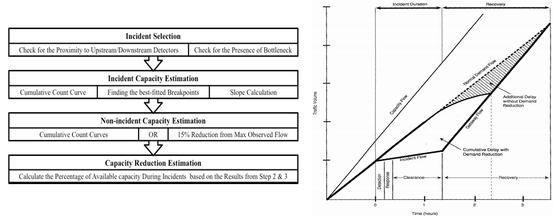
- This study reports the ratio of available capacity due to incidents on four-lane freeways based on Maryland and Northern Virginia data by estimating the maximum throughput at the location of incidents.
- Different real world incident scenarios are studied and the results are compared to the values reported in Highway Capacity Manual.
- Incidents are categorized in five separate groups based on their lane closure patterns as:
  - ❑ shoulder disablement,
  - ❑ shoulder incident,
  - ❑ one lane closed,
  - ❑ two lanes closed,
  - ❑ and three lanes closed.
- Significance of Study:
  - ❑ Use of real world data for capacity reduction estimation.
  - ❑ Development of a new algorithm in incident capacity estimation based on cumulative counts to avoid difficulties in dealing with random variations in vehicle counts, and ensure sustained flow rates are calculated as the capacity.
  - ❑ Capacity reduction analysis on four-lane freeways; except in HCM there is no other published work addressing the issue of capacity reductions on four lane freeways.



HCM2010 HIGHWAY CAPACITY MANUAL

Number of Lanes (One Direction)	Shoulder Disablement	Shoulder Accident	One Lane Blocked	Two Lanes Blocked	Three Lanes Blocked
2	0.95	0.81	0.35	0.00	N/A
3	0.99	0.83	0.49	0.17	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

Methodology



- Incident Selection: Two main criteria were considered in the process of incident selection
  1. Proximity to traffic detectors (within maximum one-mile distance from upstream and downstream detectors, preferably without any on-ramp or off-ramp in between)
  2. Existence of an active bottleneck formed as a result of lane closures; Bottlenecks are identified using two speed thresholds:
     a. Traffic with speed less than 45 mph at upstream detector
     b. Traffic with speed more then 50 mph at downstream detector
- Incident Capacity Estimation:
  - ❑ To avoid difficulties in dealing with random variations in vehicle counts, incident capacity is estimated as the slope of downstream detector's cumulative count graph
  - ❑ To capture variations in slope of the cumulative count curve, breakpoints are fitted to the curve using Broken Stick Piecewise Regression optimization model
- Non-incident Capacity Estimation:
  - ❑ Queue discharge rate in normal condition (no lanes blocked) measured at downstream detector, if bottleneck still exists after the incident is cleared.
  - ❑ Otherwise, 0.85 *the maximum observed flow at downstream detector over a week before and a week after the incident.
- Capacity Reduction Estimation
  - ❑ Available Capacity Ratio (ACR) during incident:

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

$C_{incident}$ = Capacity during Incident
$C_{non\text{-}incident}$ = Non-incident Capacity

  - ❑ Efficiency, γ, of the use of the remaining lanes:

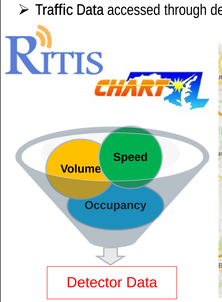
$$\gamma = \frac{ACR}{\frac{n_{incident}}{n_{non-incident}}}$$

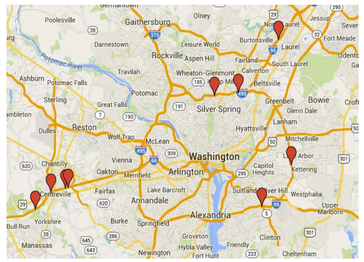
$n_{incident}$ = number of open lanes during incidents
$n_{non\text{-}incident}$ = number of open lanes during normal condition

- Hypothesis Testing: to compare our estimates of the available capacity ratio (ACR) with that of other studies reported in the Highway Capacity Manual (HCM).

Data

- Incident Data on Maryland and Northern Virginia four-lane highways obtained from the CHART and VDOT respectively for a period of six years from January 2008 to October 2014.
- In total 51 incidents selected from 10 different locations along I-495 and I-66 highways.
- Traffic Data accessed through detector query tools in RITIS at one-minute interval resolution.

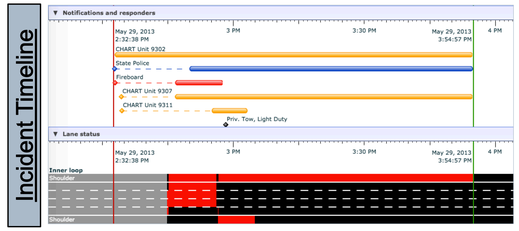




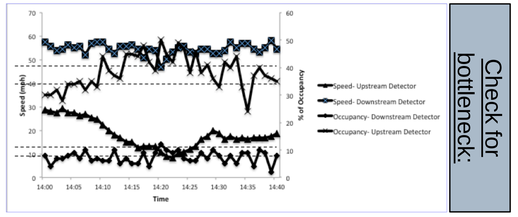
Case Study

Event ID	Event Type	Date & Time	Location	Duration	Latitude	Longitude	# of Closed Lanes
MDOT_CHART_45001fc6aa4901a60051fa2ec4235c0a	accident	5/29/13 14:32 – 15:54	I-495 inner loop prior to exit 28 md 650 new Hampshire Ave	1 hour 22 minutes	39.019012	-76.976536	3

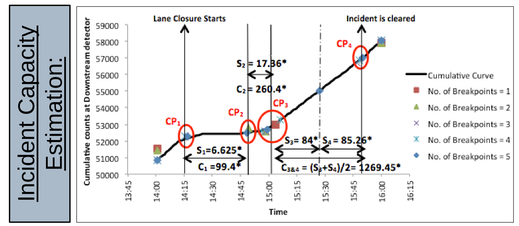
Incident Timeline



Check for bottleneck:



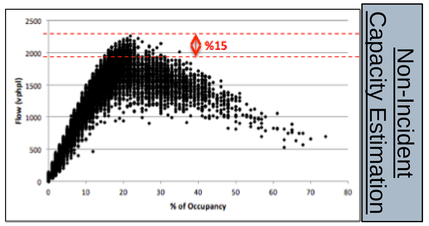
Incident Capacity Estimation:



Lane Closure Pattern	3 Lanes Blocked	Left and Right Shoulder Blocked	Left Shoulder Blocked
Measured Capacity	S_1 = 6.625 * Capacity = 99.4 vphpln	S_2 = 17.36 * Capacity = 260.4 vphpln	(S_3+S_4)/2 = 84.63 * Capacity = 1269.45 vphpln

* Slopes report the capacity in vehicle per minute per zone

Non-Incident Capacity Estimation



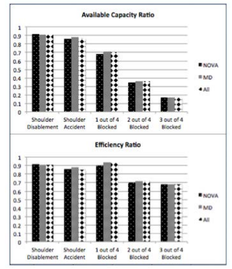
non-incident capacity =0.85*2220 = 1887 ≅ 1890 vphpln

Result

Summary of Findings

State	Type of Blocking		Shoulder Disablement	Shoulder Accident	1 out of 4	2 out of 4	3 out of 4
Maryland	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	Mea	0.91	0.88	0.71	0.36	0.17
		Std.	0.046	0.065	0.054	0.057	0.05
		HC	0.99	0.85	0.58	0.25	0.13
	Efficiency Ratio		0.91	0.88	0.94	0.72	0.68
	Number of Cases		3	7	13	5	4
	Target Sample		3	6	4	4	4
	Z Value		-3.012	1.221	8.68	4.315	2.162
	Test Result on		Is Rejected	Is	Is Rejected	Is Rejected	Is Rejected
Northern Virginia	Mean ($C_{non\text{-}incident}$)		1900 vphpl	1750 vphpl	1800 vphpl	1800 vphpl	1920 vphpl
	Mean ($C_{incident}$)		1700 vphpl	1500 vphpl	1225 vphpl	630 vphpl	335 vphpl
	ACR	Mea	0.92	0.86	0.68	0.35	0.17
		Std.	0.043	0.052	0.038	0.042	0.031
		HC	0.99	0.85	0.58	0.25	0.13
	Efficiency Ratio		0.92	0.86	0.9	0.7	0.68
	Number of Cases		2	3	5	3	6
	Target Sample		3	5	3	3	2
	Z Value		-3.967	0.335	3.852	5.832	3.634
	Test Result on		Is Rejected	Is	Is Rejected	Is Rejected	Is Rejected
All	Mean ($C_{non\text{-}incident}$)		1800 vphpl	1785 vphpl	1800 vphpl	1800 vphpl	1930 vphpl
	Mean ($C_{incident}$)		1600 vphpl	1465	1280	640 vphpl	340 vphpl
	ACR	Mea	0.91	0.87	0.70	0.36	0.17
		Std.	0.048	0.058	0.057	0.058	0.054
		HC	0.99	0.85	0.58	0.25	0.13
	Efficiency Ratio		0.91	0.85	0.93	0.72	0.68
	Number of Cases		5	10	18	8	10
	Target Sample		4	6	6	6	4
	Z Value		-3.540	1.090	8.932	5.364	2.342
	Test Result on		Is Rejected	Is	Is Rejected	Is Rejected	Is Rejected

* $\alpha = 0.05$



- The estimated ACR under different lane closure scenarios are found to be the same (at 95% level of confidence) for Maryland and Northern Virginia freeways.
- Except for shoulder accident scenario, our findings on ACRs are seen to be significantly different from HCM.
- The efficiency ratio decreases as the number of closed lanes increase.

Conclusion

- 51 real world incident cases on four lane freeway segments that caused active bottlenecks are investigated.
- The algorithm introduced in this study produces more reliable estimates of Available Capacity Ratios than the other approaches used in previous studies as it efficiently deals with variations in vehicle counts.
- Findings of this study on Available Capacity Ratios during incidents are significantly different from those reported in HCM, except for shoulder accident scenario.
- Road authorities may use the findings on ACR in their 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 to inform the travelers about the delay they should anticipate as a result of a particular incident with known number of lanes closed.

Contact Information

Golnush Masghati Amoli
Graduate Research Assistant

University of Maryland
College Park, MD 20742

T: 301-405-6550
E: golnush@umd.edu