



Traffic Congestion and Bottlenecks


Identification, Diagnosis, Solutions



U.S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

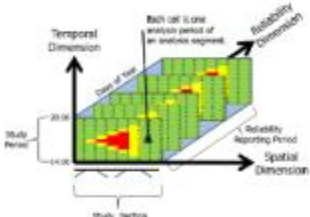




Workshop Overview



Congestion and Bottlenecks Identification, Diagnosis, and Solutions Workshop

Participant Workbook



Presented By
Federal Highway Administration



ACKNOWLEDGMENTS

This workshop on congestion and bottlenecks is sponsored by the Federal Highway Administration. Thank you for your participation in the course. An evaluation form is included within this workbook, to obtain your feedback. Please forward any additional comments to:

Project Leader Contact Information:

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Workshop Overview



- **Session One (70-90 min)**
 - **Workshop Overview (David Hale, Leidos)**
 - **Congestion and Bottleneck Concepts (Neil Spiller, FHWA)**
 - **Congestion and Bottleneck Identification (David Hale, Leidos)**
- **Break (15 min)**
- **Session Two (70-90 min)**
 - **Congestion Causal Pie Chart (Jiaqi Ma, Leidos)**
 - **Bottleneck Mitigation Strategies (Joe Bared, FHWA)**

Workshop Overview



Evaluation

CONGESTION AND BOTTLENECK WORKSHOP

Location: _____ Date: _____

Items will be rated on a scale ranging from 1 to 7 defined as follows:

1	2	3	4	5	6	7
Poor	Well Below Average	Below Average	Below Average	Good	Very Good	Excellent

Please circle the numbers below which reflect your ratings.

1. Do you feel that the objectives of this course were met? Yes ___ No ___

Comments: _____

2. Supervision and planning of the seminar or workshop was:

1	2	3	4	5	6	7
Poor			Average			Excellent

Comments: _____

3. Overall presentation was:

1	2	3	4	5	6	7
Poor			Average			Excellent

Comments: _____

4. Physical facilities were:

1	2	3	4	5	6	7
Poor			Average			Excellent

Comments: _____

5. Was the material generally presented at the correct level for this group?

Yes ___ No ___

Comments: _____

6. The course visual materials were:

1	2	3	4	5	6	7
Poor			Average			Excellent

Comments: _____

7. Overall value of the seminar or workshop to you, in your own words.

8. Suggestions for improvement.

9. What is your job title? _____

10. Employed by? Government ___ University ___ Private ___

Traffic Congestion and Bottlenecks



- Self-introductions
 - Name
 - Company
 - Reason for interest in workshop (optional)





Traffic Congestion and Bottlenecks

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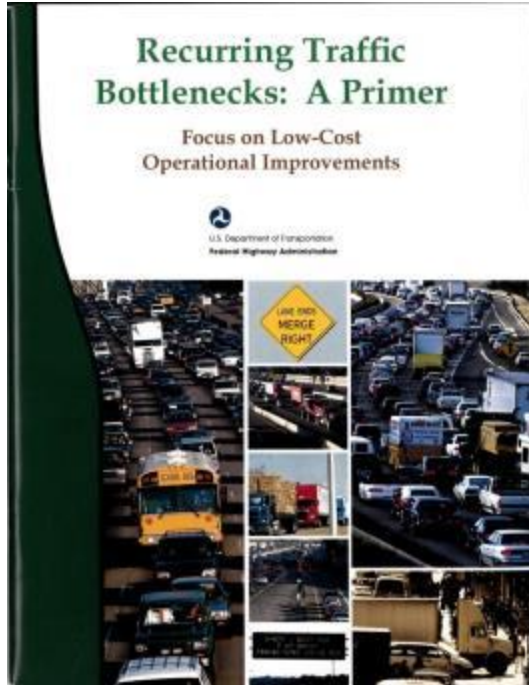
Workshop is Sponsored by



The Saxton Laboratory is located at the FHWA Turner-Fairbanks Research Center in McLean, VA.

- Comprised of three test beds:
 - Data Resources test bed (DRT),
 - Concepts and Analysis test bed, and
 - Cooperative Vehicle-Highway test bed (CVHT).

FHWA “Localized Bottleneck Reduction” Program



**FHWA BN Program
2006-2012**

**(Primer: c. 2012
Version 3)**

**FHWA BN Analysis
2013-2015**



FHWA “Localized Bottleneck Reduction” Program

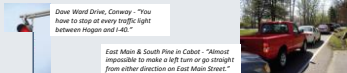


Arkansas

“Operation Bottleneck”

Metropolitan MPO (Little Rock region) conducted surveys – online, at public meetings, and via ads in the local newspapers – to solicit public comments in 2009. Local media was helped to promote the effort. Over 3,000 responses were received – in four weeks! Many responses validated already-planned projects. Some immediate actions were taken, such as foliage removed or cut back to improve sight distances, or missing or damaged signs were installed. In the short term, local governments will continue to use the information to:

- Consider new or additional traffic signage and signals
- Enhance signal coordination
- Support minor intersection improvements
- Improve access-ovelf (i.e., access management) situations as opportunities present



Dave Ward Drive, Conway. “You have to stop at every traffic light between Hogan and ads.”

East Main & South Pine in Cabot. “Almost impossible to make a left turn or go straight from either direction on East Main Street.”

Minnesota

Location – Minneapolis-St. Paul, Minnesota

Results of 2001 study of Ramp Metering Effectiveness

In September 2000, all 430 ramp meters were turned off in the Twin Cities region in response to a mandate from the MN State Legislature, following citizen complaints and questions raised by State Senator Dick Day, namely, do ramp meters work?



Objectives

- To fully explore effectiveness of ramp meters; meter “wait time” was also a key concern
- To respond to citizen’s questions and identify public perception of ramp metering
- To involve a citizens advisory board to ensure credibility of the study

Process and Findings

Cambridge Systematics was hired by MnDOT to perform the study, inclusive of getting pre-study data and incorporating any/all citizen input and ensuring a transparent process. Five weeks of “before” speed and crash data, et al, was recorded. The ramps were shut off for a pre-determined “transition” period and then turned back on for five weeks of “after” data gathering.

- Without meters
 - o 9% reduction in freeway volume; a 22 % increase in travel time; a 26% increase in crashes (even after adjusting for prior seasonal rates)
- Most survey respondents believed traffic had worsened
- After the study, 20% wanted meters left off; 10% want them “retuned”; 70% want modifications

Lessons Learned / Changes Implemented

- Neither “all” nor “nothing” was deemed best, but a new, modified approach was adopted.
 - o Fewer meters than before the study were turned back on (location candidacy was tightened and superfluous meters were removed)
 - o Hereafter, meters would wait no more than 4 minutes on local ramps or 2 minutes on freeway-to-freeway ramps
 - o Vehicles queued back to city streets will be “released” (meters temporarily shut off) and meter operation will better-respond to congestion-only times via improved use of detectors

Learned

Information is invaluable in validating concerns and providing an outlet for the public to be heard, confirm to the public that the agency is listening and can provide a response.

FHWA Localized Bottleneck Reduction Program

Florida

Location – Lake City, FL
715 to US-90

Problem – Main interchange for city is routinely congested.

The west-diamond interchange of I-95 and US-90 in the main exit to Lake City, FL, and the interchange for travel either in either direction. The area is about 2 1/2 hours of Orlando and Tampa. As it is a major routing point on the drive to these tourist areas. Nearby interchanges do not have many shoulders, so lanes of fast-lane, shoulder, truck, and car lanes. A barrier and have been built along US-90 very close to the interchange. This has led to a lot of congestion in the local area.



Solution – Intersection improvements and more turn lanes.

ICDOT studied several improvements including a roundabout. This project on the shoulder would require a right-of-way and the cost of construction was estimated to be \$1.5 million. Instead, the decision to study and test lanes in the off-street and improve the intersection directly east of the interchange on US-90. These improvements, only cost \$2.5M and can be completed in a much shorter time frame.

Lessons Learned

The design only involved adding turn lanes, reconfiguring intersections, and repaving the road. The bridge on US-90 was repaired and added as part of an interchange widening project in a week long and the new design will generate three bridge which will save \$4 of money. This will be a significant cost savings and provide a more attractive cost to maintain the passing through. This should lead to increased development and economic opportunities for the surrounding community and the city.

FHWA Localized Bottleneck Reduction Program

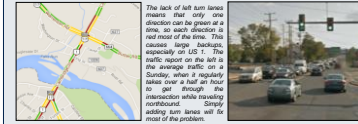
Virginia

Location – City of Fredericksburg (suburb of Washington)

US 1 and US 17 Business

Problem – No left turn lanes cause enormous backups

This intersection between two major US highways does not currently have left turn lanes on any of the four approaches. As a result, each of the four directions has to have its own signal phase for safety and operational reasons. Each approach gets about 20% of the green time, and this causes huge backups on all approaches throughout the day and even on weekends. US 1 is an important alternative to Interstate 96, which is also regularly congested.



The lack of left turn lanes means that only one direction can be given at a time, so each direction is the most of the time. This causes large backups, especially on US 1. The traffic report on the left is the average traffic on a Sunday, when it regularly takes over a half an hour to get through the intersection while traveling northbound. Simply adding turn lanes will fix most of the problem.

Solution – Turn Lanes

At \$22M for just one intersection, the project is fairly expensive (primarily because businesses at intersection were too close to the road and had to be condemned), but the benefits will be enormous. Left turn lanes will be added at all approaches and a few right turn lanes will be added. This will allow two directions of traffic to be green at once (i.e. NB and SB traffic can move at the same time, just at a normal intersection). Additionally, raised concrete medians will be added to prohibit left turns and out of businesses near the intersection. These simple improvements will decrease the average wait time at the intersection from 234 seconds to just 96 seconds when it is completed in 2011. Many people in Fredericksburg hop on I-66 for a few exits simply to avoid this intersection, and it causes a lot of congestion. Keeping locals off of the interstate will have a regional and national effect by keeping traffic flowing better on the interstate, all because of a small intersection improvement 15 miles away.

Lessons Learned

Traffic is expected to dramatically increase in the coming years as this area expands, and reducing intersection wait time will not only mitigate current traffic but also accommodate future congestion. With 7 changes, the average delay in 20 years will be better than the current average delay today. The project is expensive, but sometimes you need to invest a lot of money to avoid a major problem. Reducing delay on the interstate will allow people and goods to move more efficiently along the entire east coast.

FHWA Localized Bottleneck Reduction Program

Washington

Statewide “Moving Washington” Program since 2008

Moving Washington is the Governor’s 10-year, three-phased strategy to combat congestion: 1) *Drive Efficiently*, which exists; 2) *Manage Travel Demand*; and 3) *Add Capacity*, which itself is a three-tiered program:

- Tier 1’s are immediate, low-cost, operational fixes;
- Tier 2’s are medium-cost design-builds; and
- Tier 3’s are major future-planned system upgrades.

Problem – How to Make the Most of a Transportation Budget

Using a combination of annual and “ranked” state gas taxes, plus the normal Federal allocations, Washington uses a system of performance goals and measures to justify, warrant, and select candidate projects. Elected officials are educated to “buy in” to use metrics – and lesser political means – to determine projects. Achieving “maximum throughput” is the defining target for the basis for congestion relief decisions. “The annual percent of system that is congested” is defined as the % of lane miles that are routinely less than 70% of posted speeds. For more information: <http://www.wa.gov/movingwashington/>

Solution – Use Performance Measures as a Strong Decision Metric

Travel times and reliability are important measures to commuters and also to Washington in determining candidate projects. WSDOT aims to provide and maintain a system that yields the most productivity or efficiency, rather than focus on providing a system that is free flowing, but in which fewer vehicles can pass through a segment during peak. Maximum throughput is achieved when vehicles travel at speeds between 42 and 51 mph (roughly 70% to 85% of 60 mph) because more vehicles can pass a segment than would be at posted speeds. This happens because at the lesser speeds, vehicle headways can condense more safely. WSDOT measures “highway segmenters” (e.g. similar lane configurations, geometrics and adjacent land use) and targets the inefficient ones. Stand-alone segments are candidates for Tier 1 and Tier 2 projects (see above) and “linked” segments become candidates for Tier 3, all things considered.

Lessons Learned

In the 2000’s, several “capacity expansion projects” (a WSDOT euphemism for bottlenecks, et al) provided examples of WSDOT’s process:

- **I-405** – Adding either one- or two-lanes where necessary to reduce local congestion.
- **I-405 “South Believer”** – Adding general purpose NB and SB lanes, and a SB HOV lane.
- **SR 518** – Adding a third EB lane between I-5 and SeaTac Airport to reduce a long-suffering recurrent problem.
- **I-90 at Mill Plain East and 113rd connector** – create a direct connection to NE 112th Ave. from NB I-205 off-ramp to Mill Plain Blvd. This addressed safety problems too.
- **Increased use of intelligent technologies** – WSDOT has committed to investing in IT strategies like Active Traffic Management, more cameras and ramp meters, and strategies to manage demand (i.e. van pooling, park & ride, commute options). The ATM “Smarter Highways” signs on I-5 and SR 520, and soon-to-be on the I-90 floating bridge, are national models. In the U.S., only Minneapolis (I-95) has similar technology, on I-35W.

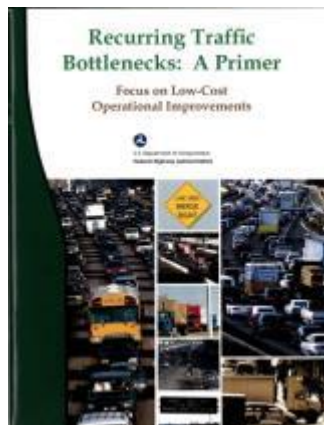
FHWA Localized Bottleneck Reduction Program

Case Studies

Real-World, Low-Cost!

Understanding Merging
“Why is recurring traffic like “cat herding?”

What is stopping us from fixing bottlenecks?



ops.fhwa.dot.gov/bn/index.htm

“(Combating) traffic is like combating ever-evolving weather fronts”

Are you a “profiteering” lane merger or an “altruistic” enabler?

Problem Statement



- U.S. traffic congestion is worsening, and the resulting economic damages are increasing
- A TTI report suggests that vehicle emissions are accelerating economic damages by causing short-term and long-term health issues (asthma, lung cancer, climate change) on top of traditional mobility-based economic costs
- There is decreasing reliability of surface transportation because studies show it takes more time to ensure on-time arrival/delivery/reliability.

Problem Statement



- Tight budgets for transportation
- Autonomous vehicles are not yet ready
- Agencies must demonstrate return-on-investment
- Mitigation of bottlenecks is a top priority
- This workshop
 - describes new methods of precise congestion identification
 - updates the congestion causal pie chart
 - presents new research on bottleneck mitigation

Workshop Overview



We will cover:

1. Congestion and bottleneck concepts
2. Congestion and bottleneck identification methods
3. Modernized causes of congestion pie chart
4. Featured bottleneck mitigation strategies



- 1. Congestion and bottleneck concepts**
2. Congestion and bottleneck identification methods
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Difference between . . .



- Nonrecurring
 - When an **event** occurs (*The delay dissipates when the event is removed*)
- Recurring
 - “Bottleneck” -- When an **operational influence** is overwhelmed by traffic overburden (*The delay dissipates when the overburden subsides*)
 - “Systemic” -- overarching; urban density; pervasive (*Can be reduced by reducing demand on automobile trips*)

event = weather, accident, incident, work zone

operational influences = on/off ramps, merges, lane drops, curves, traffic signals, junctions, narrow underpasses

“Congestion” vs “Bottlenecks”



A “bottleneck is congestion” but “congestion” is often-times more than just a bottleneck.

Speaking of “Recurring” congestion --

When too many vehicles compete along all segments of a facility, "congestion" will inevitably result, and is overarching. But when only determinant, subordinate segments of that facility are routinely over taxed, then "operationally recurring bottlenecks" within the facility are said to exist.

Speaking of “Nonrecurring” congestion – the event-based problem is temporary and therefore is usually termed “an incident” and not pervasive “congestion”

Defining Bottleneck Congestion



“Localized sections of highway where traffic experiences reduced speeds and delays due to recurring operational conditions or nonrecurring traffic-influencing events”

- Characterized by generally low speeds, high delays
- Measured differently by planners, engineers, academics
- All BN's have **Duration, Intensity, Variability, Extent (DIVE)**
- Congestion occurs pervasively along entire corridor
- *Recurring* bottlenecks repeat at specific locations
 - Cause 40-80%(?) of all congestion
 - Caused by “operational influence” + traffic overburden
 - Can often be mitigated with low-cost solutions



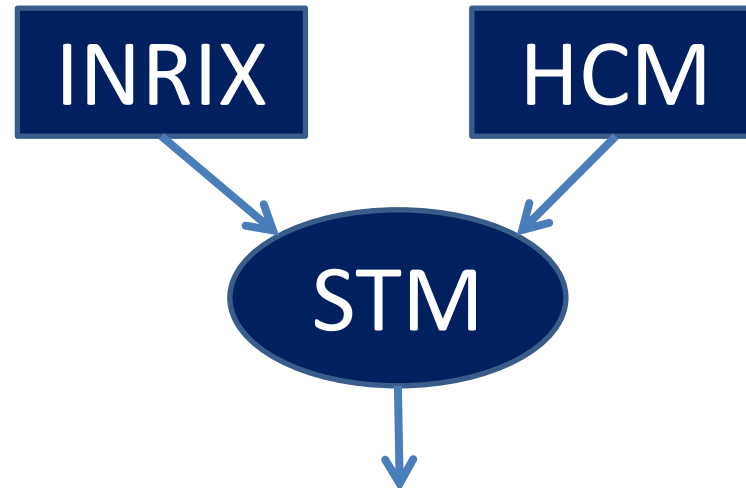
- Duration
 - How long did the event last?
- Intensity
 - Computed as a 2-D percentage of congestion
- Variability
 - Percentile difference between that day and a “nominal” day
- Extent
 - Longest horizontal length of the BN

D. I. V. E. exists regardless of whether recurring or nonrecurring

Spatiotemporal Traffic Matrix (STM)



“Measurements” versus “Models”

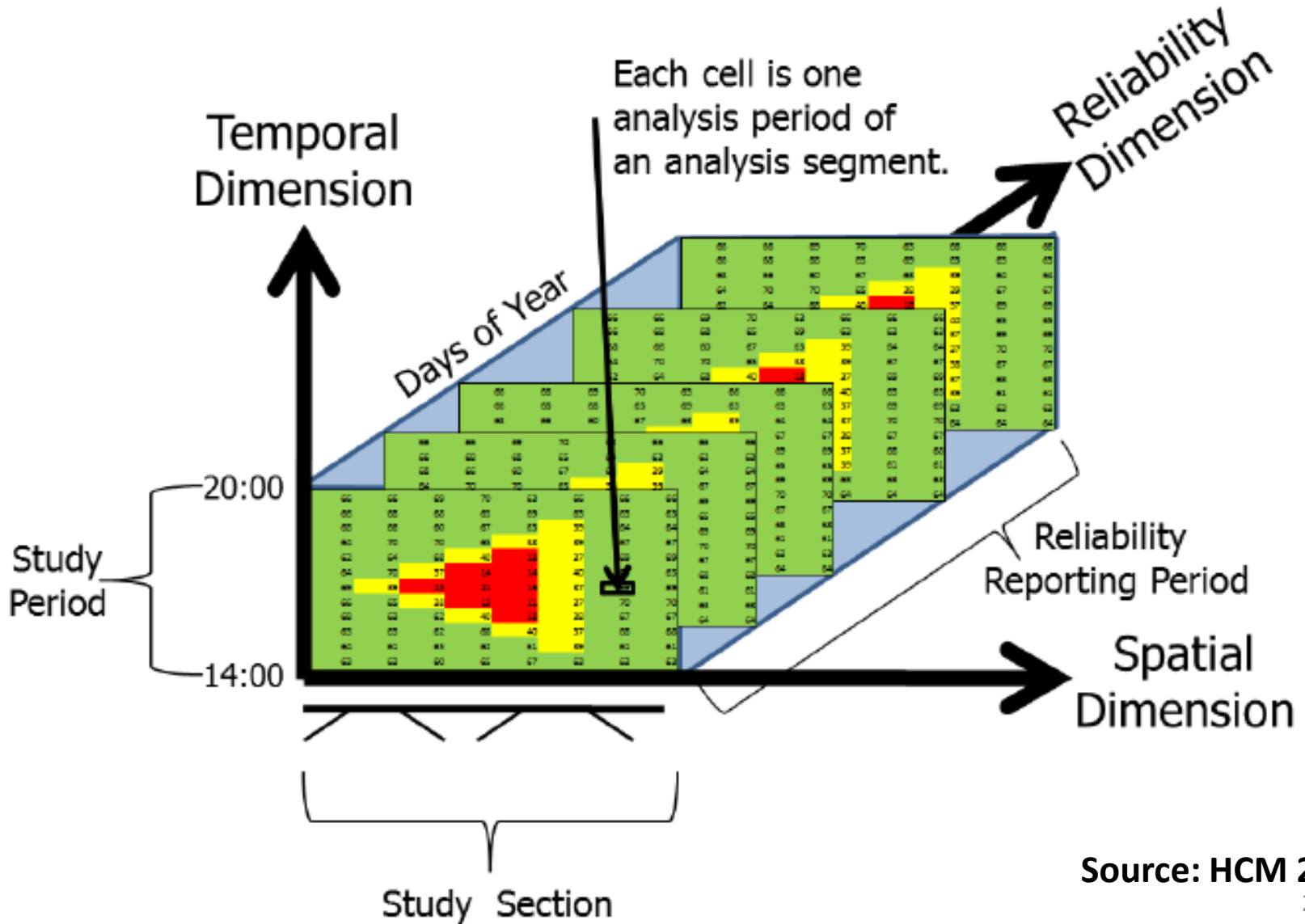


**Performance
Measures**

1. Duration
2. Intensity
3. Variability
4. Extent

**Prioritize
Locations**

Spatiotemporal Traffic Matrix (STM)



Source: HCM 2010

Bottleneck Solutions



- Solutions “playbook”
 - Developed by Texas A&M, Cambridge Systematics
 - Framework with 7 bottleneck categories
 - Each category has many proposed solutions
 - Report appendix (40 pages) details all 70 solutions
- Micro-simulation and benefit-cost analysis
 - 5 promising cost-effective solutions
- Alternative intersections/interchanges (DDI, RCUT, MUT, DLT)
- Additional innovative treatments (Spring 2015)

Bottleneck Solutions



Geometric Fixes

- widen
- lengthen
- grade-separate
- CF intersections
- roundabouts
- auxiliary lanes
- restripe

Operational Fixes

- reversible lanes
- signal modifications
- signal redesign
- frontage system
- close, combine or relocate a ramp(s)

Active Traffic Mgmt.

- ramp metering
- use hard shoulders
- speed harmonization
- managed lanes
- variable speed limits
- queue jumps
- signal priority

Overlap . . .

- access management
- redesign
- restore lane continuity

Active Bottleneck

Geometric Challenges				Operational Challenges		
Roadway Specific	Facility Specific	Specific to Interchanges	Intersections /TCD/ITS	Agency Related	Driver Related	Non-motorist Related
<ol style="list-style-type: none"> 1. Design Speed 2. Number of Lanes 3. Lane Width 4. Presence and Type of shoulders 5. Lane drops 6. Lane reduction transition 7. Hz clearance 8. VI clearance 9. Sun Glare Alignment 10. Hz alignment 11. VI alignment 12. SSD 13. Pavement friction/surface 14. Cross Slope 15. Super-elevation 16. Access pts 17. Mid-block Crossing 18. Medians 19. Lighting/Glare 	<ol style="list-style-type: none"> 1. Bridges 2. Tunnels and underpass 3. Collector-distributor network 	<ol style="list-style-type: none"> 1. Merge and diverge sections 2. Auxiliary lanes 3. Weaving areas 4. On-ramp/off-ramp 5. Acceleration/ deceleration lanes 	<ol style="list-style-type: none"> 1. Intersection sight distance 2. Left-turn and Right-turn lane overflow 3. Parking 4. TCD (signal, stop sign, etc.) 	<ol style="list-style-type: none"> 1. Managing demand 2. Intersection spacing 3. Interchange spacing 4. Policy on entry/exit ramp placement 5. Posted speed limit (static/dynamic) 6. Signal timing administration 7. Traffic composition 8. Work zone 9. Roadway closure administration 10. Incident management and clearance 11. Ramp metering 12. Heavy vehicle lane restrictions 	<ol style="list-style-type: none"> 1. Bunching vehicle 2. Roadside distraction/rubbe rnecking 3. Non-roadside distractions 4. Unsafe vehicle condition for weather condition 5. Aggressive lane change/weaving 6. Driving unauthorized roadway section 7. Driver performance in work zone 8. Driver performance when involved in an incident 	<ol style="list-style-type: none"> 1. Sub-optimal peds and bicyclist performance

10. Sub-optimal Driver Performance with regard to emergency vehicles

a. Description/Definition of the Element

- i. Drivers may slow down and/or get distracted when they hear emergency vehicle sirens, but cannot locate the direction the vehicle is coming from.
- ii. Drivers may slow down *below* the design speed limit when they are traveling near a law enforcement vehicle, even if the vehicle is not responding to an emergency.

b. Theoretical/Empirical Effects: Drivers who do not move over or are slow to move over can slow emergency services.

c. Existing Solutions

- i. Emergency Vehicle Preemption (EVP) - uses “special control features in traffic signals to provide clear guidance on whether autos should stop (providing a red display) or go (providing a green display) at signalized intersections during the approach of Emergency Vehicles (EVs). In these systems, ITS systems attempt to reduce the “surprise” factor, which may cause drivers to make bad decisions or perform poorly. The benefit of the ITS is the change in the performance of the traffic flow as a result of improved driver behavior.”^{clxvii}
- ii. Larger Shoulders for vehicles to pull over.
- iii. Properly timed signals that coordinate with emergency vehicles
 - i. Sirens that can be heard consistently rather than when the vehicle is right behind you.
 - ii. Enforcement and stricter penalties for non-compliance

d. New Solutions

- i. Interaction with ITS and personal GPS devices as well as automated vehicle guidance systems to alert drivers ahead of time

Summary



- Traffic congestion is worsening
 - Economic damage, vehicle emissions, decreasing reliability
- Tight budgets for transportation
- Connected/autonomous vehicles not ready
- Agencies must show return on investment
- Need precise identification of bottlenecks
- Bottleneck mitigation strategies
 - Mobility analysis, benefit-cost analysis

Preview – Next Session



1. Congestion and bottleneck concepts
- 2. Congestion and bottleneck identification methods**
3. Modernized causes of congestion pie chart
4. Featured bottleneck mitigation strategies



Congestion and Bottleneck Identification

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Workshop Overview

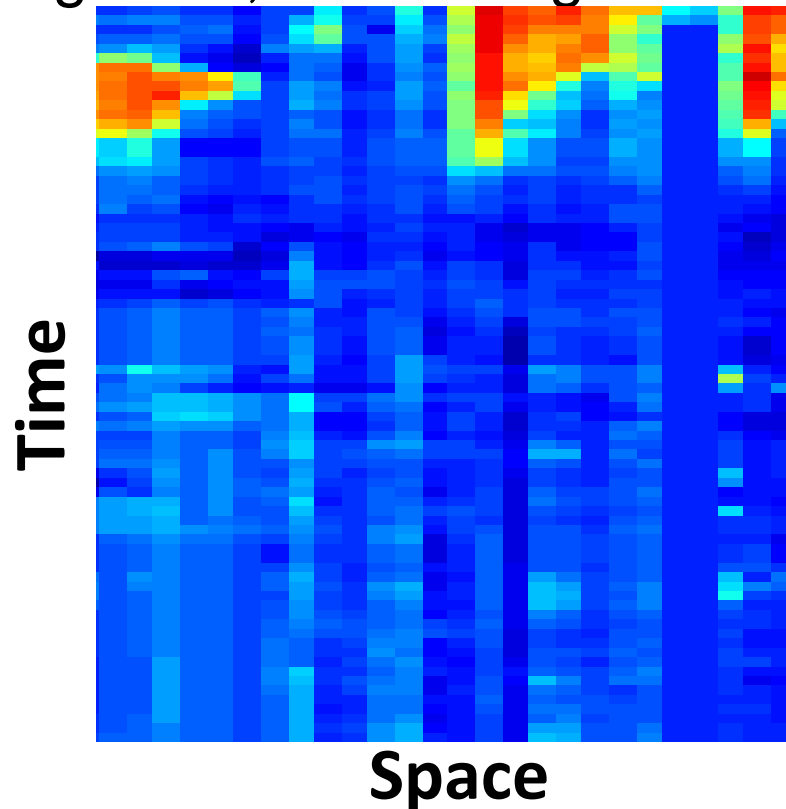


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Introduction



- Space-time matrix (STM) helps identify congestion
- Several colors represent several speed levels
- A simpler (two-color) matrix could identify bottlenecks
 - Blue = uncongested, red = congested

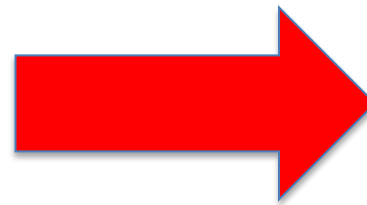
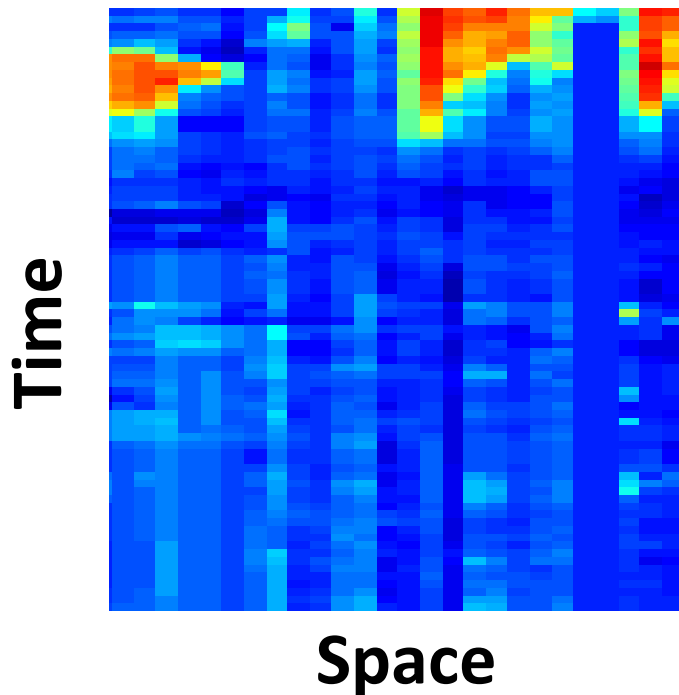


Introduction

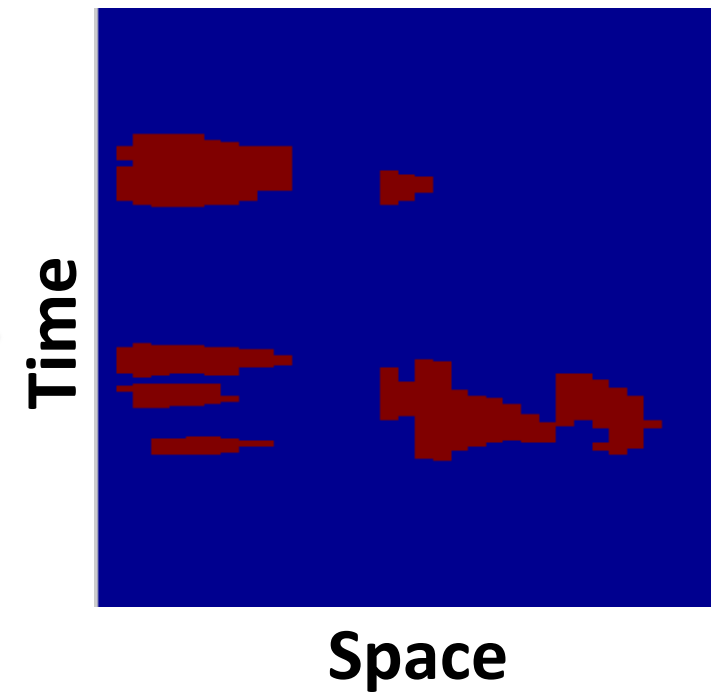


- Cut-off speeds can convert raw matrix to binary matrix
 - Blue = uncongested, red = congested

RAW MATRIX



BINARY MATRIX



Factors Affecting Cutoff Speed



- Arterial vs. Freeway
 - Arterials have lower cut-off speeds
 - 45 mph considered slow on freeway?
 - 25 mph considered slow on arterial?
- Urban vs. suburban
- Free-flow speeds (or posted speed limits)
- Work zones
- Weather conditions, visibility levels
 - VTTI algorithm computes cut-off speeds
 - accounts for weather, visibility, and free-flow speed

Cutoff Speed Model Development



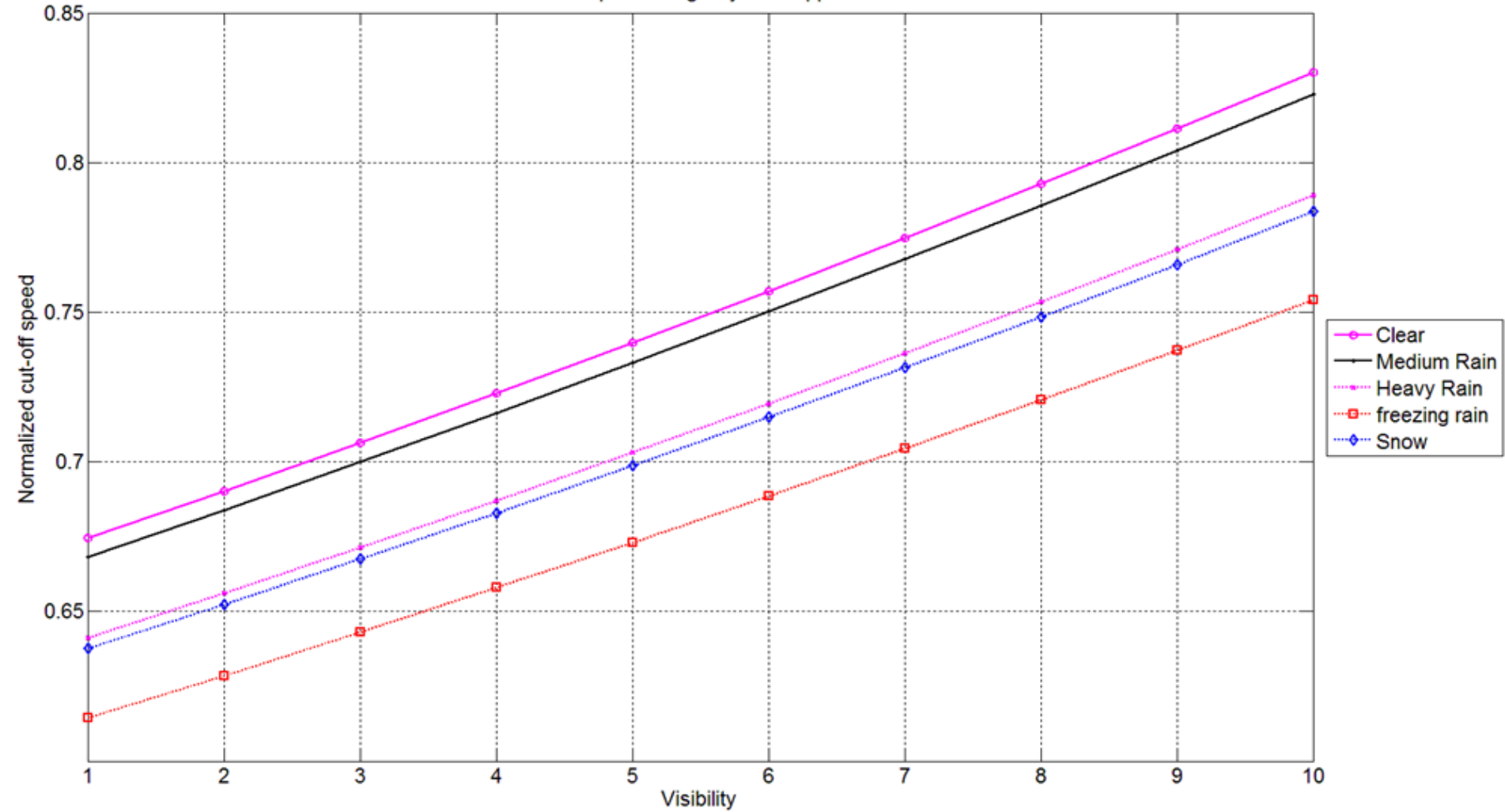
- Based on INRIX data from VA, CA, and TX
 1. 2011~2013 data along I-66 eastbound
 2. 2012 data along US-75 northbound
 3. 2012 data along I-15 southbound



Cutoff Speed Model



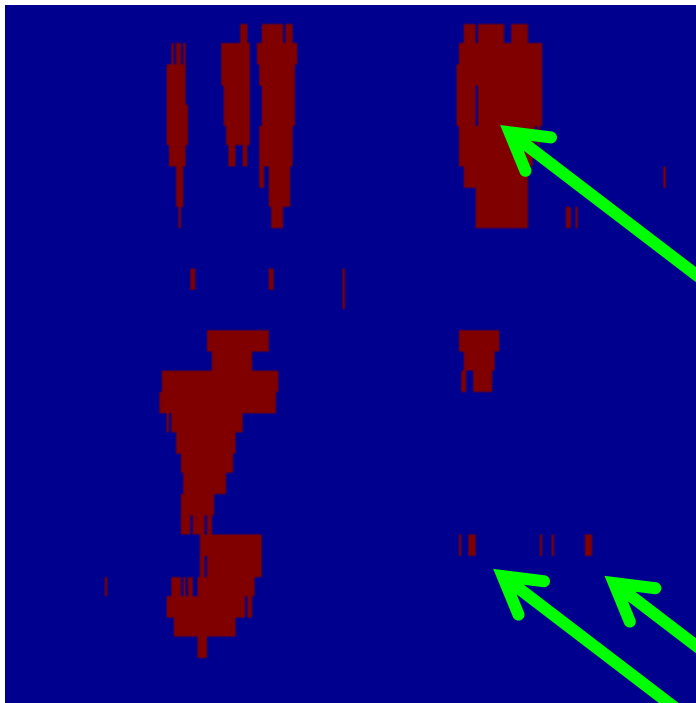
Cut-off speed using Bayesian approach



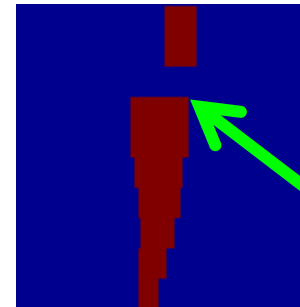
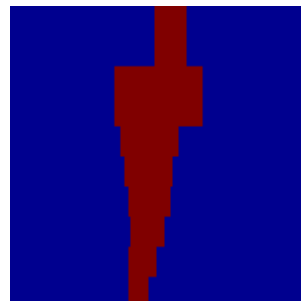
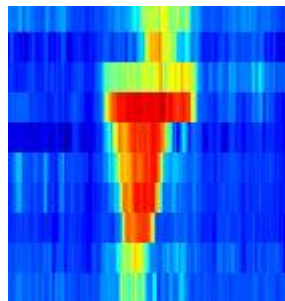
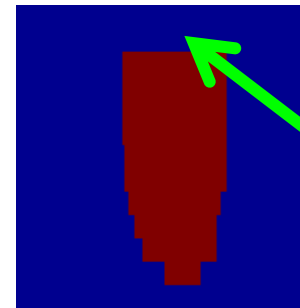
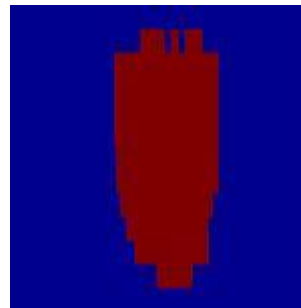
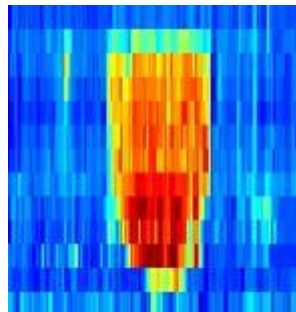
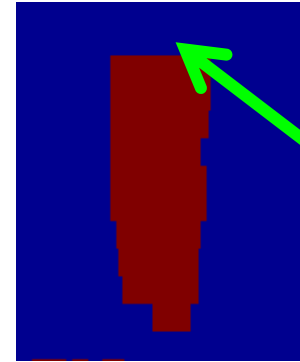
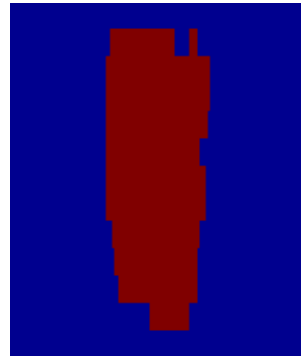
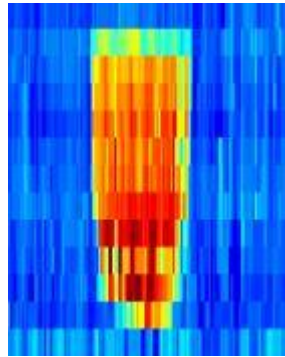
Bottleneck Matrix Processing



- Eliminate “noise”
- Fill in missing data



Bottleneck Matrix Processing



Speed matrix

before removing
acceleration area

after removing
acceleration area

Bottleneck Matrix Processing



- “Delay caused by bottleneck” calculation
 - For segment i at time interval t , need actual speed, and free-flow speed

$$d_i(t) = l_i \times q_i(t) \times \left(\frac{1}{u_i(t)} - \frac{1}{u_f} \right)$$

$$\text{Total Delay} = \sum_{\Omega} d_i(t)$$

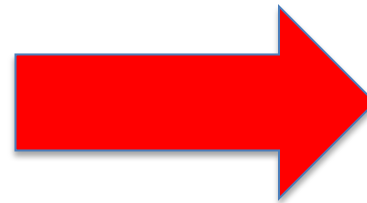
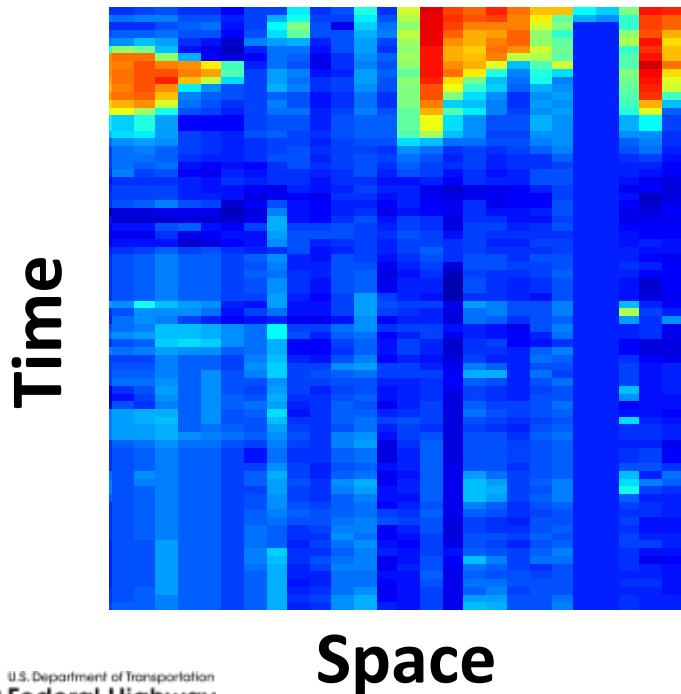
d = delay, l = length, q = flow, u = speed

Arterial Congestion Identification

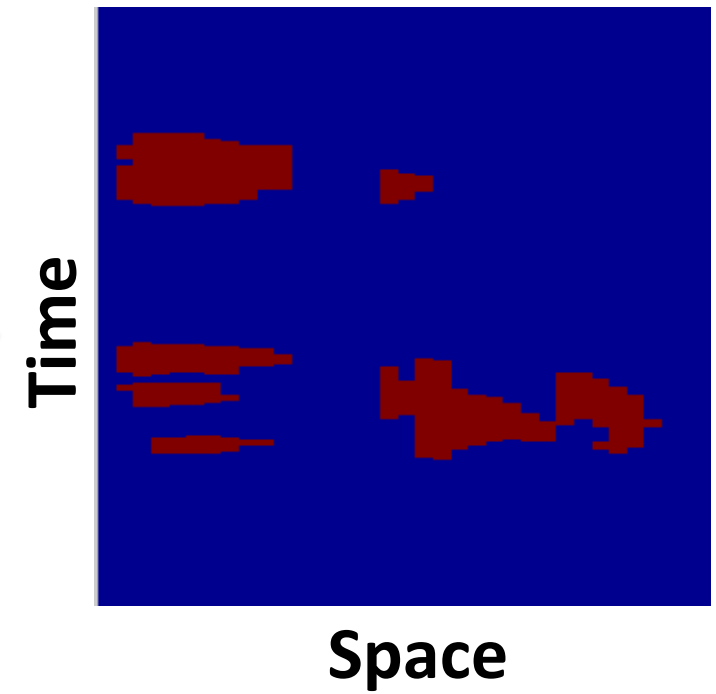


- Some delay caused by signals (not congestion)
- Lower accuracy of INRIX data on arterials
- Wavelet model might help

RAW MATRIX



BINARY MATRIX



Software Tool Overview



- VTTI tool features
 - Algorithm to compute bottleneck cut-off speeds
 - Graphical spatiotemporal matrix (STM)
 - Weather and visibility modeling
 - Filters for acceleration areas and “noise”
 - Delay due to bottleneck, shockwave speed
- CBI tool features
 - User-defined bottleneck cut-off speeds
 - Graphical spatiotemporal matrix (STM)
 - Intensity and variability statistics, percentile results
 - Directly imports INRIX files
 - User-friendly GUI (graphical user interface)

Congestion and Bottleneck Identification (beta version)

Data Import Filters

Direction: NORTHBOUND

Universal Filters (Graphical and Numeric)

Free-Flow Speed: From File

Cut-Off Speed:

Hours:

<input type="checkbox"/> 12 am	<input type="checkbox"/> 4 am	<input type="checkbox"/> 8 am	<input type="checkbox"/> 12 pm	<input checked="" type="checkbox"/> 4 pm	<input type="checkbox"/> 8 pm
<input type="checkbox"/> 1 am	<input type="checkbox"/> 5 am	<input type="checkbox"/> 9 am	<input type="checkbox"/> 1 pm	<input checked="" type="checkbox"/> 5 pm	<input type="checkbox"/> 9 pm
<input type="checkbox"/> 2 am	<input type="checkbox"/> 6 am	<input type="checkbox"/> 10 am	<input type="checkbox"/> 2 pm	<input checked="" type="checkbox"/> 6 pm	<input type="checkbox"/> 10 pm
<input type="checkbox"/> 3 am	<input type="checkbox"/> 7 am	<input type="checkbox"/> 11 am	<input checked="" type="checkbox"/> 3 pm	<input type="checkbox"/> 7 pm	<input type="checkbox"/> 11 pm

Mode: Congestion Cutoff Model Proportional

Spatiotemporal Matrix Graphical Display Filters

Date: 2014-09-22 Gridlines Labels Hotspots

Numeric Performance Measure Filters

Period: Daily

Centile: 85th Intensity

Months:

<input type="checkbox"/> Jan	<input checked="" type="checkbox"/> Apr	<input checked="" type="checkbox"/> Jul	<input checked="" type="checkbox"/> Oct
<input type="checkbox"/> Feb	<input checked="" type="checkbox"/> May	<input checked="" type="checkbox"/> Aug	<input checked="" type="checkbox"/> Nov
<input checked="" type="checkbox"/> Mar	<input checked="" type="checkbox"/> Jun	<input checked="" type="checkbox"/> Sep	<input checked="" type="checkbox"/> Dec

Data Files

Main:

TMC:

Import Data Successfully imported 954556 records

Numeric Performance Measures

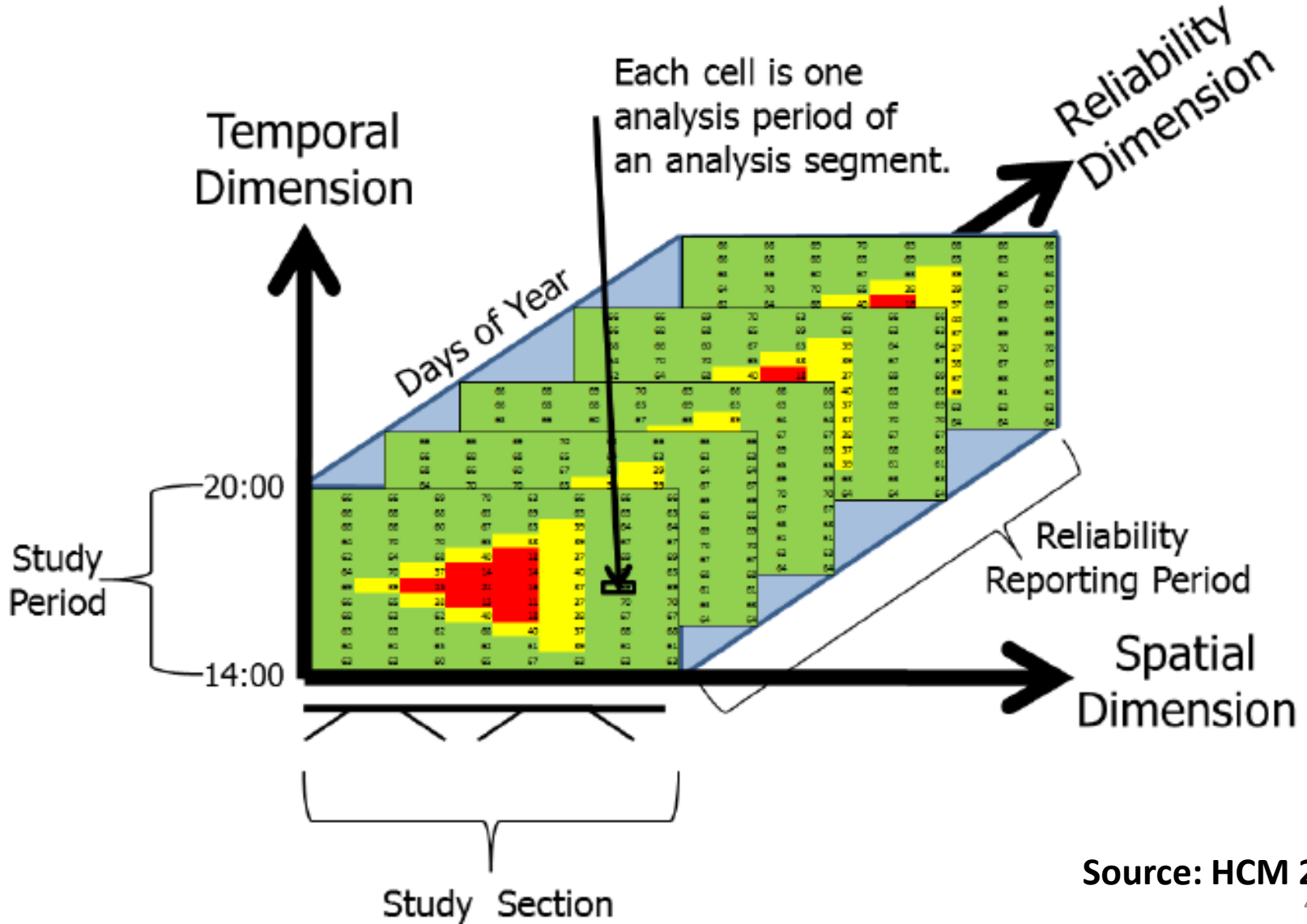
Duration: 80 minutes at mile 3.5 (out of 6.6)

Intensity: 3.5% Speed Drop: 0.5%

Variability: N/A

Extent: 0.9 miles at interval 28 (out of 48)

Spatiotemporal Traffic Matrix (STM)

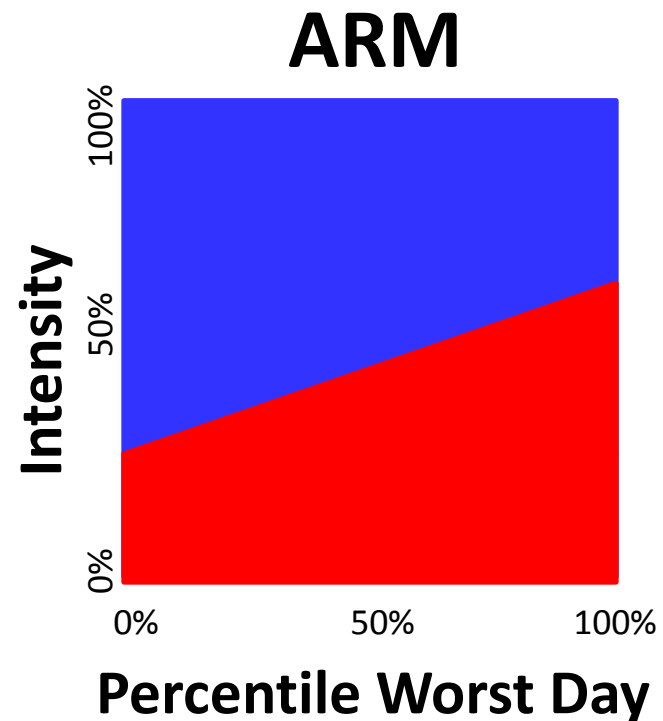
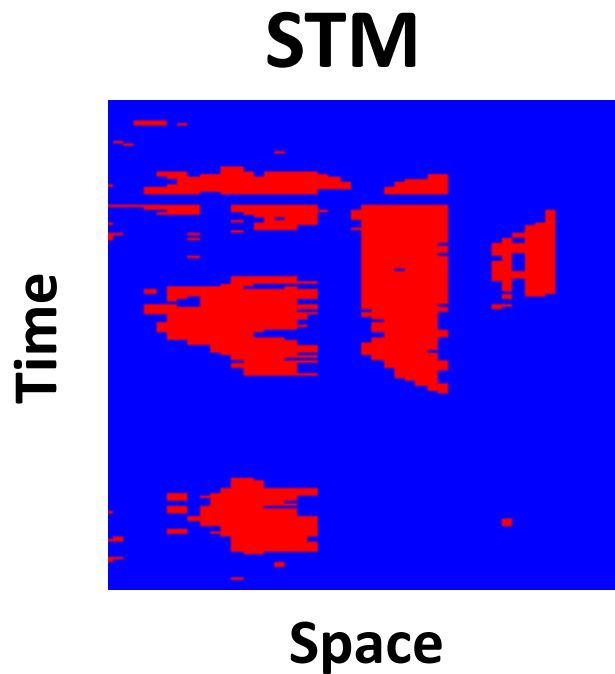


Source: HCM 2010

STM Versus ARM



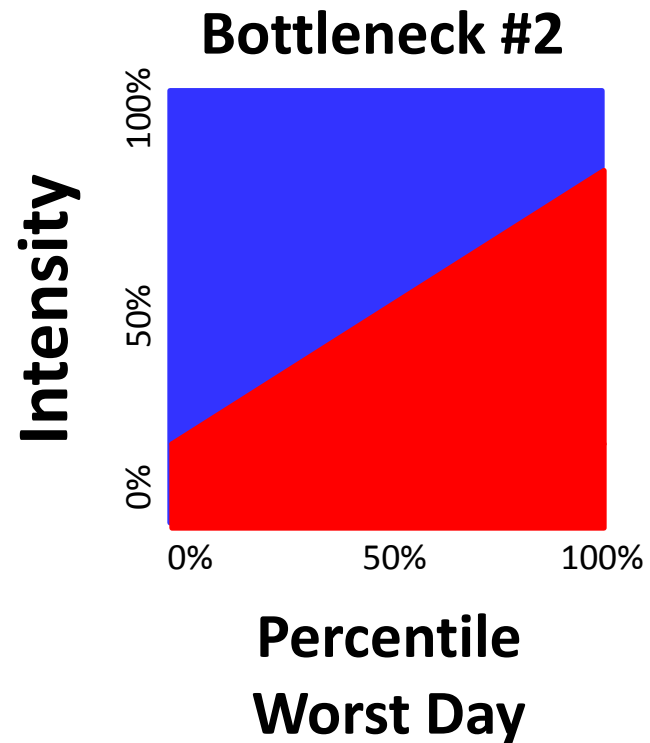
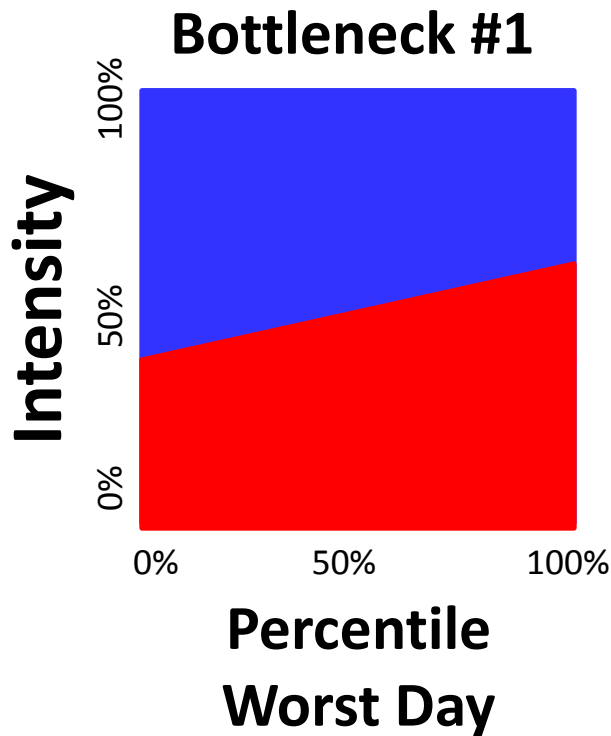
- STM (Spatiotemporal Traffic State Matrix)
- ARM (Annual Reliability Matrix)



Comparing ARMs



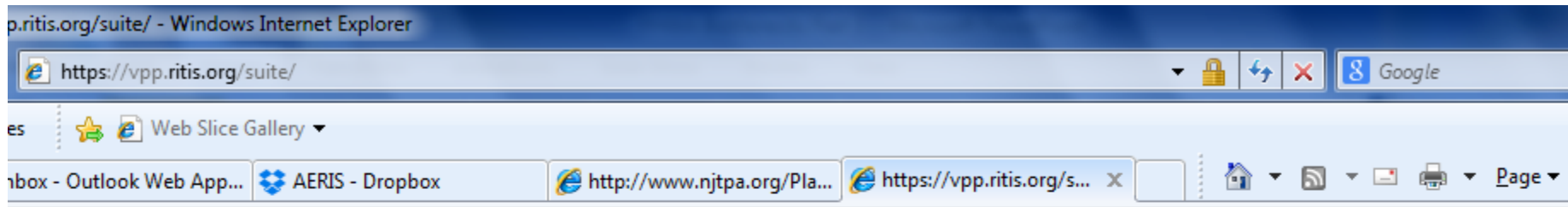
- STM (Spatiotemporal Traffic State Matrix)
- ARM (Annual Reliability Matrix)



Software Tool Overview



- Downloading INRIX files from RITIS
 - Readings.csv
 - TMC_Identification.csv
- <https://vpp.ritis.org/suite/download/>



Sign in to your RITIS account

Email address

Password

The Vehicle Probe Project Suite



Access to the Vehicle Probe Project Suite is linked to your [RITIS](#) account. If you do not have a [RITIS](#) account, you can request one [here](#).

In addition, only members of public sector agencies that have signed the [Vehicle Probe Data Use Agreement](#) will be granted access to the Vehicle Probe Project Suite.

Software Tool Overview



2. Date Range

01/01/2014 - 12/31/2014

+ Add another date range

3. Days of week

Sun Mon Tue Wed Thu Fri Sat

4. Time of day

12 : 00 AM -to- 11 : 59 PM

+ Add another time of day

5. Fields

Speed Historic average speed Reference speed
 Travel time Confidence score C-Value

6. Averaging

Don't average 5 minutes 10 minutes
 15 minutes 30 minutes 1 hour

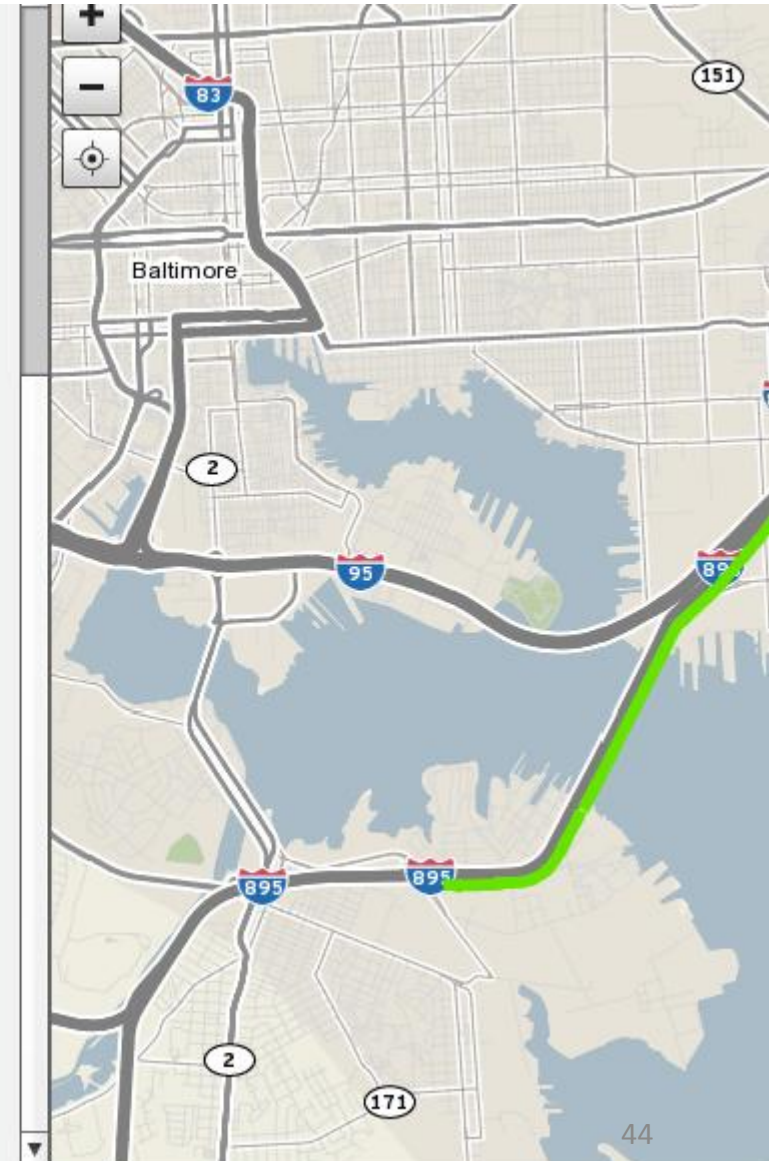
7. Description

Northbound I-895

8. Notification

Send me an email when this export is ready

Submit download request



Software Tool Demo



[Play demo](#)

Example of Ranking Bottlenecks



- In practice, probably better to compare bottlenecks
- However, our test datasets are full corridors
- Example problem
- PM peak hour analysis only (4-7 PM)
- One year of historical data (2014)
- Bottleneck mode only
- Proportional segments (length matters)
- 25 mph arterial cut-off speed
- 45 mph freeway cut-off speed
- 85th percentile intensity (speed drop tiebreaker)

Ranking Freeway Bottlenecks



- Annual intensity and reliability
 - Bottleneck Intensity Index (BII), Speed Drop (SD)

I-695

BII 52%

SD 33%

I-495

BII 46%

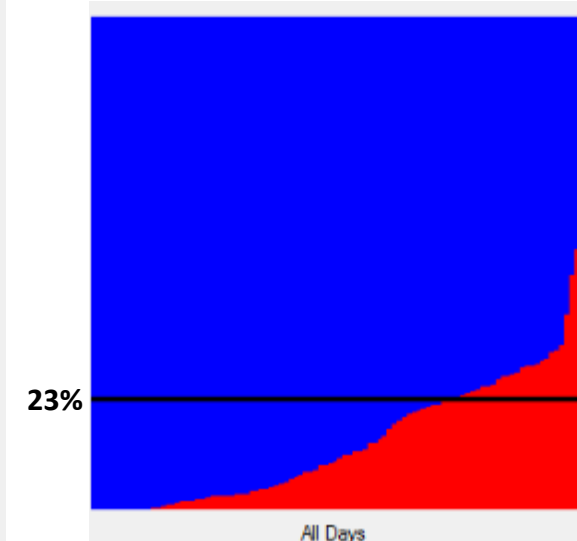
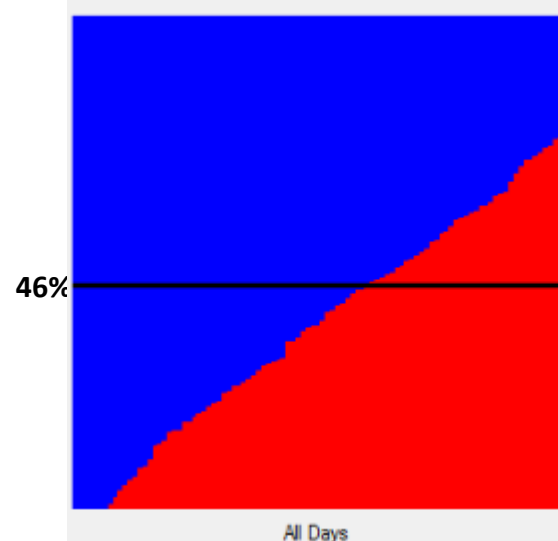
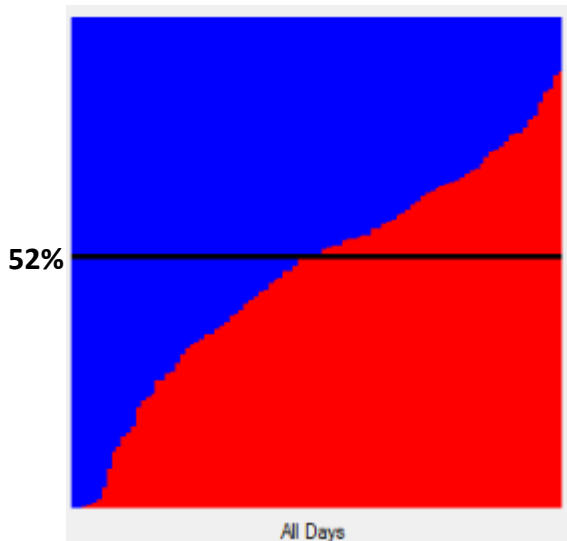
SD 17%

I-895

BII 23%

SD 11%

←---Intensity--->



←---Percentile worst day--->

Ranking Arterial Bottlenecks



- Annual intensity and reliability
 - Bottleneck Intensity Index (BII), Speed Drop (SD)

US-13

BII 64%

SD 21%

MD-147

BII 24%

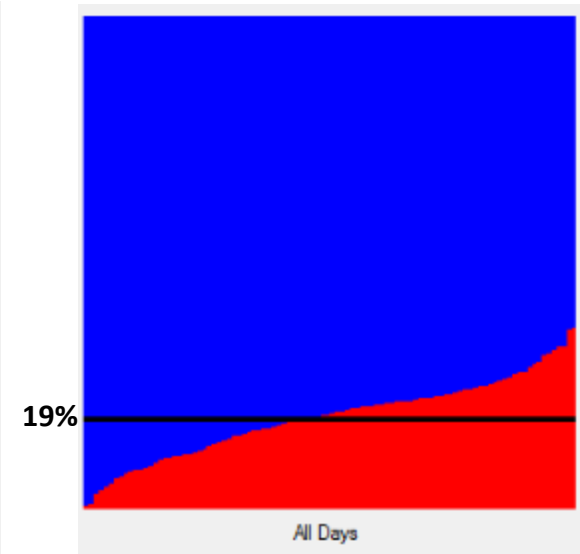
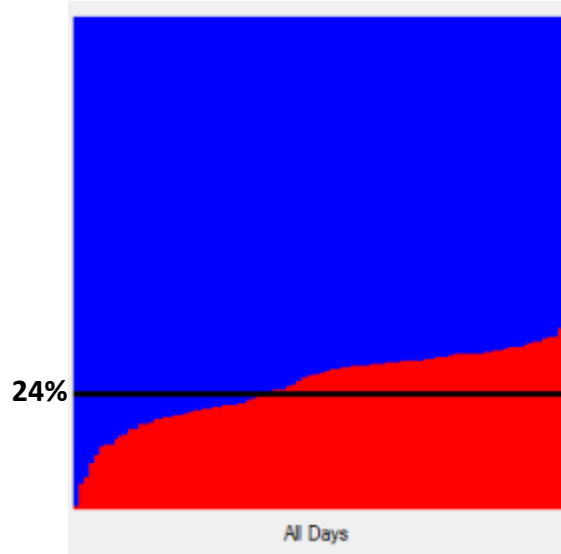
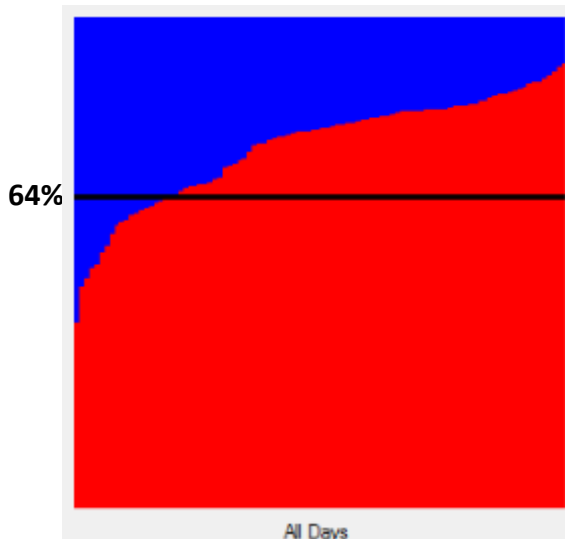
SD 6%

US-50

BII 19%

SD 6%

←---Intensity--->

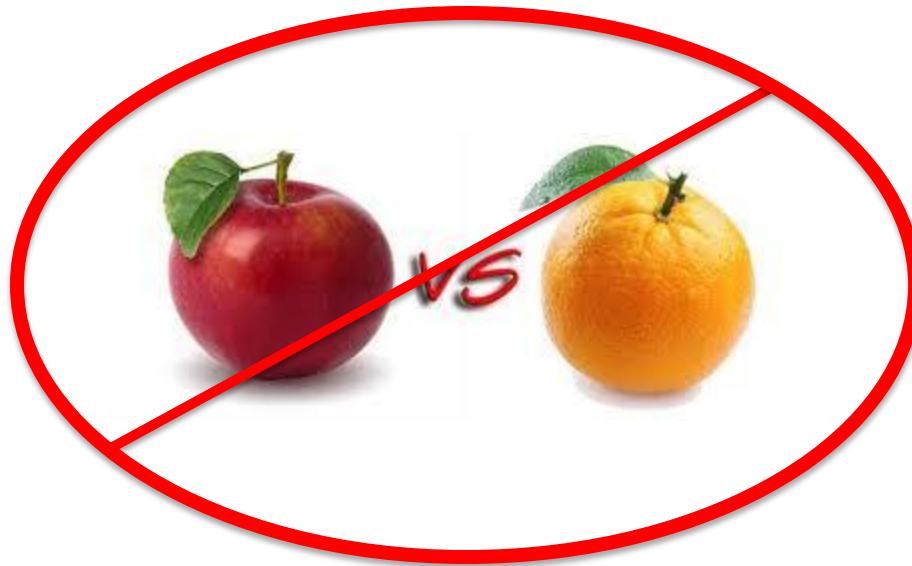


←---Percentile worst day--->

Ranking Bottlenecks



- When comparing different INRIX datasets...
- They should have the same
 - Interval duration (e.g., 5-minute)
 - Corridor length (sum of all segments)
 - Hours of day, days of week, months of year



Possible Future Development



- VTTI models and processing methods
 - Import and analyze weather and visibility data
 - Eliminate noise and acceleration areas
 - Fill in missing data
 - Shockwave speed, delay due to bottleneck
- Wavelet model for surface arterials
 - Filter out mandatory signal delay
- Batch processing
 - Automatically load and rank numerous datasets
- New performance measures
 - Travel time index, variance, standard deviation, others?

Summary



- Precise assessment of bottlenecks
- Customize your analysis with software
 - Time period of analysis
 - Congestion cut-off speed
 - Percentile results
- Prioritize problem areas
- Justify transportation investments



1. Congestion and bottleneck concepts
2. Congestion and bottleneck identification methods
- 3. Modernized causes of congestion pie chart**
4. Featured bottleneck mitigation strategies



Congestion Pie Chart

Identification, Diagnosis, Solutions



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Workshop Overview



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**FHWA Report, "Traffic Congestion and Reliability:
Linking Solutions to Problems" July 2004**



Data-Driven Analysis



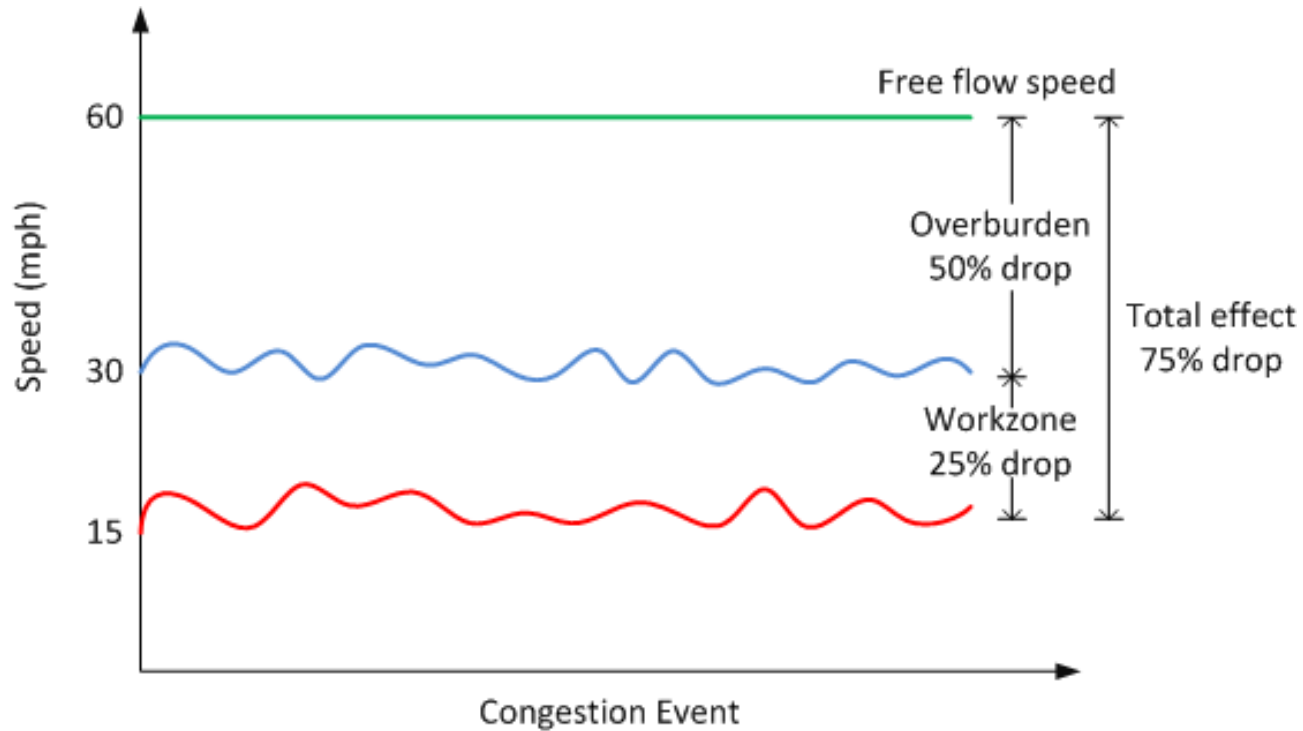
- Data continuously collected in the field
 - Incident code (0 = no incident, 1 = incident)
 - Weather code (0 = good weather, 1 = bad weather)
 - Workzone code (0 = no active wz, 1 = active wz)
- Congestion identification (using VTTI method)
 - Congestion code (0 = uncongested, 1 = congested)
 - “Speed drop” percentage

Data-Driven Analysis



- Dilemma of “multiple factors”
- How to measure impact of “overburden”
 - $v/c > 100\%$
- Example problem:
 - Free-flow speed = 60 mph, actual speed = 15 mph
 - 75% speed drop
 - Workzone code = 1 (weather & incident codes = 0)
- How much speed drop caused by $v/c > 1$ (Overburden)?
- How much speed drop caused by workzone?

Data-Driven Analysis

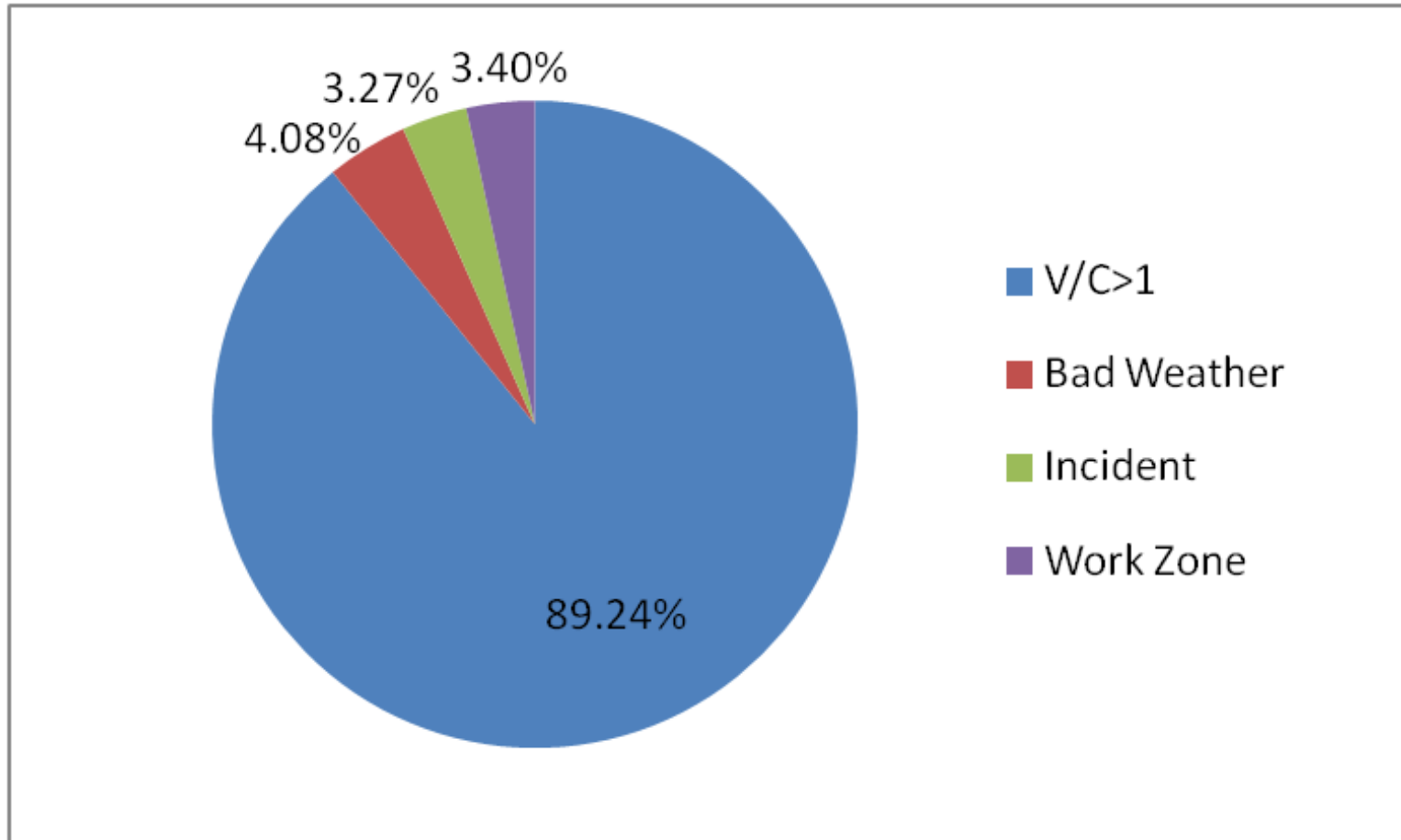


	Speed Drop	Final
Overburden	50%	66.7%
Workzone	25%	33.3%

Eastbound I-66 Pie Chart



- Updated, weighted pie chart with spatio-temporal effects



Pie Chart Software



- Open-source tool
- Compatible with Microsoft Access

Congestion Events

Congested Road Segments:

1)	Rd: 1	MM: 30	Time: 7:00:00 AM
2)	Rd: 1	MM: 30	Time: 7:00:00 AM
3)	Rd: 1	MM: 31	Time: 7:00:00 AM
4)	Rd: 2	MM: 10	Time: 2:00:00 PM
5)	Rd: 2	MM: 20	Time: 4:30:00 PM
6)	Rd: 2	MM: 22	Time: 4:30:00 PM
7)	Rd: 3	MM: 15	Time: 3:30:00 PM
8)	Rd: 3	MM: 15	Time: 4:30:00 PM

Road: 1
Start Mile Marker: 31
End Mile Marker: 31
Date: 1/8/2013
Start Time: 7:00:00 AM
End Time: 9:00:00 AM
Localized
Non-Recurring
Non-Repeatable
Causality:
V/C > 1: 48.86%
Congestion Cause 1 (weather) (1): 41.29%
Congestion Cause 2 (work zone) (1): 9.85%

Surface Arterial Pie Chart



- How difficult to find congestion causes?
 - Arterials much more difficult than freeways
- Complexity of field data sources
 - Not uniform, not standardized
 - Inductive loops, radar, video, ITS devices
- Possible arterial congestion causes
 - Poor signal timing
 - Inadequate geometry
 - Multimodal effects
 - Safety designs
 - Freeway congestion causes (weather, incidents, work zones, overburden)

Arterial Data Analysis



Incidents on Eastbound of Broward Blvd.

Type	Date	Time	Road	Location	Duration
Congestion	8/5/2014	8:21:20	SR-842 EB	US-1	95
Congestion	8/7/2014	8:07:24	SR-842 EB	US-1	25
Congestion	8/7/2014	10:52:29	SR-842 EB	US-1	265
Congestion	8/8/2014	7:48:29	SR-842 EB	US-1	422
Congestion	8/12/2014	8:42:42	SR-842 EB	NW 7 Ave	80
Vehicle Alert	8/12/2014	9:55:05	SR-842 EB	NW 7 Ave	5
Road Work - Scheduled	8/12/2014	10:16:33	SR-842 EB	Andrew Ave	117
Congestion	8/14/2014	7:52:09	SR-842 EB	US-1	124
Congestion	8/18/2014	7:55:51	SR-842 EB	I-95	10
Congestion	8/18/2014	8:41:23	SR-842 EB	Andrew Ave	60
Congestion	8/19/2014	8:50:22	SR-842 EB	US-1	118
Disabled Vehicle	8/20/2014	8:24:22	SR-842 EB	I-95	24
Congestion	8/20/2014	9:12:22	SR-842 EB	NW 7 Ave	21
Congestion	8/21/2014	9:07:09	SR-842 EB	NW 7 Ave	21
Road Work - Scheduled	8/21/2014	12:32:12	SR-842 EB	US-441	48
Road Work - Scheduled	8/21/2014	17:40:03	SR-842 EB	US-441	23
Congestion	8/22/2014	8:28:44	SR-842 EB	I-95	76
Congestion	8/25/2014	7:48:28	SR-842 EB	Andrew Ave	170
Disabled Vehicle	8/25/2014	17:16:05	SR-842 EB	US-1	15
Congestion	8/25/2014	8:12:09	SR-842 EB	NW 7 Ave	72
Congestion	8/27/2014	7:41:22	SR-842 EB	I-95	15
Congestion	8/27/2014	8:21:10	SR-842 EB	NW 7 Ave	122
Congestion	8/28/2014	7:25:25	SR-842 EB	NW 7 Ave	127
Road Work - Scheduled	8/28/2014	10:16:05	SR-842 EB	US-441	202
Disabled Vehicle	8/28/2014	12:38:28	SR-842 EB	NW 7 Ave	7
Congestion	8/29/2014	7:54:19	SR-842 EB	I-95	12
Road Work - Scheduled	8/29/2014	8:58:12	SR-842 EB	NW 31 Ave	252

Incidents on Westbound of Broward Blvd.

Type	Date	Time	Road	Location	Duration
Congestion	8/1/2014	14:11:29	SR-842 WB	I-95	254
Road Work - Scheduled	8/4/2014	11:22:25	SR-842 WB	I-95	429
Congestion	8/4/2014	15:22:52	SR-842 WB	I-95	145
Congestion	8/5/2014	12:21:52	SR-842 WB	NW 7 Ave	278
Congestion	8/7/2014	8:09:45	SR-842 WB	NW 7 Ave	22
Congestion	8/7/2014	10:42:52	SR-842 WB	NW 7 Ave	490
Congestion	8/8/2014	11:07:27	SR-842 WB	NW 7 Ave	245
Congestion	8/11/2014	14:20:52	SR-842 WB	NW 7 Ave	252
Crash	8/12/2014	9:24:44	SR-842 WB	NW 7 Ave	22
Congestion	8/12/2014	11:44:00	SR-842 WB	I-95	274
Congestion	8/14/2014	15:42:14	SR-842 WB	I-95	90
Congestion	8/14/2014	17:15:24	SR-842 WB	I-95	24
Congestion	8/15/2014	14:09:18	SR-842 WB	I-95	222
Congestion	8/16/2014	15:06:11	SR-842 WB	I-95	202
Crash	8/18/2014	17:11:07	SR-842 WB	I-95	77
Congestion	8/19/2014	17:45:49	SR-842 WB	I-95	27
Congestion	8/20/2014	15:12:55	SR-842 WB	I-95	152
Congestion	8/21/2014	15:29:45	SR-842 WB	I-95	65
Congestion	8/22/2014	9:01:19	SR-842 WB	I-95	49
Congestion	8/22/2014	15:29:42	SR-842 WB	I-95	72
Congestion	8/25/2014	17:09:49	SR-842 WB	I-95	52
Congestion	8/26/2014	15:25:24	SR-842 WB	I-95	176
Disabled Vehicle	8/26/2014	17:19:24	SR-842 WB	Andrew Ave	17
Congestion	8/27/2014	15:29:28	SR-842 WB	I-95	151
Congestion	8/28/2014	15:45:20	SR-842 WB	I-95	180
Congestion	8/28/2014	16:44:22	SR-842 WB	NW 7 Ave	101
Crash	8/28/2014	17:25:02	SR-842 WB	I-95	27
Congestion	8/29/2014	15:25:29	SR-842 WB	I-95	147

Arterial Incident Records

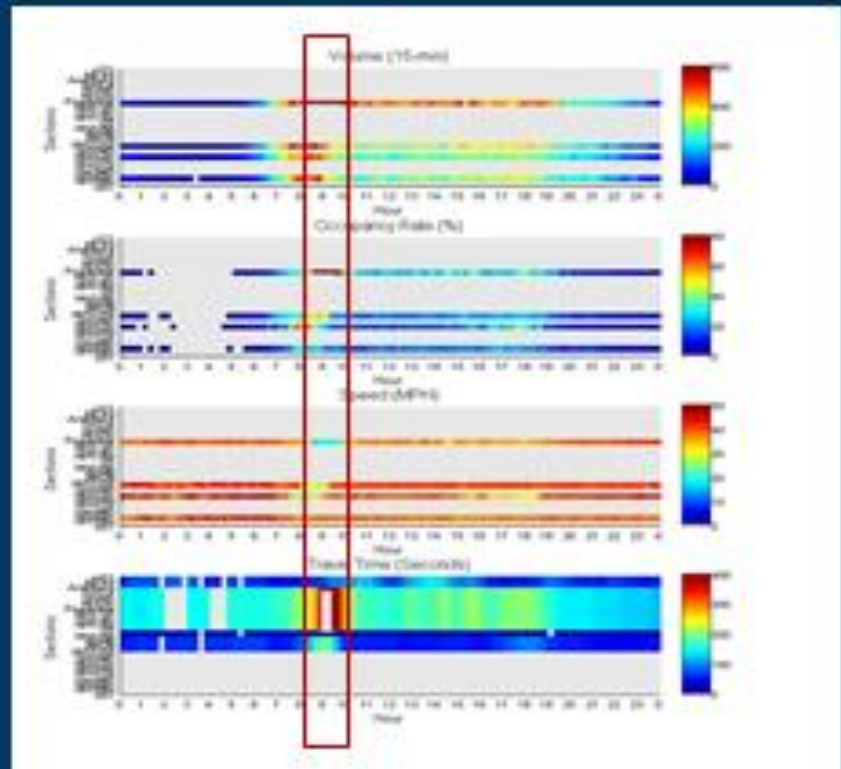
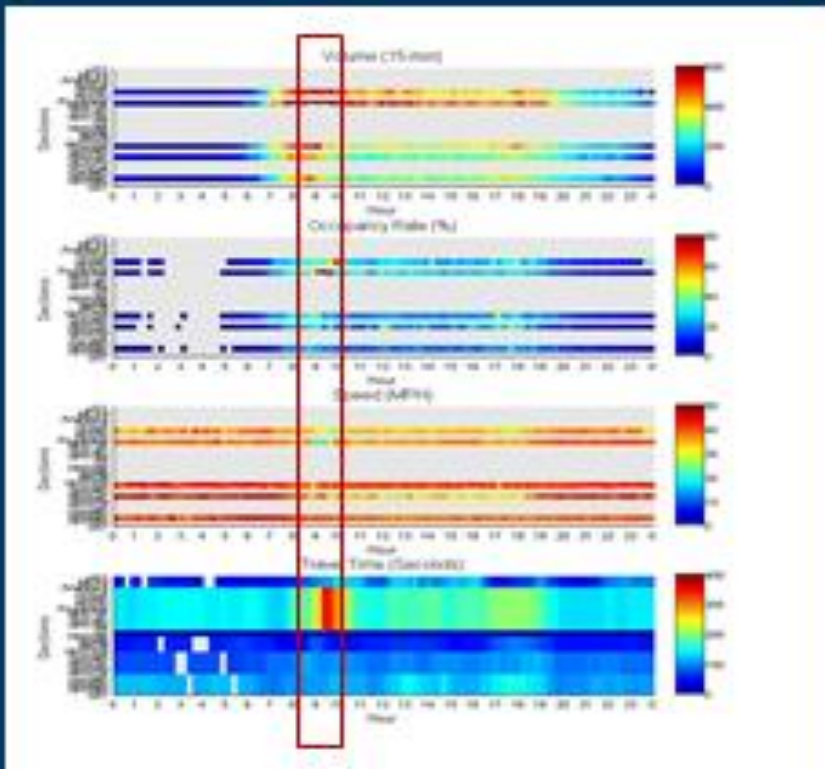


August 26 – Congestion (1)

Incident #	Incident Type	Date	Time	Major Rd	Minor Rd	Duration(min)
1025	Congestion	8/26/2014	8:13:09	SR-842 EB	NW 7 Ave	72

Normal-day Traffic on Eastbound of Broward Blvd.

Incident Traffic on Eastbound of Broward Blvd.

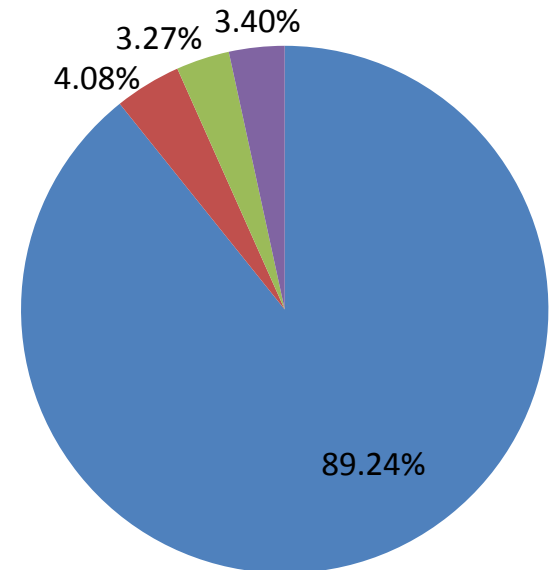
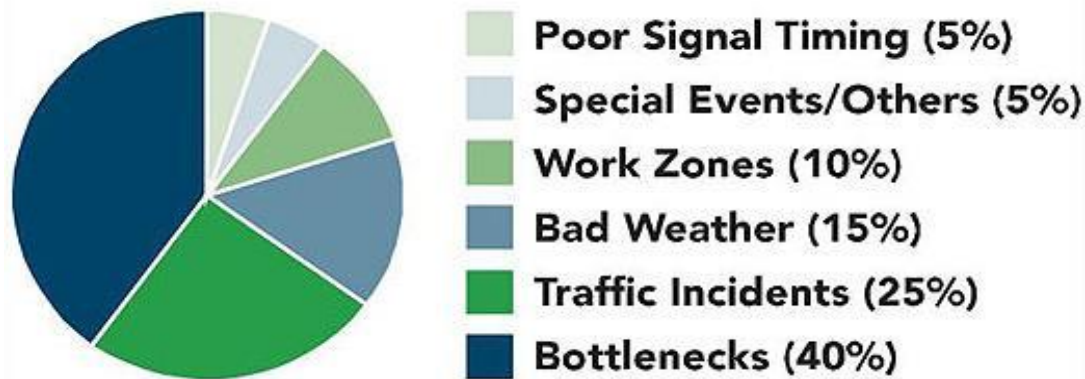


Summary



- Data-driven congestion causal pie chart
 - Bigger impact: road geometry, bad weather
 - Smaller impact: incidents, work zones
- Coming soon
 - Surface arterial pie chart
 - Analysis of more freeways

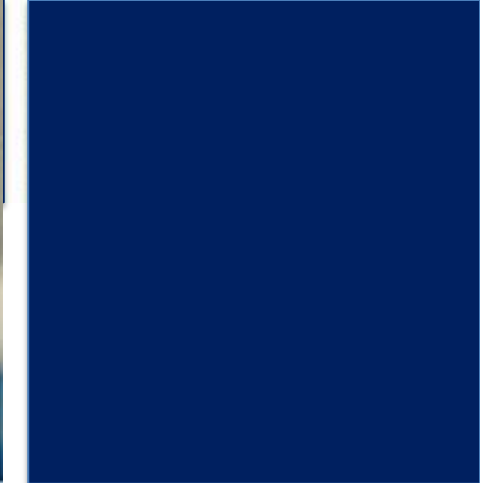
- V/C>1
- Bad Weather
- Traffic Incidents
- Work Zones



Preview



1. Congestion and bottleneck concepts
2. Congestion and bottleneck identification methods
3. Modernized causes of congestion pie chart
- 4. Featured bottleneck mitigation strategies**



Bottleneck Mitigation Strategies

Identification, Diagnosis, Solutions



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Active Bottleneck

Geometric Challenges				Operational Challenges		
Roadway Specific	Facility Specific	Specific to Interchanges	Intersections /TCD/ITS	Agency Related	Driver Related	Non-motorist Related
<ol style="list-style-type: none"> 1. Design Speed 2. Number of Lanes 3. Lane Width 4. Presence and Type of shoulders 5. Lane drops 6. Lane reduction transition 7. H_z clearance 8. V_I clearance 9. Sun Glare Alignment 10. H_z alignment 11. V_I alignment 12. SSD 13. Pavement friction/surface 14. Cross Slope 15. Super-elevation 16. Access pts 17. Mid-block Crossing 18. Medians 19. Lightings /Clear 	<ol style="list-style-type: none"> 1. Bridges 2. Tunnels and underpass 3. Collector-distributor network 	<ol style="list-style-type: none"> 1. Merge and diverge sections 2. Auxiliary lanes 3. Weaving areas 4. On-ramp/off-ramp 5. Acceleration/ deceleration lanes 	<ol style="list-style-type: none"> 1. Intersection sight distance 2. Left-turn and Right-turn lane overflow 3. Parking 4. TCD (signal, stop sign, etc.) 	<ol style="list-style-type: none"> 1. Managing demand 2. Intersection spacing 3. Interchange spacing 4. Policy on entry/exit ramp placement 5. Posted speed limit (static/dynamic) 6. Signal timing administration 7. Traffic composition 8. Work zone 9. Roadway closure administration 10. Incident management and clearance 11. Ramp metering 12. Heavy vehicle lane restrictions 	<ol style="list-style-type: none"> 1. Bunching vehicle 2. Roadside distraction/rubbernecking 3. Non-roadside distractions 4. Unsafe vehicle condition for weather condition 5. Aggressive lane change/weaving 6. Driving unauthorized roadway section 7. Driver performance in w_z 8. Driver performance when involved in an incident 	<ol style="list-style-type: none"> 1. Sub-optimal peds and bicyclist performance

Featured Bottleneck Solutions



- 1. Dynamic Lane Grouping**
2. Dynamic Merge Control
3. Acceleration Lane Extension
4. Hard Shoulder Running
5. Lane Narrowing to Add a Lane
6. Alternative Intersections and Interchanges

Innovative Solutions (coming soon)

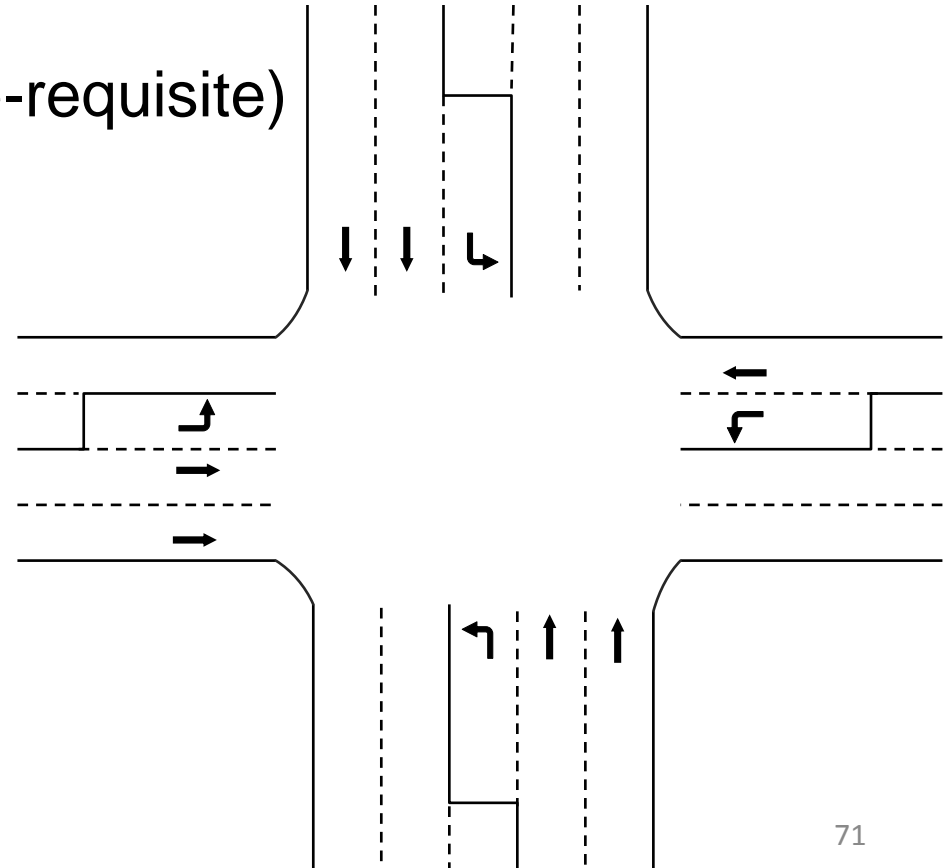


- 1. Dynamic Hard Shoulder Running**
- 2. Contraflow Left-Turn Lanes**
- 3. Freeway Merge with Variable Speed Limits**
- 4. Signal Optimization via SPSA**

Dynamic Lane Grouping (DLG)



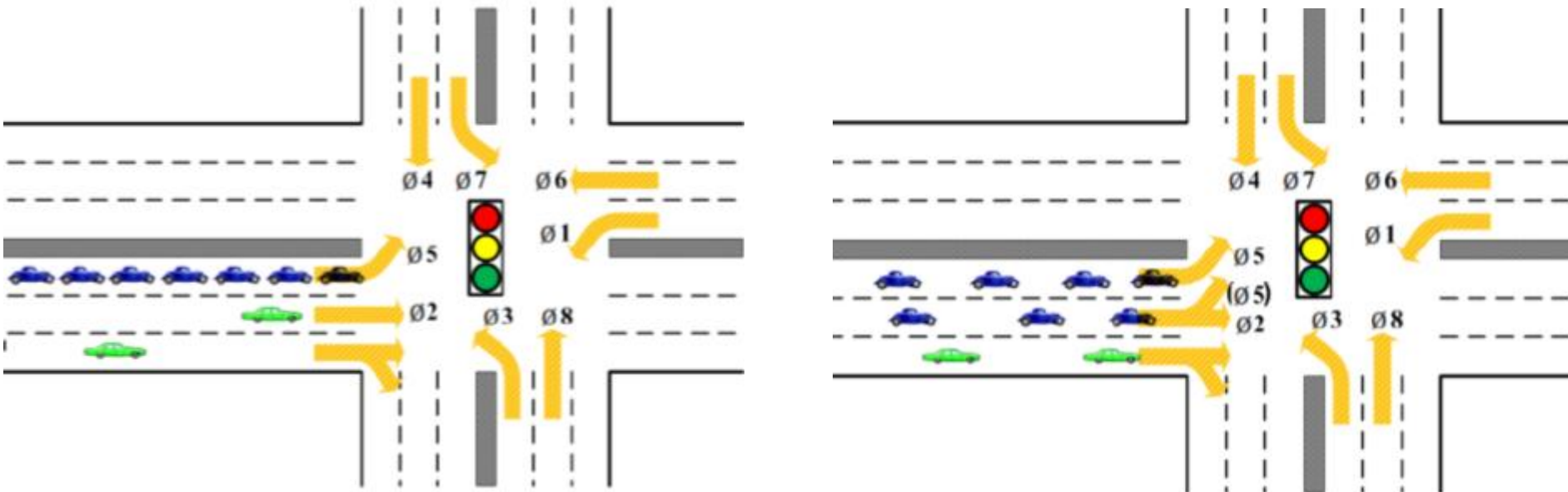
- Dynamically assigns lanes to turning movements
- Scan for good candidates among many intersections
- Four screening criteria
 - Safe turning geometry (pre-requisite)
 - Volume change
 - Volume per lane
 - Degree of saturation



Dynamic Lane Grouping (DLG)



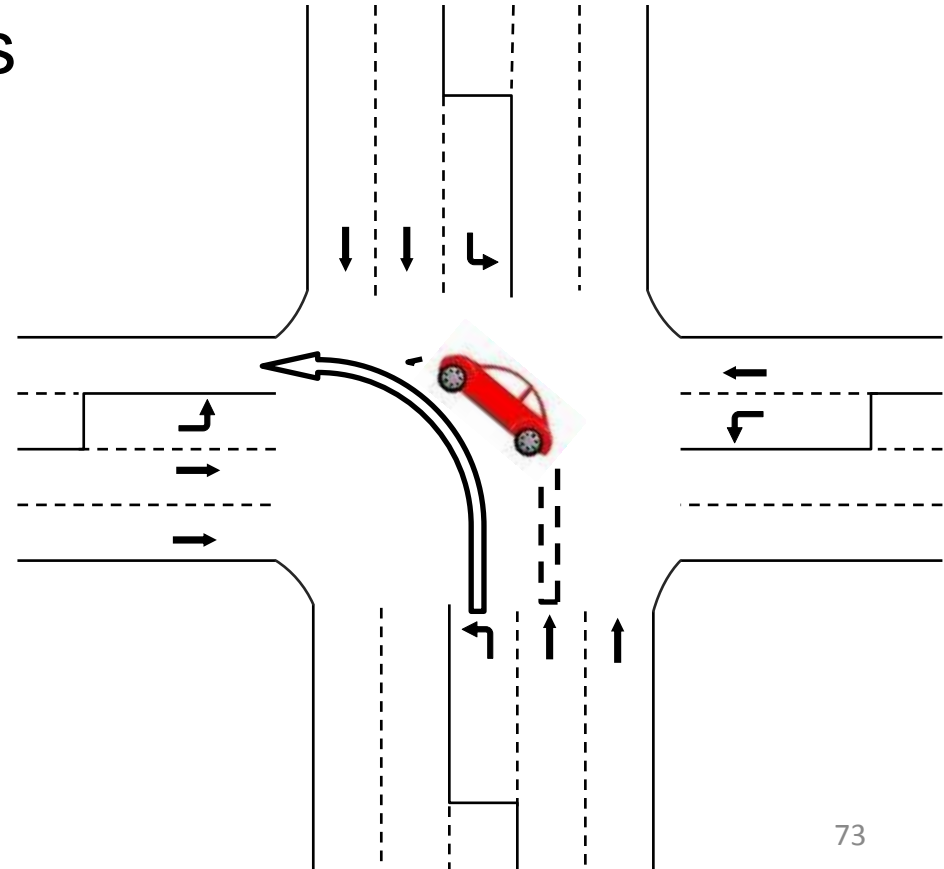
- Visual example: convert middle lane to a left-turn lane, during certain times of the day



Dynamic Lane Grouping (DLG)



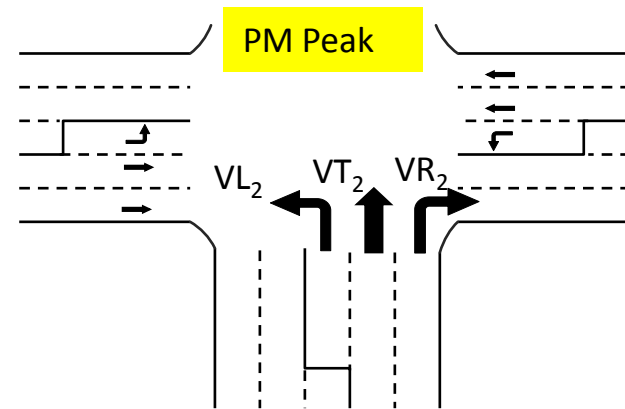
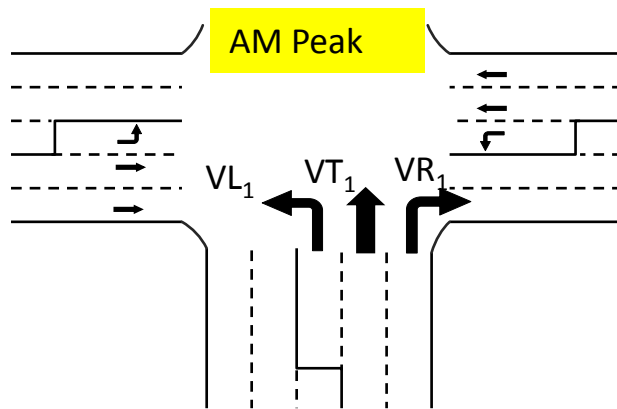
- Screening criteria #1: Safe Turning Geometry
- Pre-requisite
- Adequate number of receiving lanes
- At least two through lanes



Dynamic Lane Grouping (DLG)



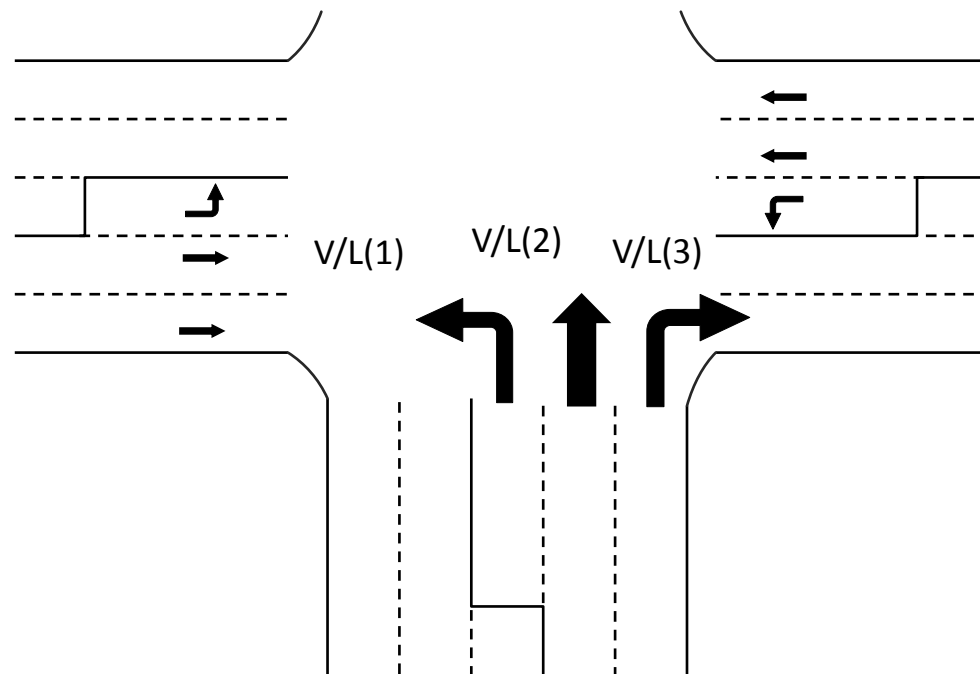
- Screening criteria #2: Volume Change
- Compare AM and PM peak volumes
- LT or RT volumes increase by at least 20%
- TH volumes decrease by at least 20%



Dynamic Lane Grouping (DLG)



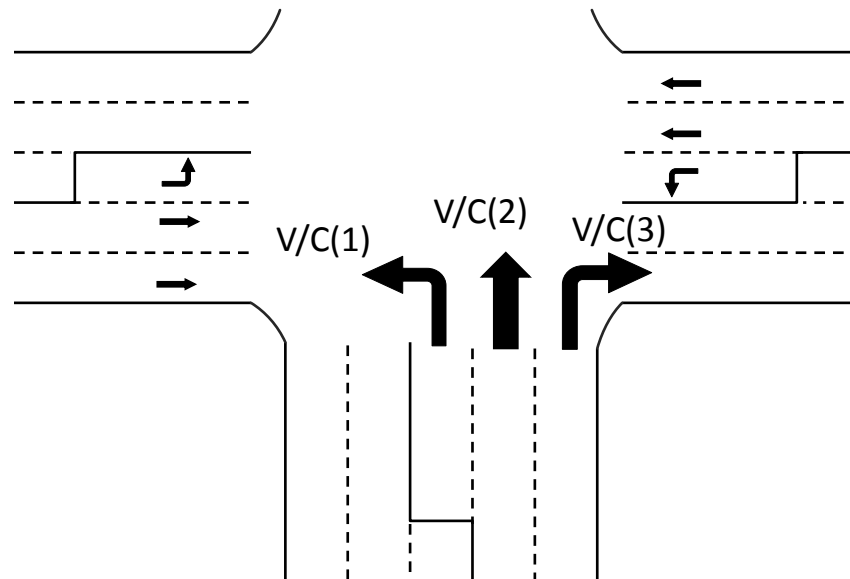
- Screening criteria #3: Volume per Lane
- Left-turn or right-turn volume per lane exceeds through volume per lane by at least 50%



Dynamic Lane Grouping (DLG)



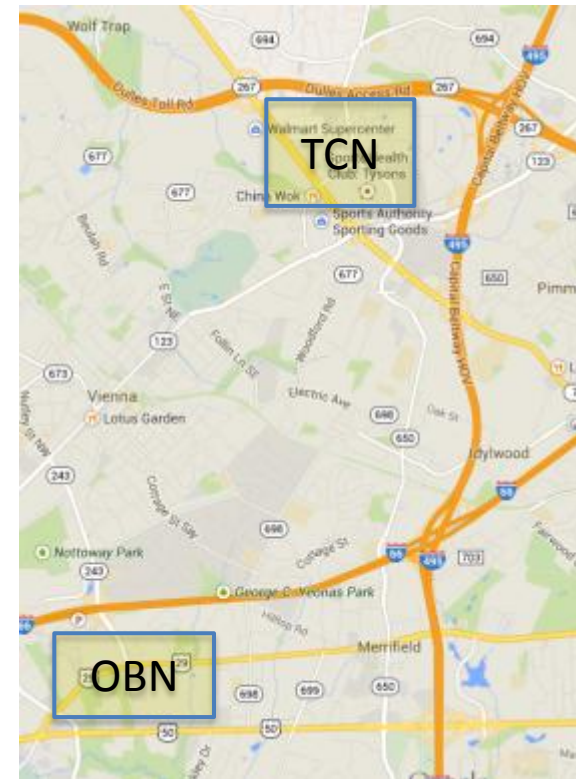
- Screening criteria #4: V/C Ratio
- High left-turn or right-turn V/C ($> 70\%$)
- Low through V/C ($< \frac{\# \text{ Through Lanes} - 1}{\# \text{ Through Lanes}}$)



Dynamic Lane Grouping (DLG)



- Case study of 17 intersections (along 2 networks in Virginia)
 - TCN network
 - OBN network
- 8 candidate movements (LT and RT) per intersection
- 8 candidate time periods
- $17 \times 8 \times 8 = 1,088$ candidates



Dynamic Lane Grouping (DLG)



- Degree of saturation criterion
 - Best identification rate
 - Fewest number of false positives

Network Name	OBN	TCN	ID Rate
# of candidates	448	640	
Volume/Capacity	6(5)	2(2)	87.5%
Volume/Lane	4(1)	42(7)	17.4%
Volume Change	4(2)	12(1)	18.8%

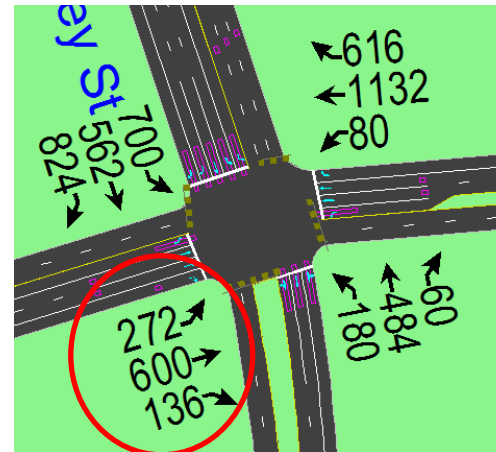
Dynamic Lane Grouping (DLG)



- DLG improvements at Lee Highway @ Nutley Street
- Sunday peak period: switch to dual left turns



Sunday Peak



Weekday PM Peak

	Volume/Capacity	Volume/Lane
Left-Turn	0.99	452
Through	0.31	223

Dynamic Lane Grouping (DLG)



[Play before video](#)

	EBL	EBT	EBR	Total
Volume	452	446	188	
Base Delay/Veh (s)	147	25	9	60
DLG Delay/Veh (s)	78	27	9	47

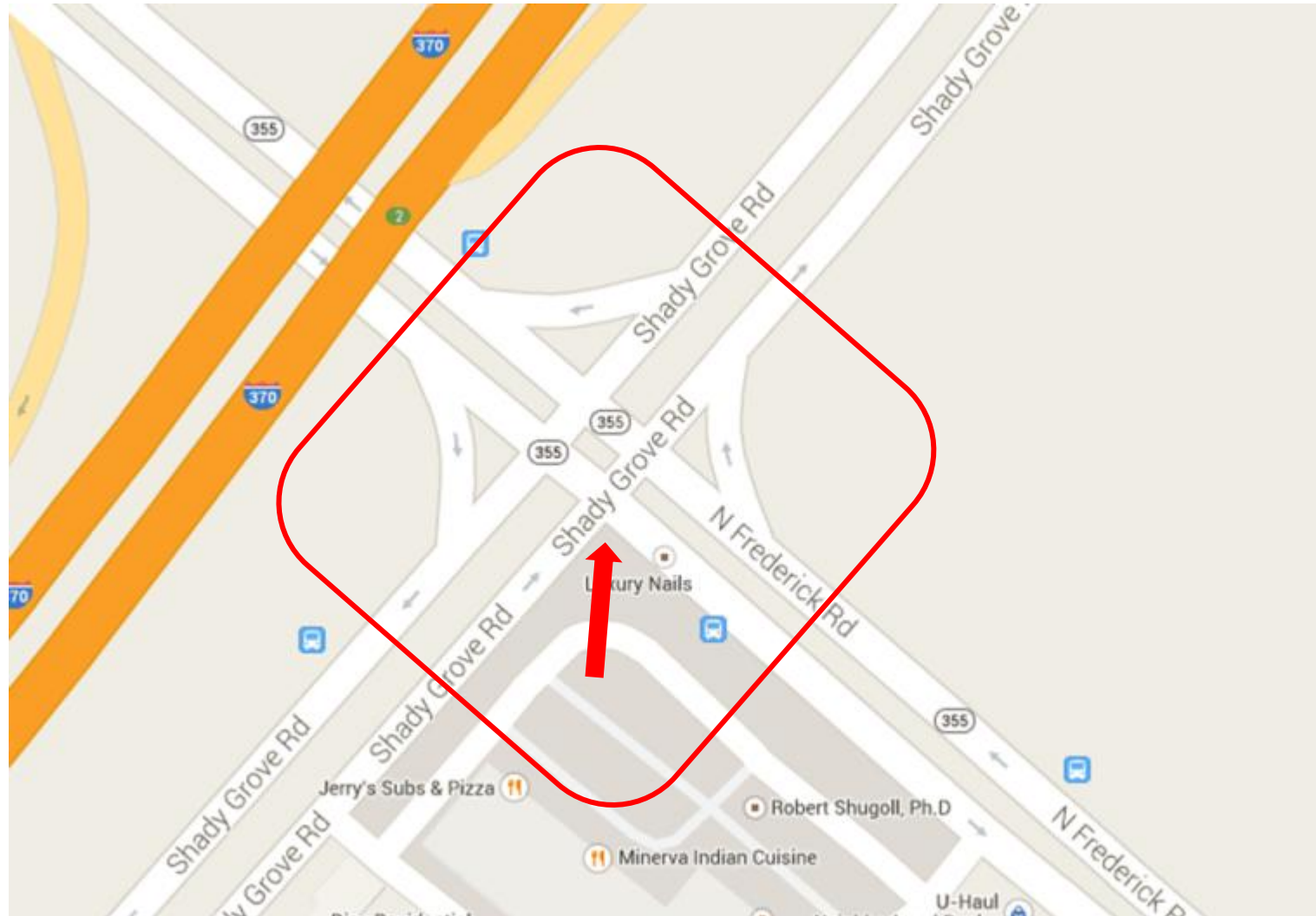
Dynamic Lane Grouping (DLG)



[Play after video](#)

	EBL	EBT	EBR	Total
Volume	452	446	188	
Base Delay/Veh (s)	147	25	9	60
DLG Delay/Veh (s)	78	27	9	47

Dynamic Lane Grouping (DLG)



Dynamic Lane Grouping (DLG)



Morning Peak



Hour	Shady Grove Road From West			
	L	T	R	TOT
6:00	119	428	404	951
7:00	370	477	926	1773
8:00	445	569	1087	2101
9:00	350	831	1395	2576
10:00	478	748	691	1917
11:00	488	933	743	2164
12:00	562	963	689	2214
13:00	567	1096	820	2483
14:00	701	1236	844	2781
15:00	660	1070	568	2298
16:00	1092	1757	495	3344
17:00	950	1865	678	3493
18:00	1030	1862	629	3521

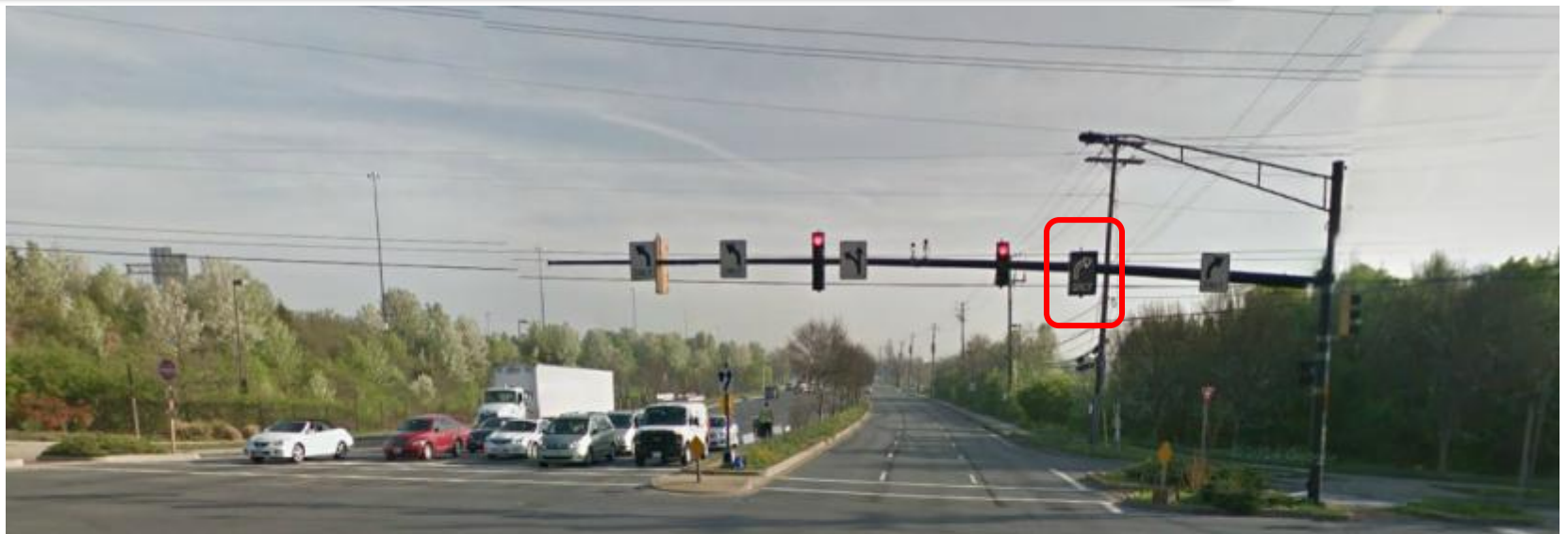
Evening Peak



Dynamic Lane Grouping (DLG)



Dynamic Lane Grouping (DLG)



Dynamic Lane Grouping (DLG)



[Play DLG in the field](#)

Dynamic Lane Grouping (DLG)



- Benefit-cost analysis based on SHRP2 report
 - Commuter travel time valued at 50% of prevailing wage rate
 - National wage rate of \$21 per hour in the year 2009
- Simplifying assumptions
 - 250 commuting days per year
 - No life-saving benefits or GDP benefits
 - No safety costs or environmental costs

$$\frac{\$21}{hr} \times \frac{1 \text{ wage rate}}{2} \times \frac{1.6 \text{ persons}}{veh} = \frac{\$17}{veh \cdot hr}$$

Benefit-Cost Analysis



- Annual benefits between \$68K and \$295K
- Greatest benefits at high-volume intersections
- Benefit-cost ratios between 5:1 and 22:1
- This analysis assumed
 - 15-year lifespan for DMS signs, capital cost of \$125K, O&M costs of \$2K per year, 250 commuting days per year

	<u>Capital Cost</u>	<u>Operating Cost</u>
Dynamic Message Sign	\$47-117K	\$2.4-6K
Dynamic Message Sign Tower	\$25-120K	
Dynamic Message Sign – Portable	\$18-25K	\$1.2-2K

Summary



- DLG reduces the gap between supply and demand
- Screening criteria quickly identify candidate locations
- Volume/Capacity was the top screening criterion
 - Few false positives
 - Candidates showed noticeable delay reductions
- Volume Change and Volume/Lane do not require signal data
- Case study results
 - DLG reduced overall intersection delay 15-30% in some cases

Featured Bottleneck Solutions

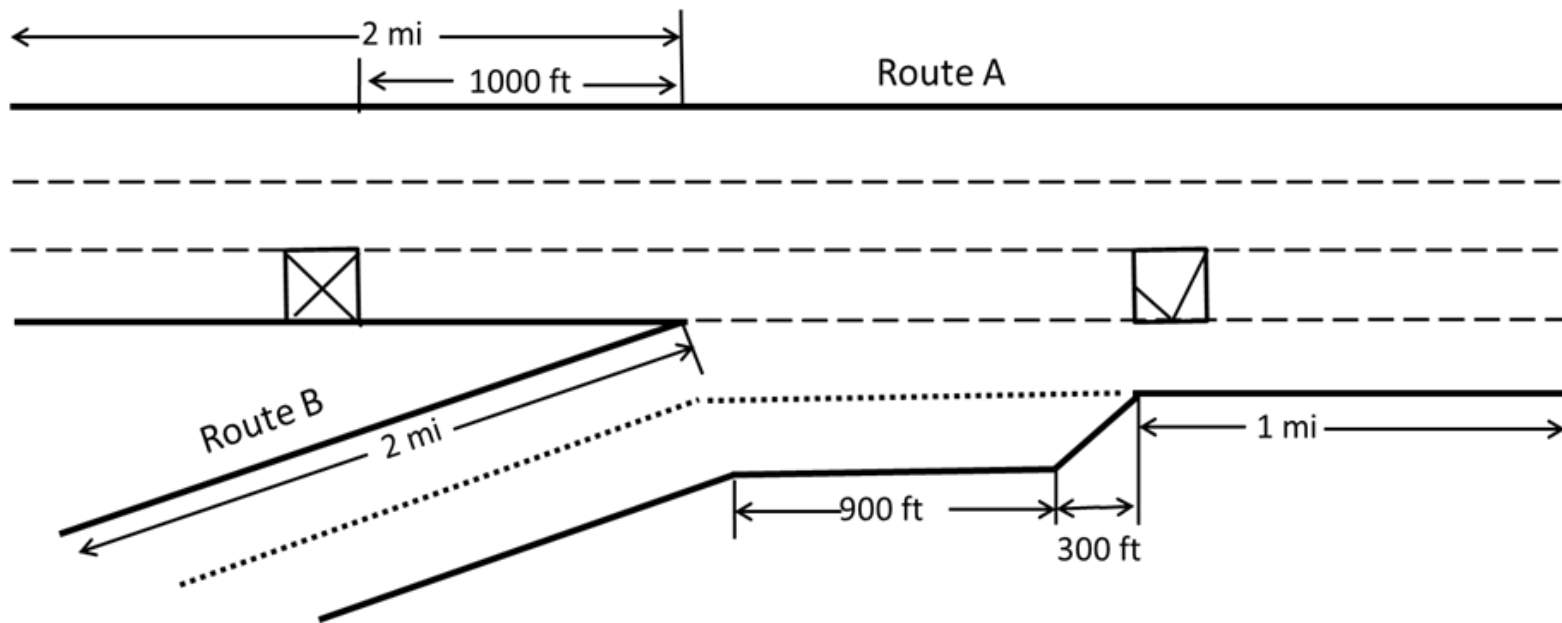


1. Dynamic Lane Grouping
- 2. Dynamic Merge Control**
3. Acceleration Lane Extension
4. Hard Shoulder Running
5. Lane Narrowing to Add a Lane
6. Alternative Intersections and Interchanges

Dynamic Merge Control (DMC)



- Dynamic lane closing (mainline or on-ramp)
- Goal is to reduce friction in the merging area



Florida – Lane reconfiguration



1-la off ramp tested as 2-lane ramp

3 Lanes

Before: FDOT tried a faux work zone to change 3 lanes to 2



2-la merge is now permanent

2 Lanes

After: the plan worked so well they made it permanent

Dynamic Merge Control (DMC)



- Source: “Managed Lanes in the Netherlands” by Bert Helleman

Situation without
merging control



Unregistered Situation with
merging control 16:29



Dynamic Merge Control (DMC)



- Source: “Managed Lanes in the Netherlands” by Bert Helleman

Evaluation results



Red route	Free flow	Without IMC	With IMC	Change %
mean travel time	4.76	11.03	10.42	- 8%
mean travel speed	98	41	45	+ 8%
Vehicle hours of delay	-	1558	1361	- 13%

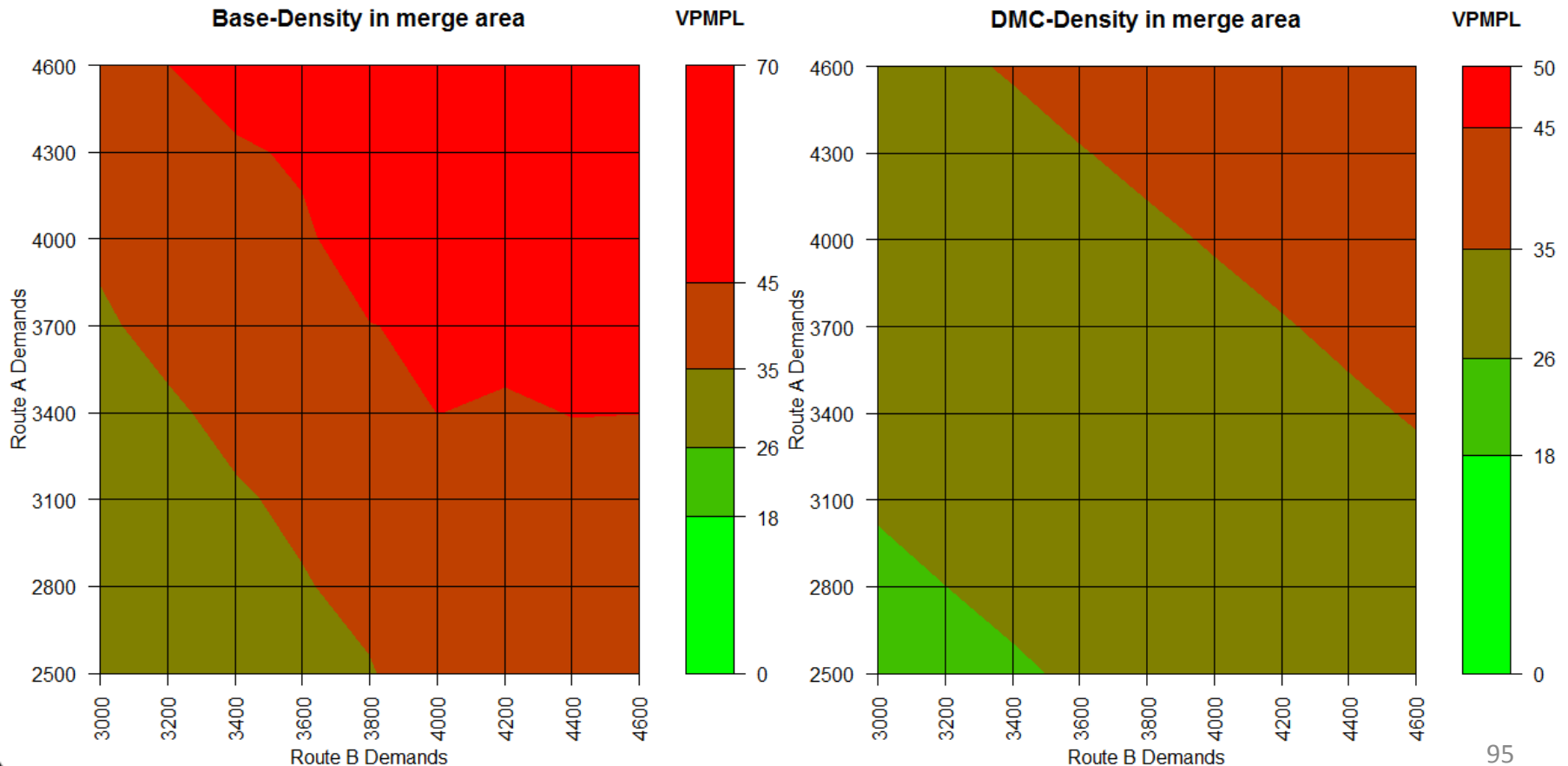


Blue route	Free flow	Without IMC	With IMC	Change %
mean travel time	2.78	7,07	6.56	- 7%
mean travel speed	106	42	45	+ 7%
Vehicle hours of delay	-	1455	1398	- 4%

Dynamic Merge Control (DMC)



- Hypothetical network study (3-lane merge with 2-lane)
- DMC substantially improved flows for all demand combinations

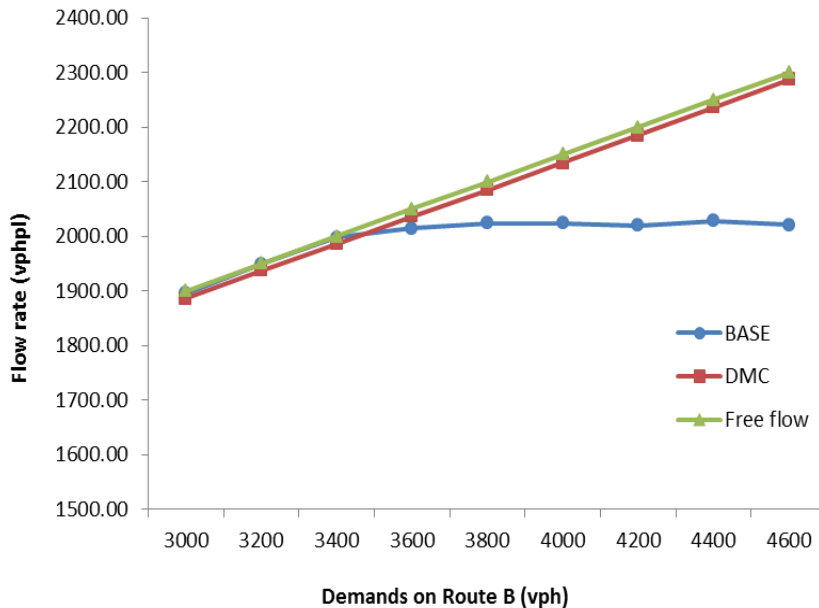


Dynamic Merge Control (DMC)

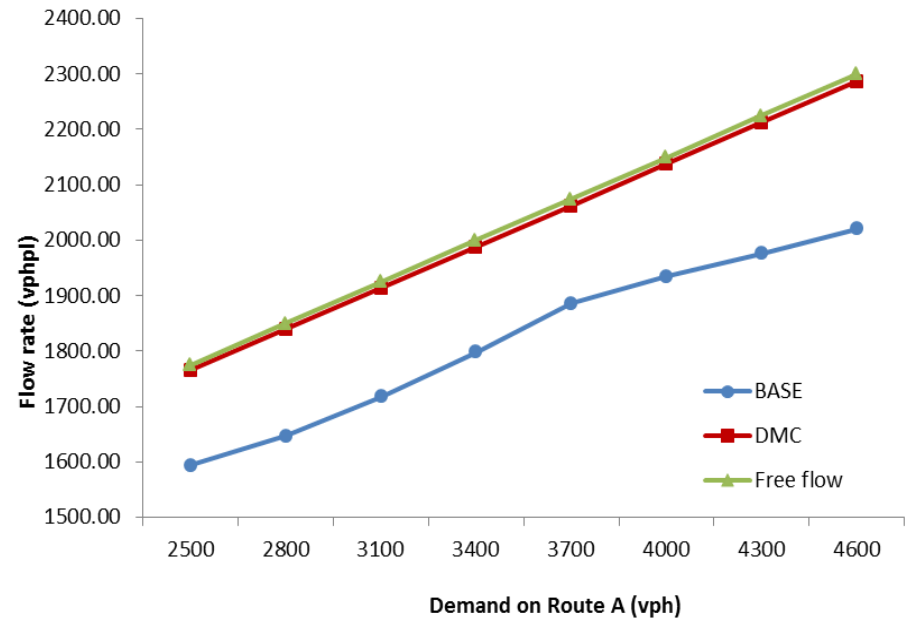


- Hypothetical network study
- Without DMC, merge-area capacity constrained by weaving friction

RAMP



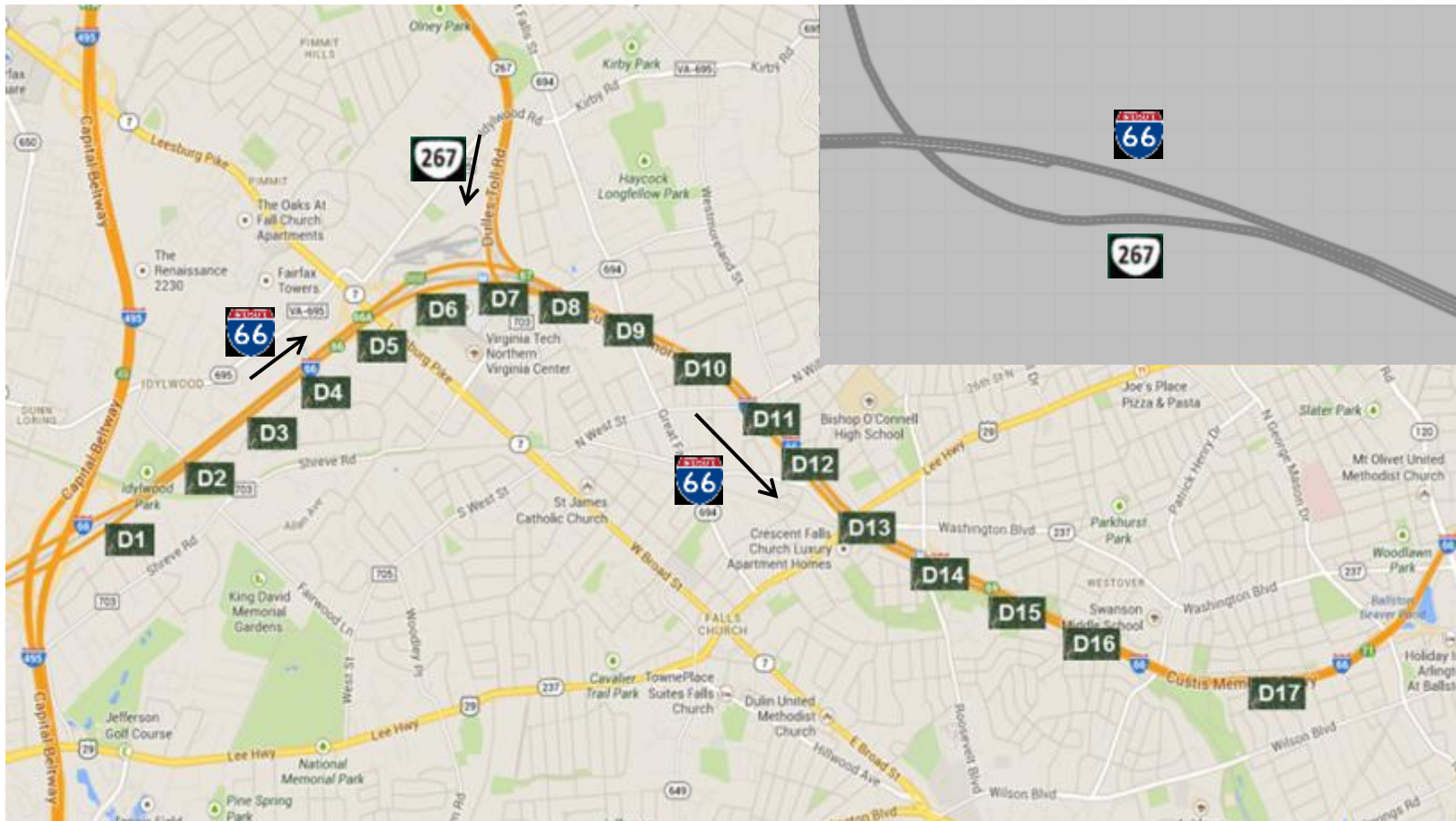
MAINLINE



Dynamic Merge Control (DMC)



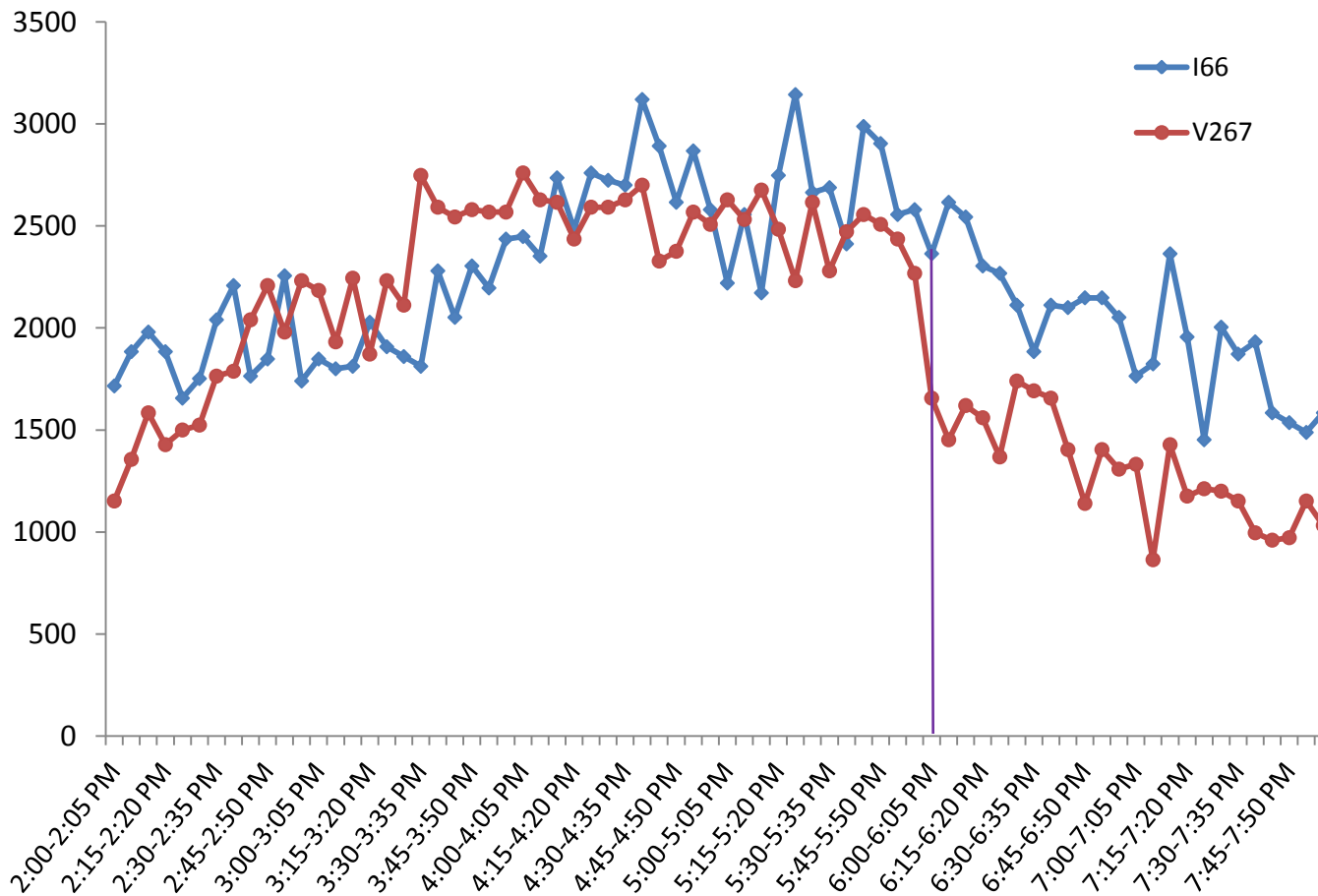
- Real-world network study (Virginia's I-66)



Dynamic Merge Control (DMC)



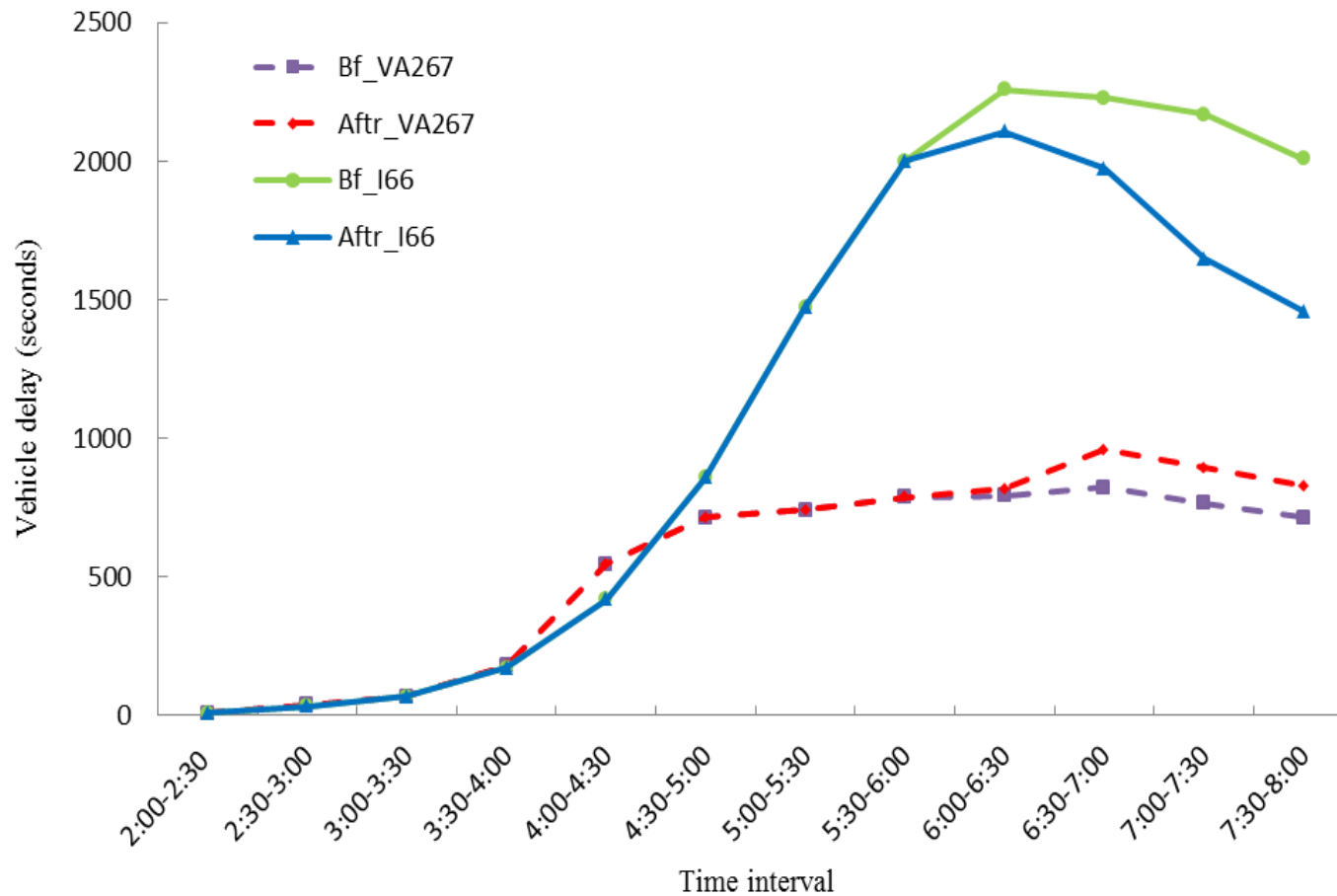
- Real-world network study (Virginia's I-66)



Dynamic Merge Control (DMC)



- Real-world network study (Virginia's I-66)



Before DMC



[Play video](#)

After DMC



[Play video](#)

Benefit-Cost Analysis



- Annual benefits between \$236K and \$1.02M
- Greatest benefits at high-volume on-ramps
- Benefit-cost ratio between 8:1 and 36:1
- This analysis assumed
 - 15-year lifespan for DMS signs, capital cost of \$250K, O&M costs of \$6K per year, 250 commuting days per year

	<u>Capital Cost</u>	<u>Operating Cost</u>
Dynamic Message Sign	\$47-117K	\$2.4-6K
Dynamic Message Sign Tower	\$25-120K	
Dynamic Message Sign – Portable	\$18-25K	\$1.2-2K

Summary



- DMC strategy produced benefits at all demand combinations
- Strongest benefits when on-ramp demand reaches 1900 vphpl
- Less weaving friction in the merge area
 - increases capacity
 - delays formation of bottlenecks

Featured Bottleneck Solutions



1. Dynamic Lane Grouping
2. Dynamic Merge Control
- 3. Acceleration Lane Extension**
4. Hard Shoulder Running
5. Lane Narrowing to Add a Lane
6. Alternative Intersections and Interchanges

Extending Acceleration Lanes



- Acceleration lane merging causes severe bottlenecks
- AASHTO guidelines: some acceleration lanes too short
- Paramics simulations: 3-lane and 4-lane corridors
 - increasing from 500 to 1000 feet
 - increasing from 500 to 1500 feet



Extending Acceleration Lanes

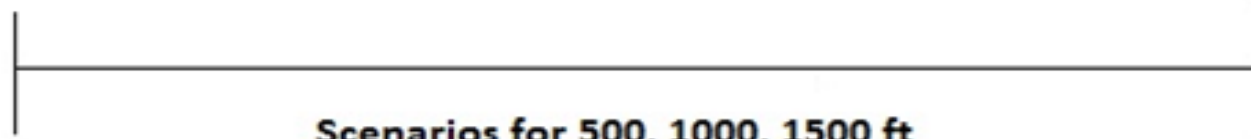


	Through Lanes	Ramp Speed	Acceleration Length	AASHTO Guideline
No.	(Number)	(Mph)	(Feet)	(Feet)
1	3	40	500	780+300 taper
2	3	40	1000	780+300 taper
3	3	40	1500	780+300 taper
4	3	30	500	1160+300 taper
5	3	30	1000	1160+300 taper
6	3	30	1500	1160+300 taper
7	4	40	500	780+300 taper
8	4	40	1000	780+300 taper
9	4	40	1500	780+300 taper
10	4	30	500	1160+300 taper
11	4	30	1000	1160+300 taper
12	4	30	1500	1160+300 taper

Extending Acceleration Lanes

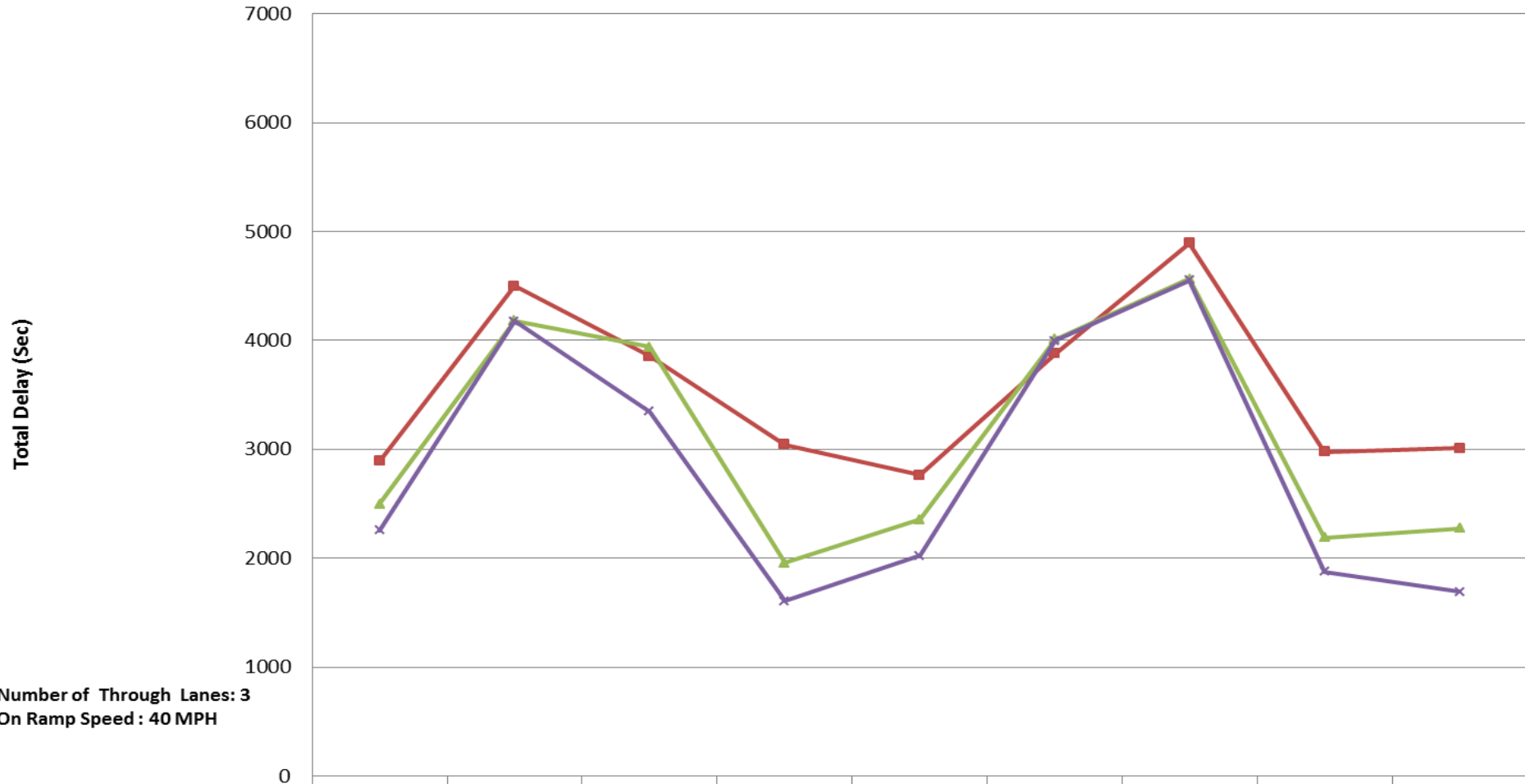


Scenario No.	Through Demand (Vehicles)	ON Ramp Demand (Vehicles)
1	4847	1278
2	5047	1278
3	5547	778
4	4147	1578
5	3547	1978
6	5797	578
7	5347	1078
8	4547	1428
9	4047	1678



Scenarios for 500, 1000, 1500 ft
that include taper length

Total Delay (Minutes)



	1	2	3	4	5	6	7	8	9
500 Feet	2890	4497	3855	3044	2764	3880	4892	2976	3011
1000 feet	2495	4182	3939	1958	2354	4011	4564	2189	2272
1500 feet	2255	4176	3344	1603	2025	3998	4552	1876	1691
Through Demand (Veh.)	4847	5047	5547	4147	3547	5797	5347	4547	4047
On Ramp Demand (Veh.)	1278	1278	778	1578	1978	578	1078	1428	1678

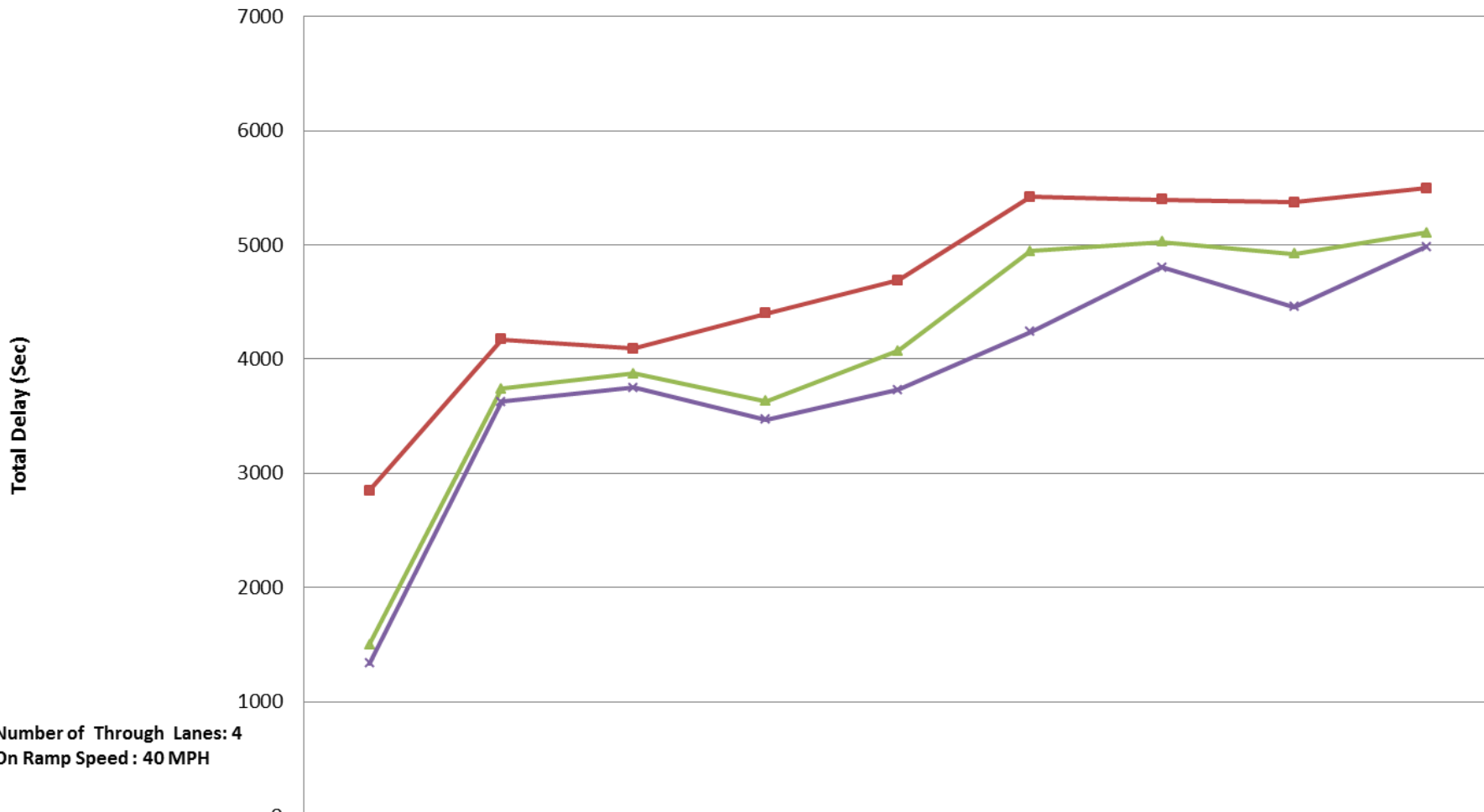
Extending Acceleration Lanes



Volume demands (4-lane configuration)

Scenario No.	Through Demand (Vehicles)	ON Ramp Demand (Vehicles)
10	5347	1278
11	5647	1278
12	6147	1278
13	5347	1478
14	5347	1678
15	5647	1478
16	5647	1678
17	6147	1478
18	6147	1678

Total Delay (Minutes)



Number of Through Lanes: 4
On Ramp Speed : 40 MPH

	10	11	12	13	14	15	16	17	18
500 Feet	2850	4171	4092	4400	4687	5421	5394	5374	5496
1000 feet	1500	3742	3875	3630	4072	4945	5028	4920	5106
1500 feet	1335	3624	3751	3472	3731	4236	4801	4458	4982
Through Demand (Veh.)	5347	5647	6147	5347	5347	5647	5647	6147	6147
On Ramp Demand (Veh.)	1278	1278	1278	1478	1678	1478	1678	1478	1678

Benefit-Cost Analysis



- Annual benefits between \$45K and \$79K
- Greatest benefits when on-ramp flow > 1400 veh/hr/ln
- No benefits when on-ramp flow < 800 veh/hr/ln
- Benefit-cost ratios between 1:1.4 and 20:1
- TTI research on acceleration lanes
 - simple shoulder conversion cost between \$50K and \$100K
 - complex retrofits can cost over \$1M
 - Arlington TX spent \$640K to extend ramp/accel lane (2014)

	1000 feet	1500 feet
3-lane, 40 mph	\$ 27,965	\$ 44,965
3-lane, 30 mph	\$ 34,354	\$ 61,058
4-lane, 40 mph	\$ 43,562	\$ 67,717
4-lane, 30 mph	\$ 42,712	\$ 78,838

Summary



- Increasing from 500 to 1000 feet
 - reduced delay by 14% (average)
- Increasing from 500 to 1500 feet
 - reduced delay by 23% (average)
- Reduced delay up to 36% when on-ramp flow > 1400 veh/hr/ln
- No delay reduction when on-ramp flow < 800 veh/hr/ln

Featured Bottleneck Solutions

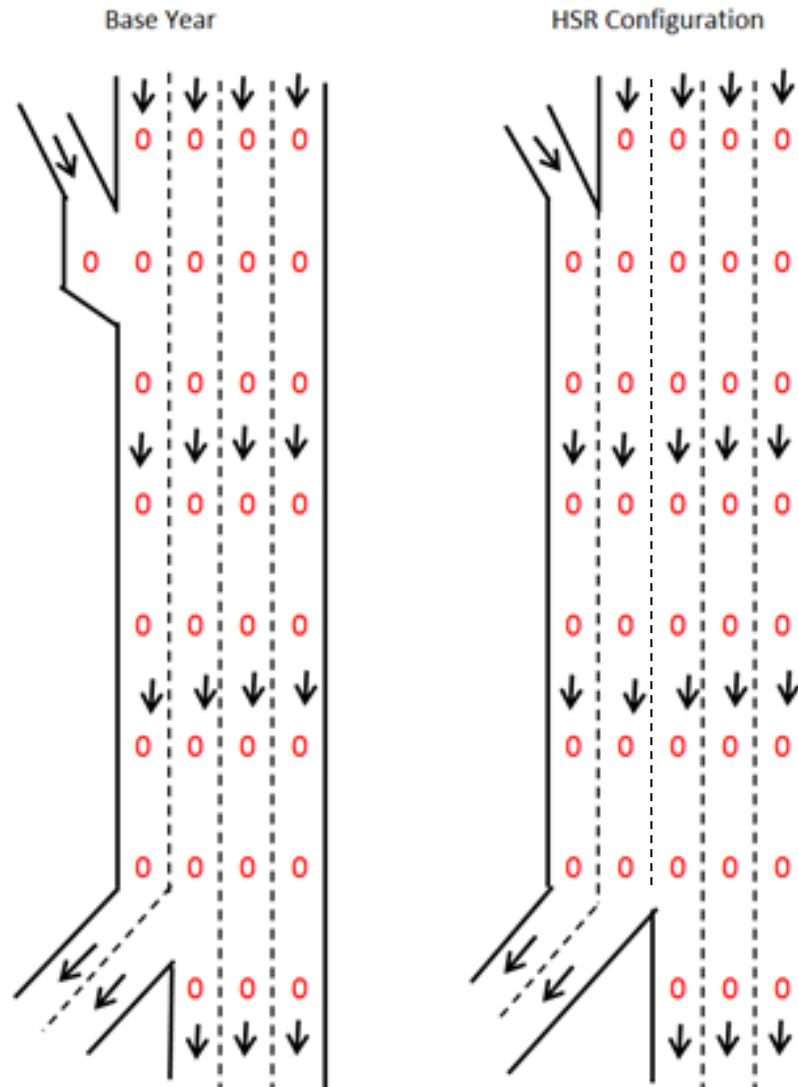


1. Dynamic Lane Grouping
2. Dynamic Merge Control
3. Acceleration Lane Extension
- 4. Hard Shoulder Running**
5. Lane Narrowing to Add a Lane
6. Alternative Intersections and Interchanges

Hard Shoulder Running (HSR)



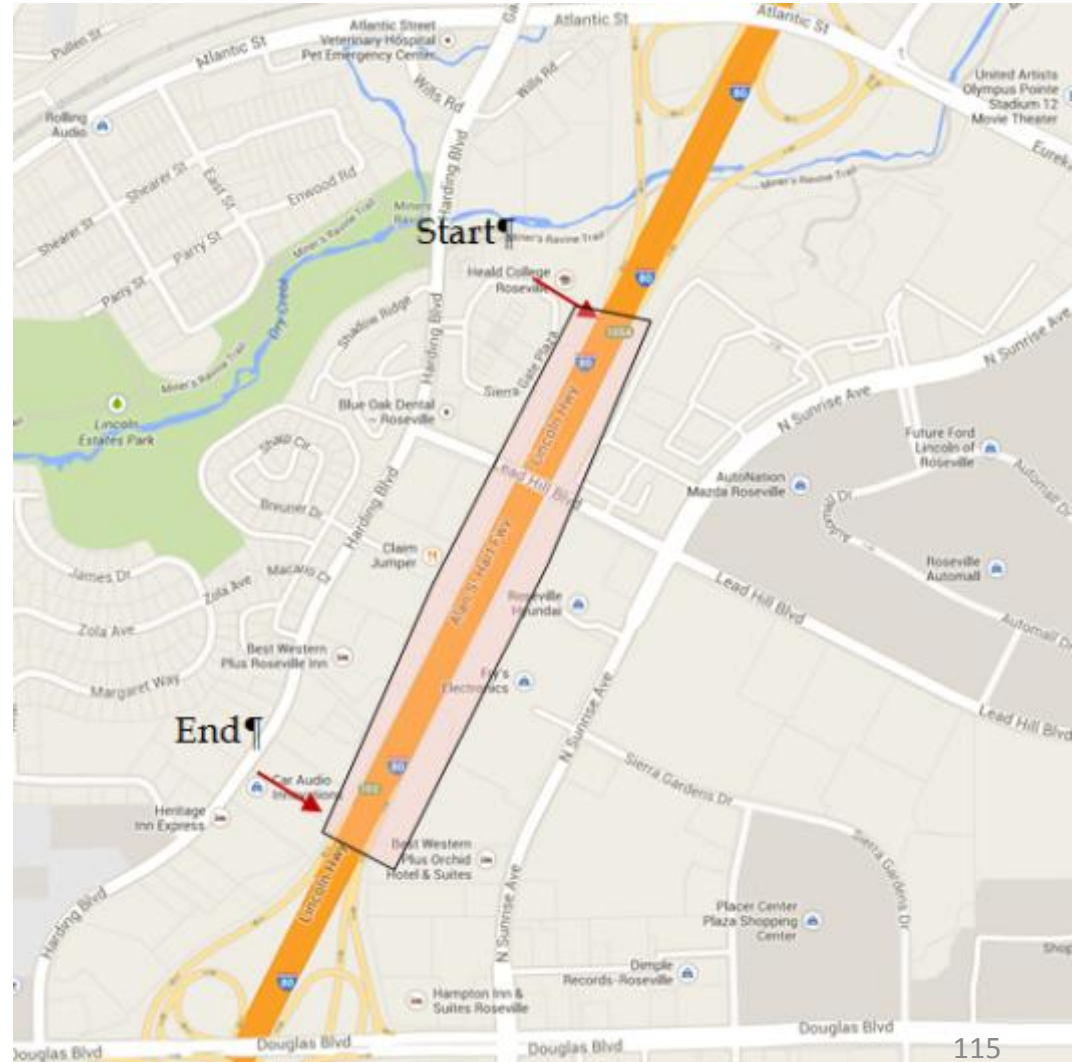
- Use of limited hard shoulder running for better merge control



Hard Shoulder Running (HSR)



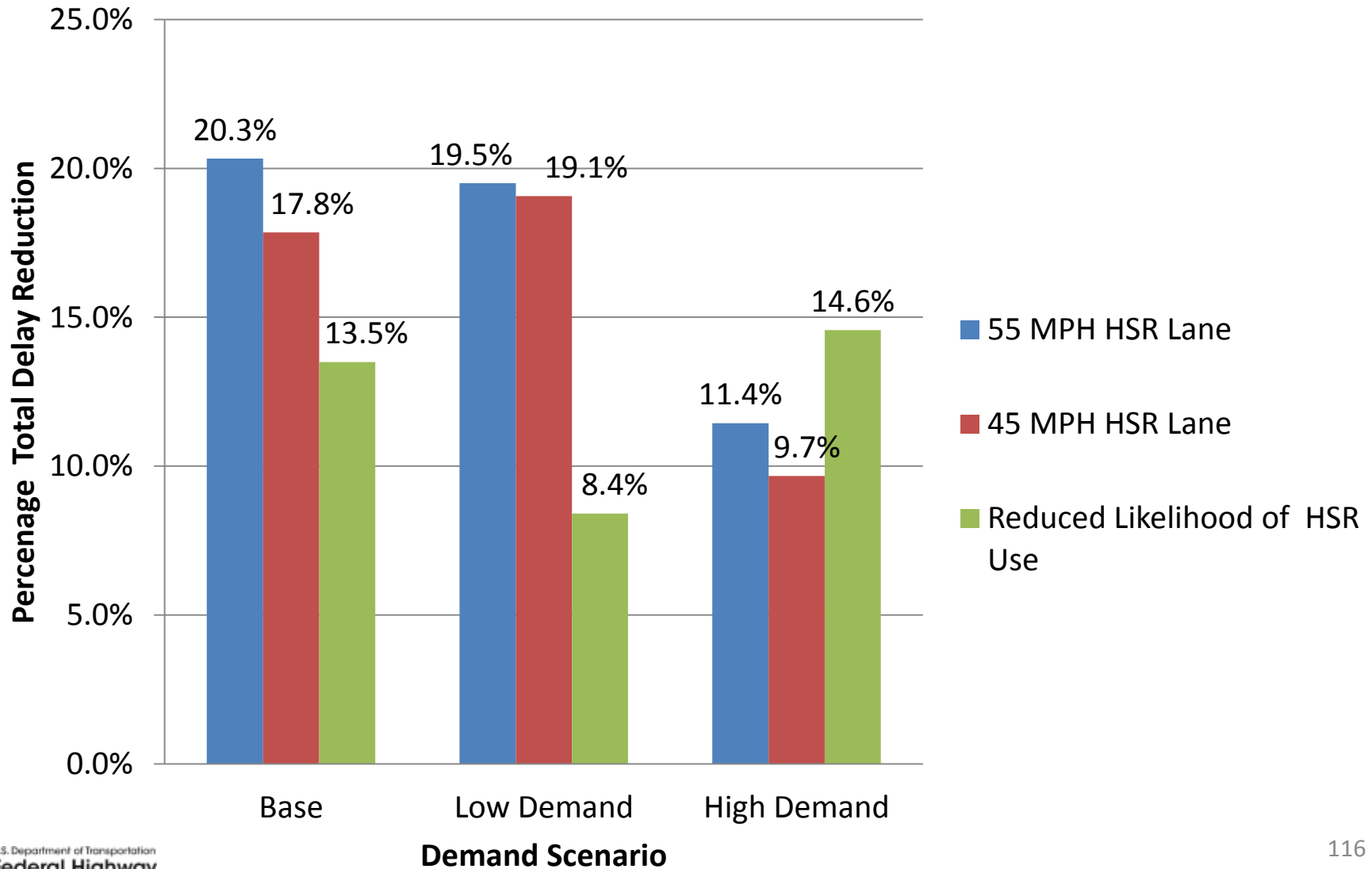
- Simulation scenarios
 - Demand level (*3)
 - Speed limit and likelihood of use (*3)



Hard Shoulder Running (HSR)



HSR- Total Percentage Delay Reduction



Benefit-Cost Analysis



- Benefit-cost ratios between 1:1 and 21:1
- Assumptions
 - 30-year life, annual O&M \$6-12K, start-up costs \$0.25-1.5M

Simulation No.	Demand	HSR Type	Total Delays (Hours)	Annual Savings (\$)
1	Base	No HSR	136.4	--
2	Base	55 MPH HSR Lane	108.7	\$353,100
3	Base	45 MPH HSR Lane	112.1	\$309,900
4	Base	Reduced HSR Use	118.0	\$234,600
5	Low	No HSR	96.3	--
6	Low	55 MPH HSR Lane	77.5	\$239,700
7	Low	45 MPH HSR Lane	78.0	\$233,400
8	Low	Reduced HSR Use	88.2	\$103,200
9	High	No HSR	224.9	--
10	High	55 MPH HSR Lane	199.1	\$329,100
11	High	45 MPH HSR Lane	203.1	\$278,100
12	High	Reduced HSR Use	192.1	\$418,200

Featured Bottleneck Solutions

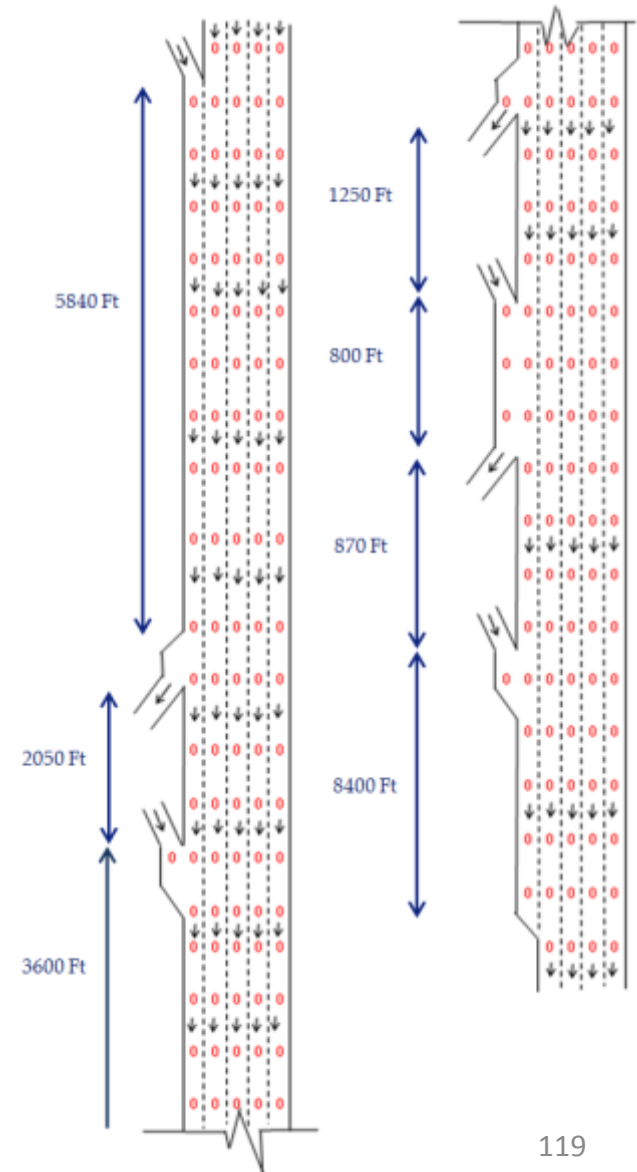


1. Dynamic Lane Grouping
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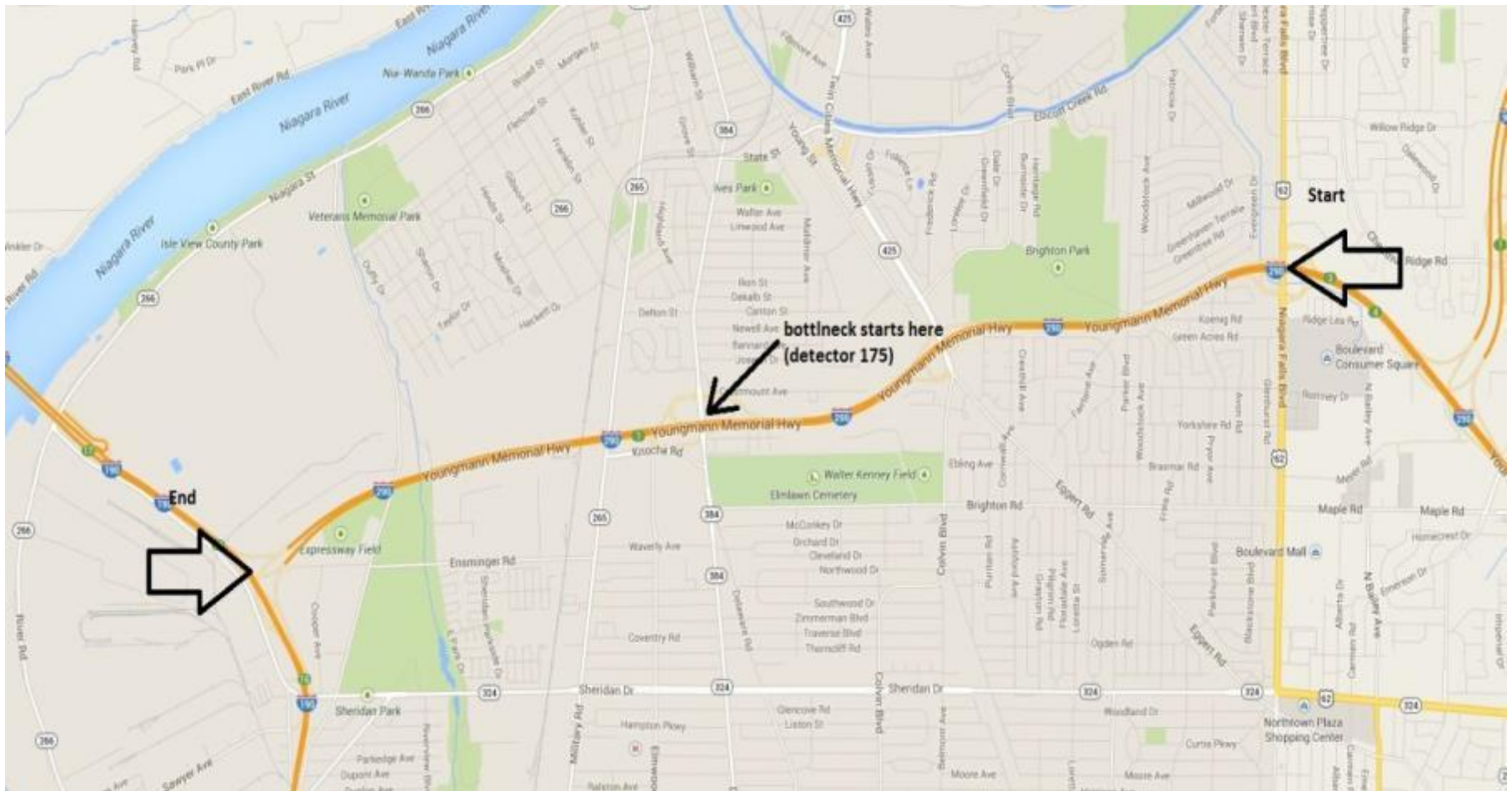
Lane Narrowing to Add a Lane



- Reducing lane width to 10'
 - often without construction,
 - or requisition of additional space
- Compared vs. five 12-foot lanes
 - impact of additional roadway
 - vs. redistributing the existing one



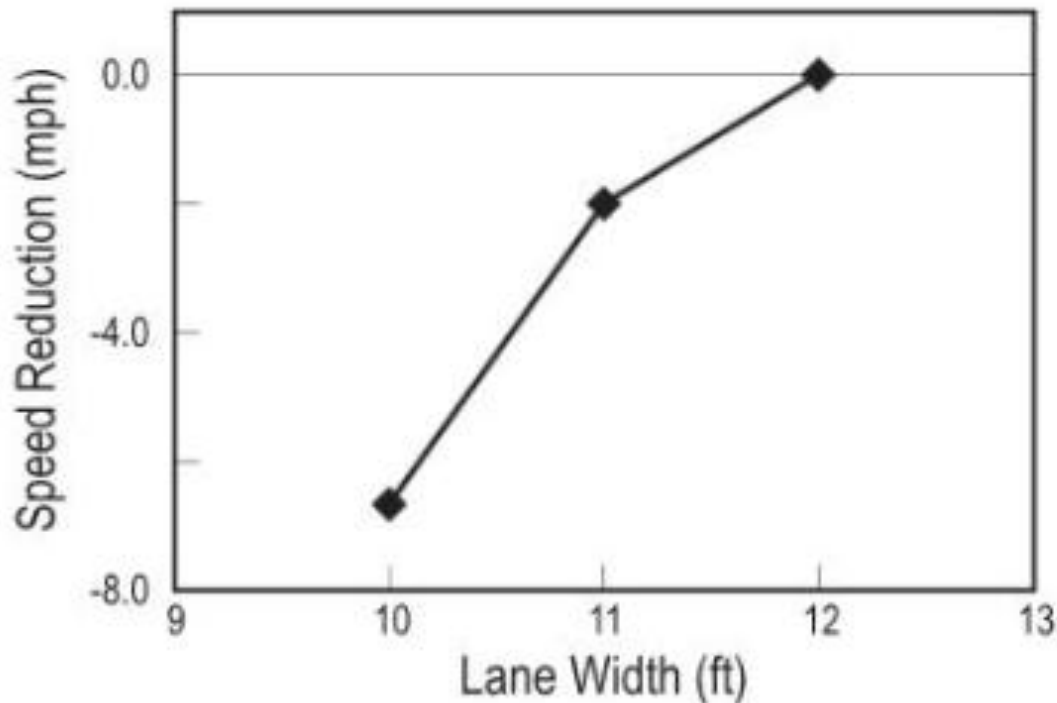
Lane Narrowing to Add a Lane



Lane Narrowing to Add a Lane



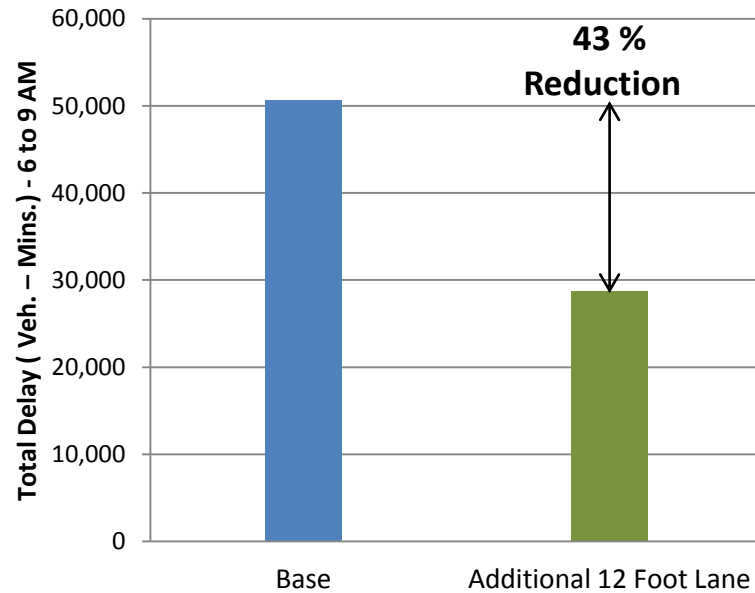
- Drivers reduce speed on lanes narrower than 12 feet
 - HCM, TransModeler



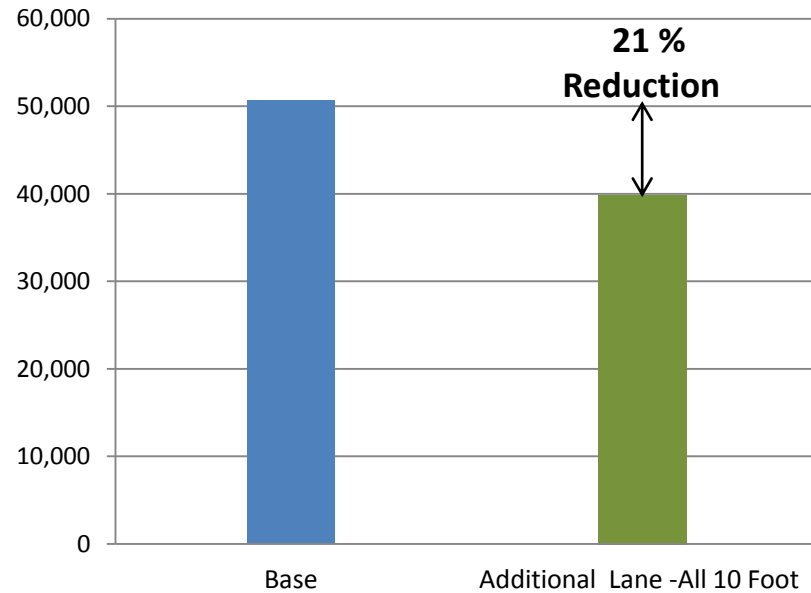
Lane Narrowing to Add a Lane



Construction of Additional Lane



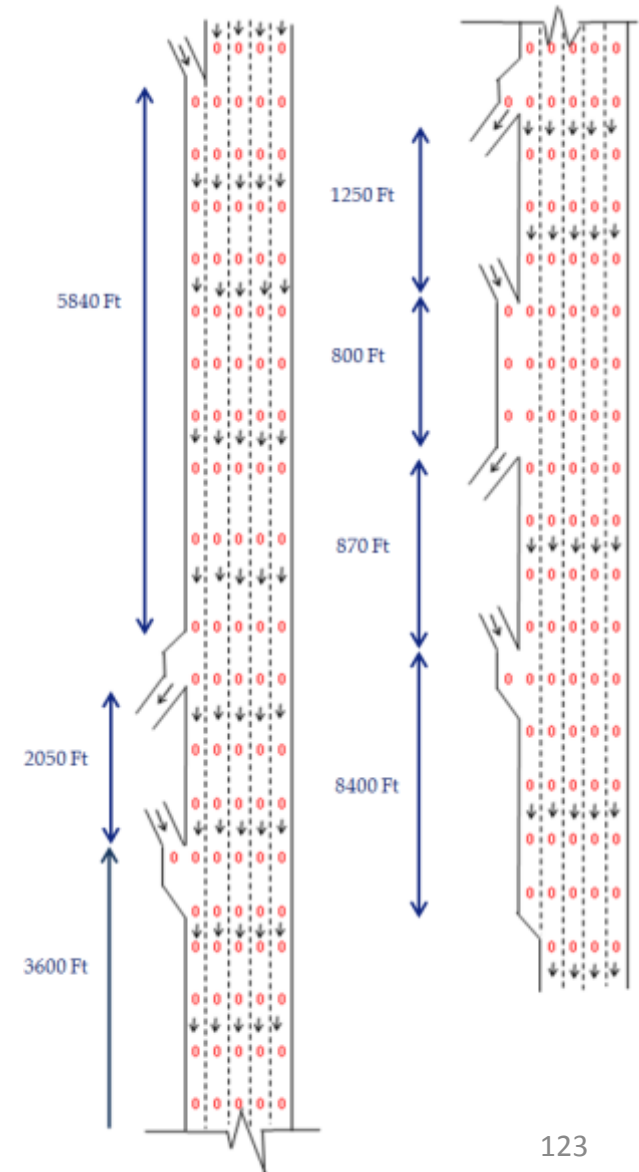
Low-Cost Alternative



Lane Narrowing to Add a Lane



- Benefit-cost ratio of roughly 20:1
- Assumptions
 - 30-year life
 - annual O&M of \$26K per mile
 - start-up cost of \$2M



Featured Bottleneck Solutions



1. Dynamic Lane Grouping
2. Dynamic Merge Control
3. Acceleration Lane Extension
4. Hard Shoulder Running
5. Lane Narrowing to Add a Lane
- 6. Alternative Intersections and Interchanges**

Alternative Intersection Design



Diverging Diamond Interchange



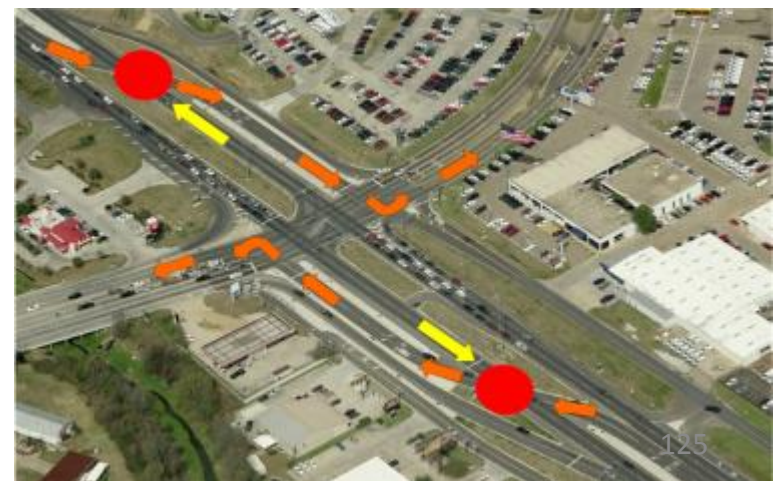
Median U-Turn



Restricted Crossing U-Turn



Displaced Left-Turn Lane



Double Crossover Diamond Interchange aka Diverging Diamond Interchange (DDI)



Diverging Diamond Interchange (DDI)



[Play video](#)

Median U-Turn Intersection (MUT)



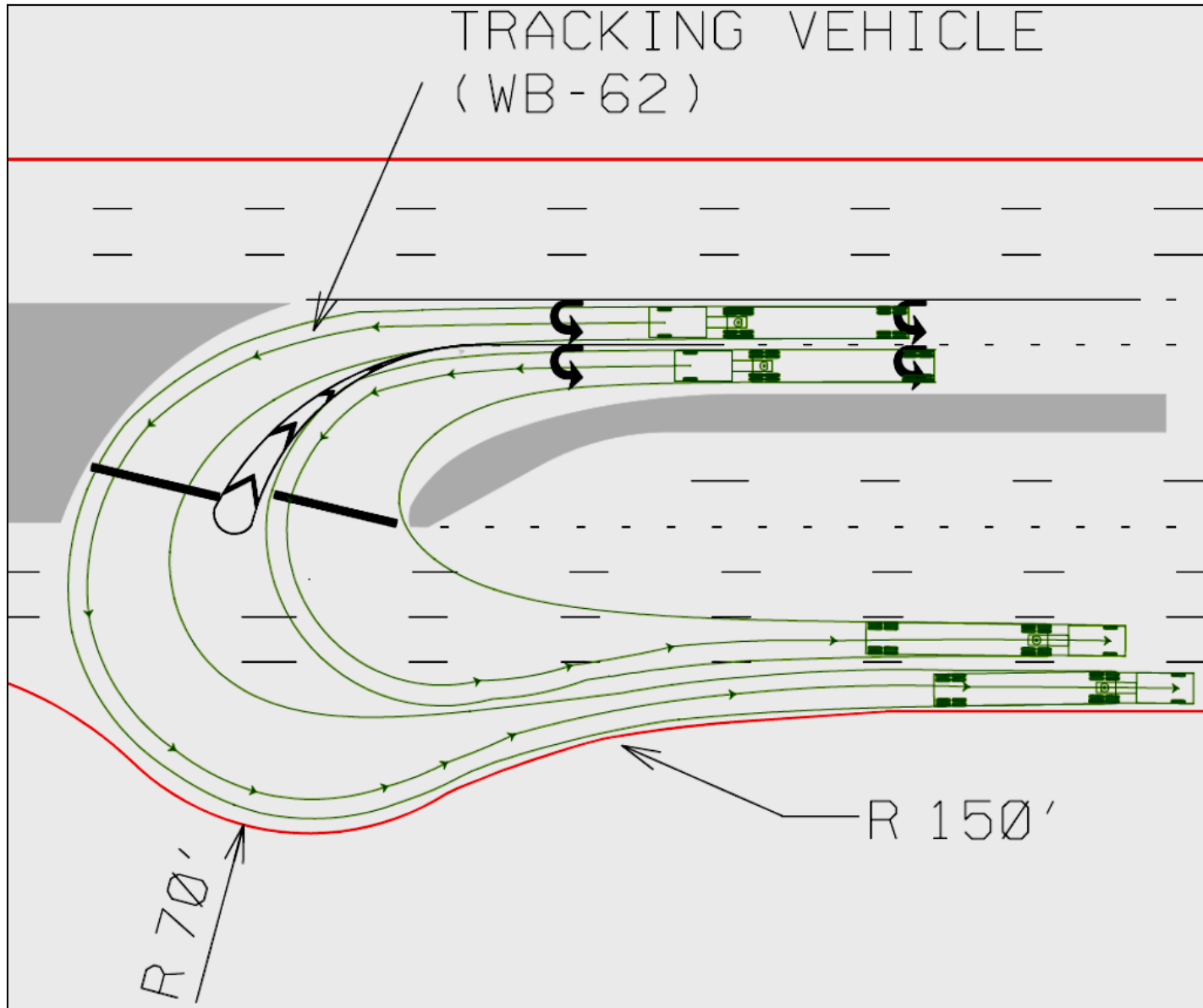
**20% to 50%
increase in
throughput**



**15% to 30%
reduction in
network
travel time**

Median U-Turn Intersection (MUT)

Wide median is not necessary



Median U-Turn Intersection (MUT)



[Play video](#)

Restricted Crossing U-Turn (RCUT)



RCUT Intersection – Implementations



U.S. Rt. 301 and Del Rhodes Ave Unsignalized RCUT in Maryland



- 53.7% reduction in injury and fatal crashes.
- 34.8% reduction in all crashes

RCUT Intersection – Implementations

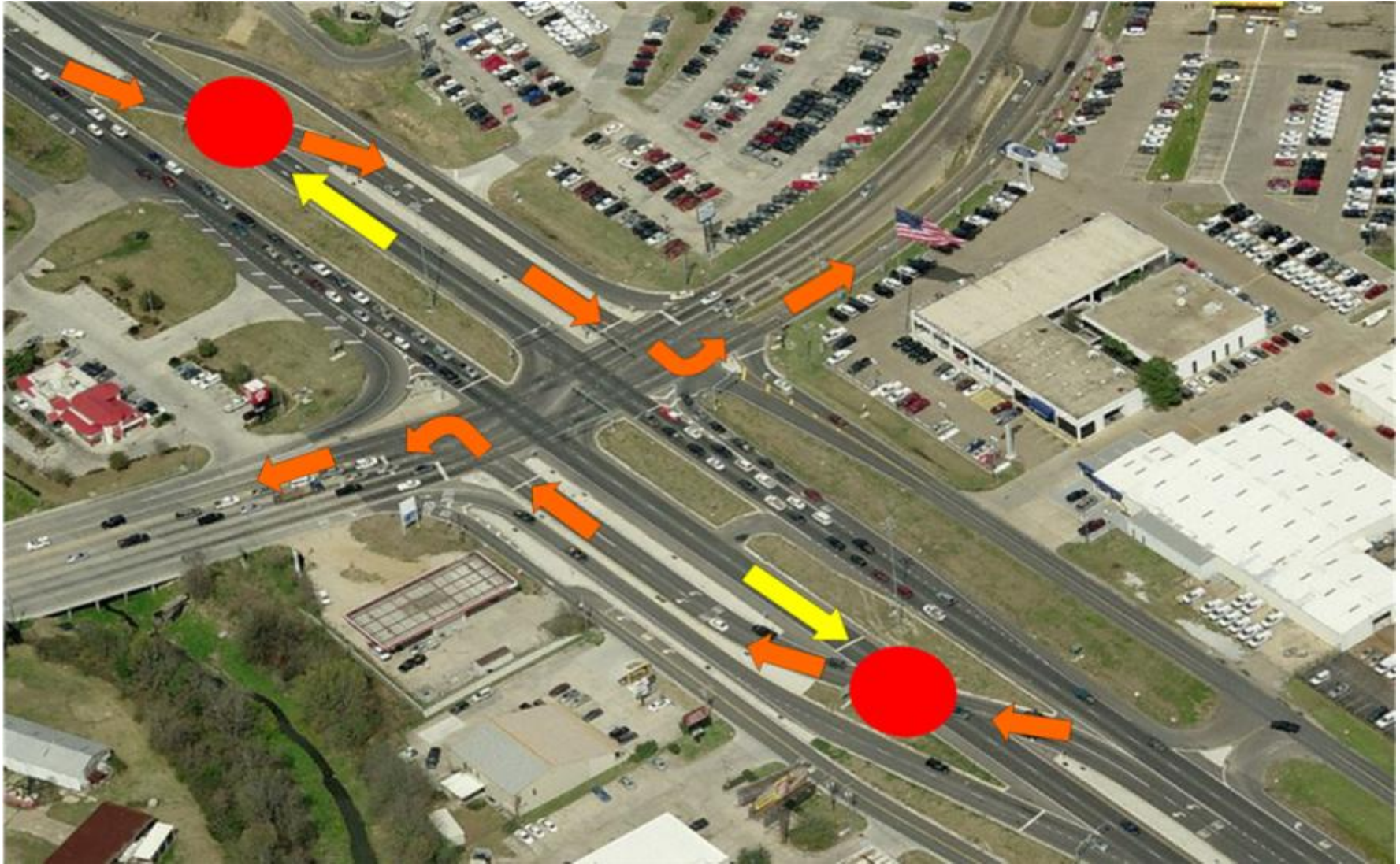


Restricted Crossing U-Turn (RCUT)



[Play video](#)

Displaced Left-Turn Intersection (DLT) aka Continuous Flow Intersection



DLT Intersection in Utah (without bypass right-merge lane)

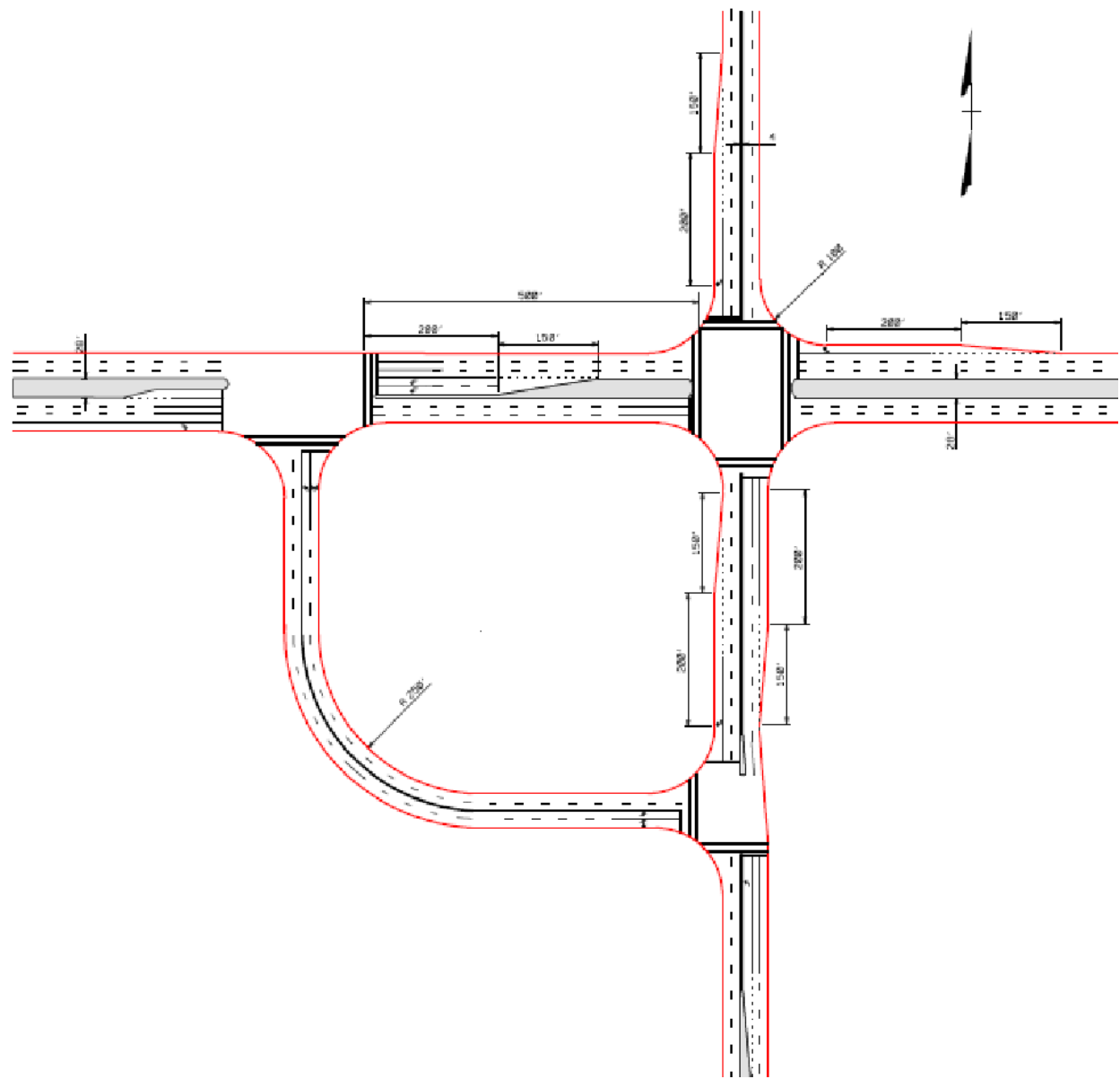


Displaced Left-Turn Intersection (DLT) aka Continuous Flow Intersection



[Play video](#)

Quadrant Roadway Intersection Design



Fairfield, OH

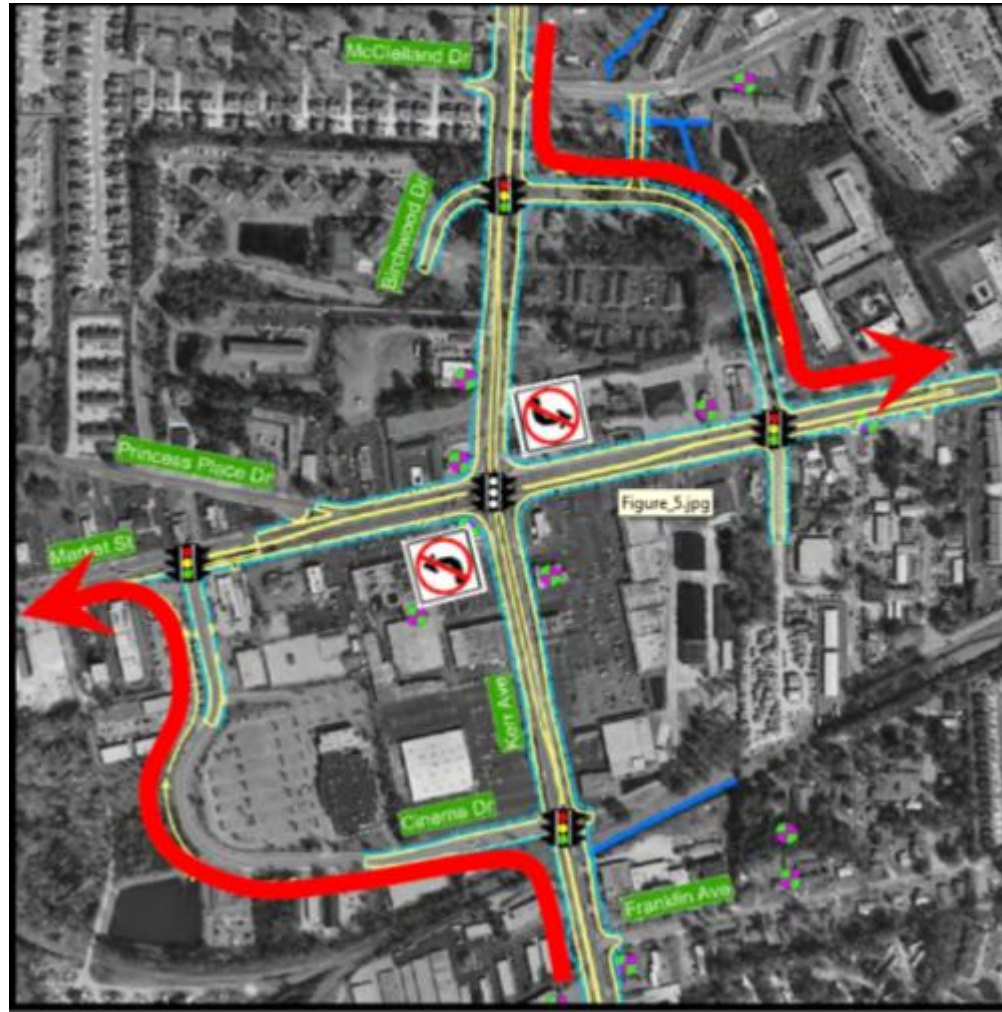
(Google map image)



Quadrant Roadway Intersection



Proposed NC Double Quadrants From Presentation by VHB, Nov. 2013



Quadrant Roadway Intersection

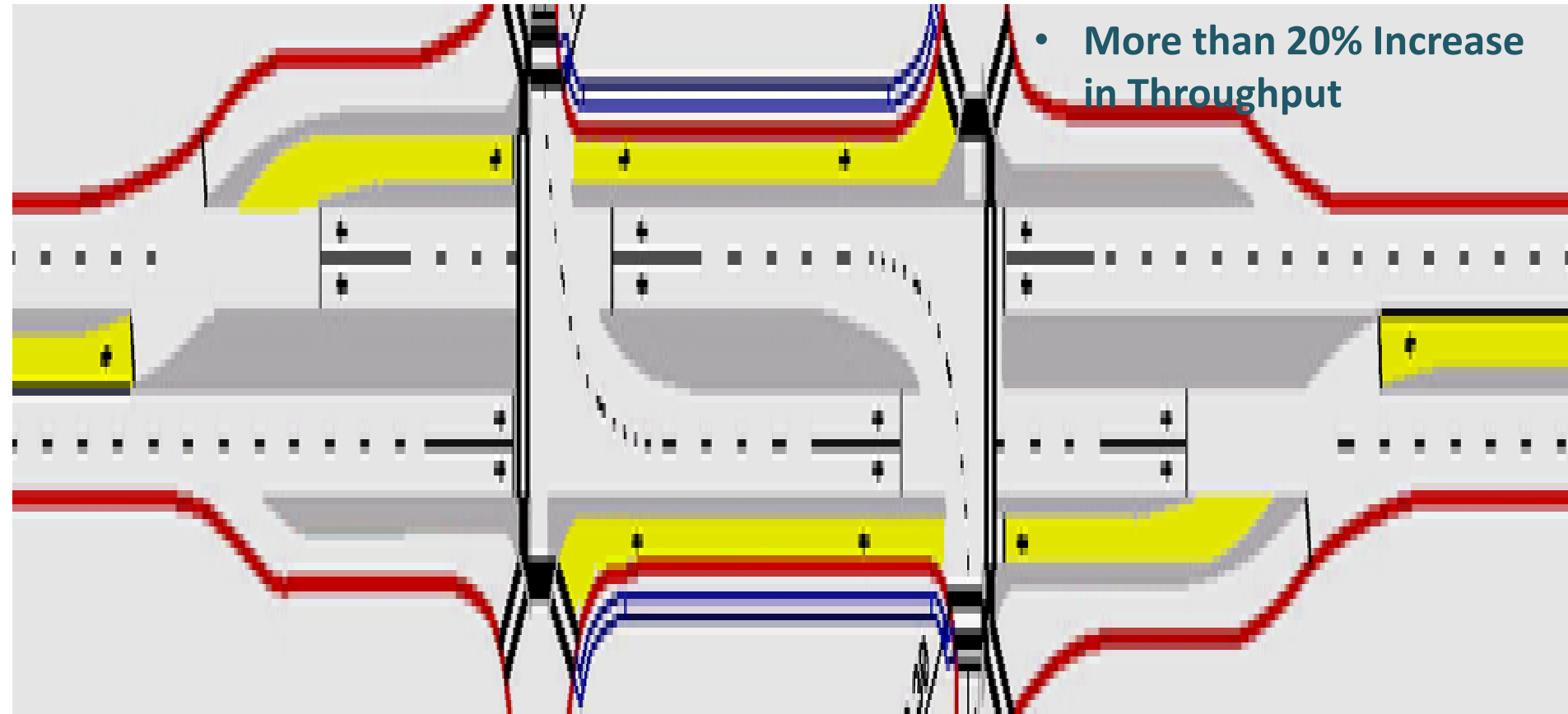


[Play video](#)

Displaced Left-Turn Interchange Concept



- More than 20% Increase in Throughput



Displaced Left-Turn Interchange



[Play video](#)

DLT Interchange with Peds



[Play video](#)

Displaced Left-Turn Interchange First Implementation in San Marcos, TX



<https://www.youtube.com/watch?v=ULyjDcEeHG0&feature=youtu.be>



Displaced Left-Turn Interchange First

Implementation in San Marcos, TX



[Play video](#)

Workshop Summary



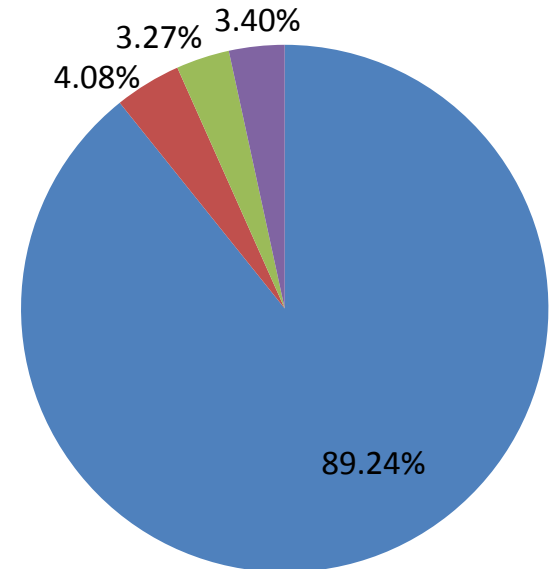
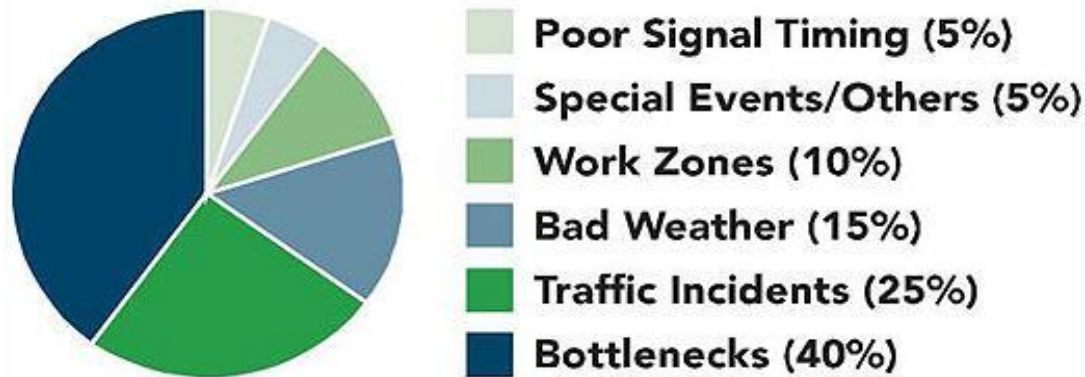
1. Congestion and bottleneck concepts
2. Congestion and bottleneck identification methods
3. Modernized causes of congestion pie chart
4. Featured bottleneck mitigation strategies

Workshop Summary

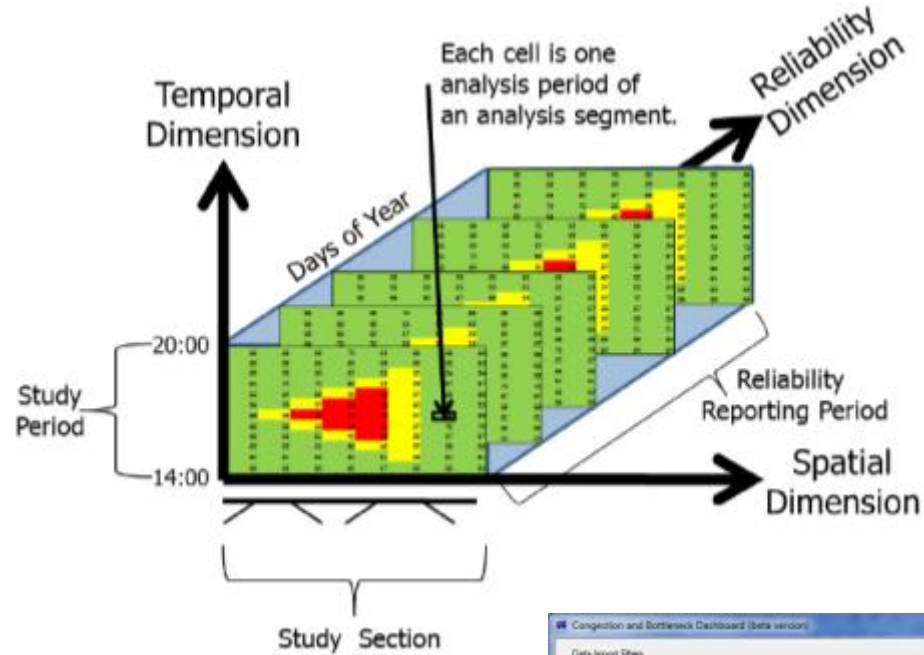


- Data-driven congestion causal pie chart
 - Bigger impact: road geometry, bad weather
 - Smaller impact: incidents, work zones
- Coming soon
 - Surface arterial pie chart
 - Analysis of more freeways

- V/C>1
- Bad Weather
- Traffic Incidents
- Work Zones



Workshop Summary

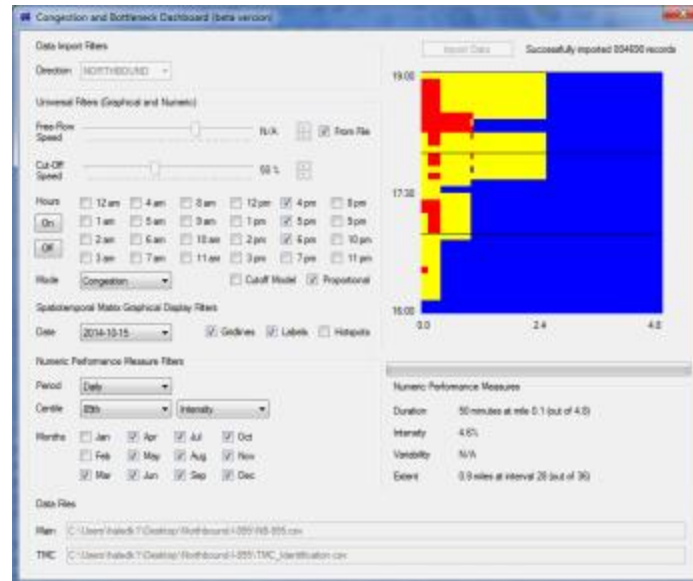


BINARY MATRIX

Time



Space





Featured Bottleneck Mitigation Strategies

1. Dynamic Lane Grouping
2. Dynamic Merge Control
3. Acceleration Lane Extension
4. Hard Shoulder Running
5. Lane Narrowing to Add a Lane
6. Alternative Intersections and Interchanges

Bottleneck Mitigation Strategies

