Traffic Demand Patterns and Signal Retiming Strategies for ITS-Data Rich Arterials

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Session 1b - Using ITS to make TSM&O Smarter

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Florida Section • District 10

ITS Florida

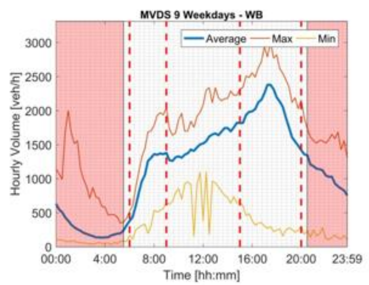
Presentation Outline

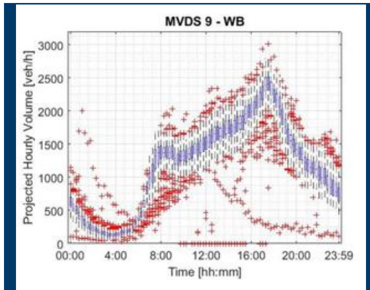
- About the project with FDOT
- Research problem – how many signal plans are needed per year?
- Methodology
- Analysis of the results
- What does this really mean? - Discussion
- Conclusions & future plans

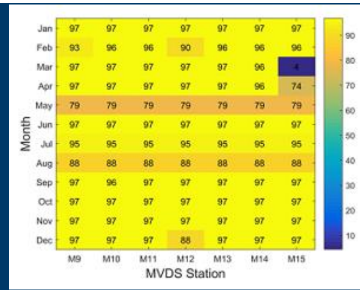
Project Description

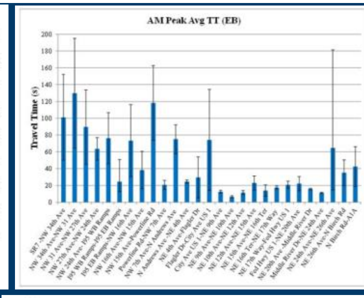
- TITLE: Analysis of Traffic Demand Patterns and Signal Retiming Strategies for ITS-data-rich Arterials
- Evaluate robustness of signal timing plans for varying traffic conditions
- Incorporate long-term field data into the decision making process
- Identify reasons for traffic congestion
- Develop a microsimulation model and test multiple representative traffic scenarios
- Test existing signal timing plans and develop new ones which may provide better flows and reduce certain congestion performance measures
- Develop a method which would help FDOT to identify conditions which warrant execution of different timing plans

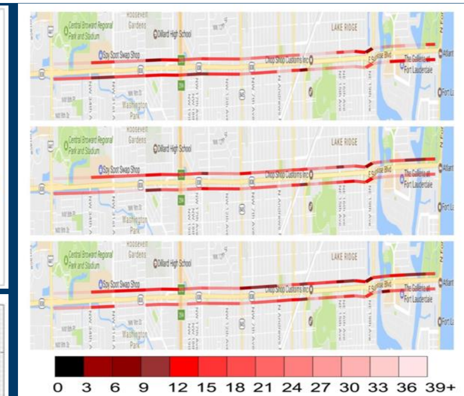
Preliminary Results – Analyzing Trends

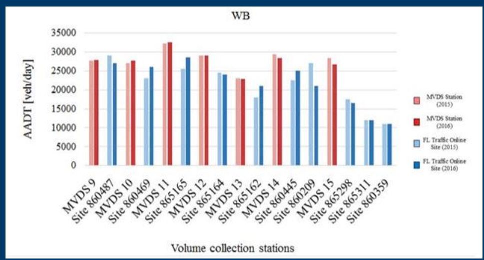


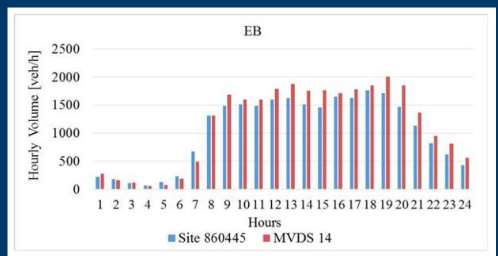


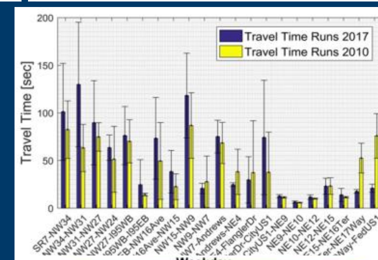


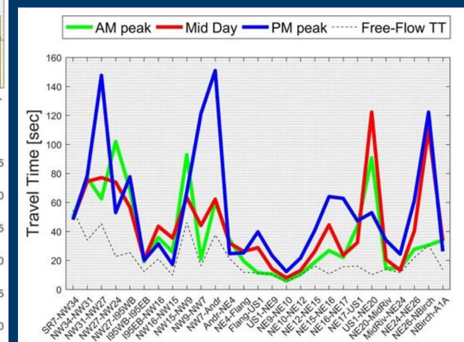


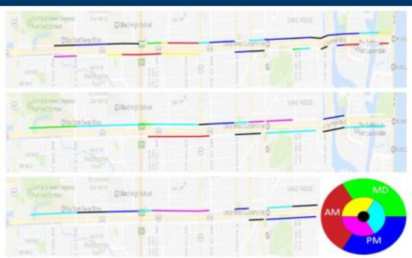


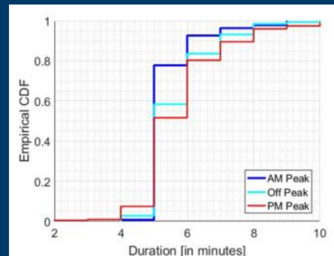


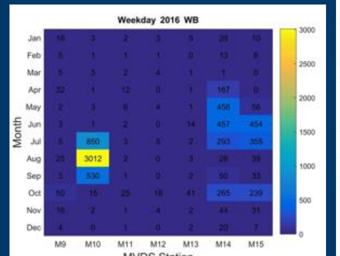


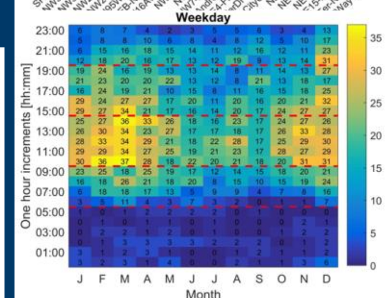












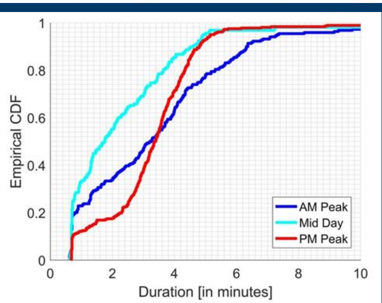
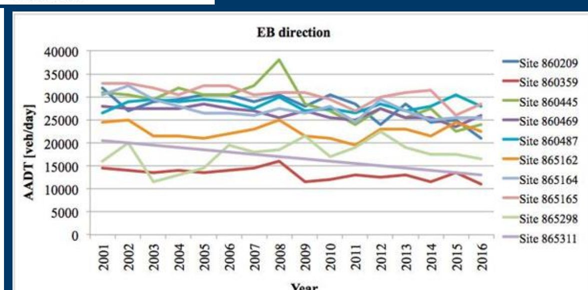
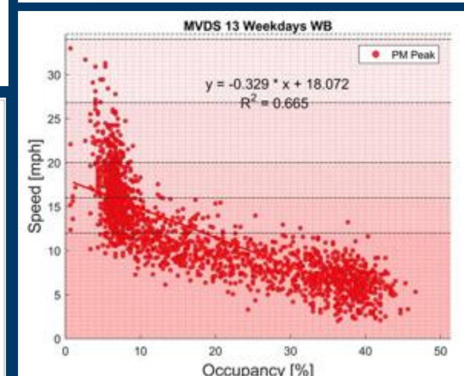


Table 9: MADT in 2015 in the EB direction

	2015 - EB						
	MVDS 9	MVDS 10	MVDS 11	MVDS 12	MVDS 13	MVDS 14	MVDS 15
Jan	28354	25336	34894	32752	26421	30832	26918
Feb	29810	26536	36057	33808	27271	31839	27426
Mar	30002	26908	36276	34011	27445	32235	28441
Apr	29168	26139	35664	33464	26834	30980	27504
May	29102	25746	35093	32760	26314	30564	26927
Jun	28621	25561	35245	32843	26199	30236	26200
Jul	28535	25514	35445	33171	26524	30349	27063
Aug	28747	25654	35295	32841	26077	30004	26991
Sep	28050	24148	33950	31495	25198	28847	25682
Oct	28901	24972	35072	32111	26064	29109	25135
Nov	27510	24635	33978	30985	25240	28335	24553
Dec	28926	25493	34652	32003	25575	28750	25458





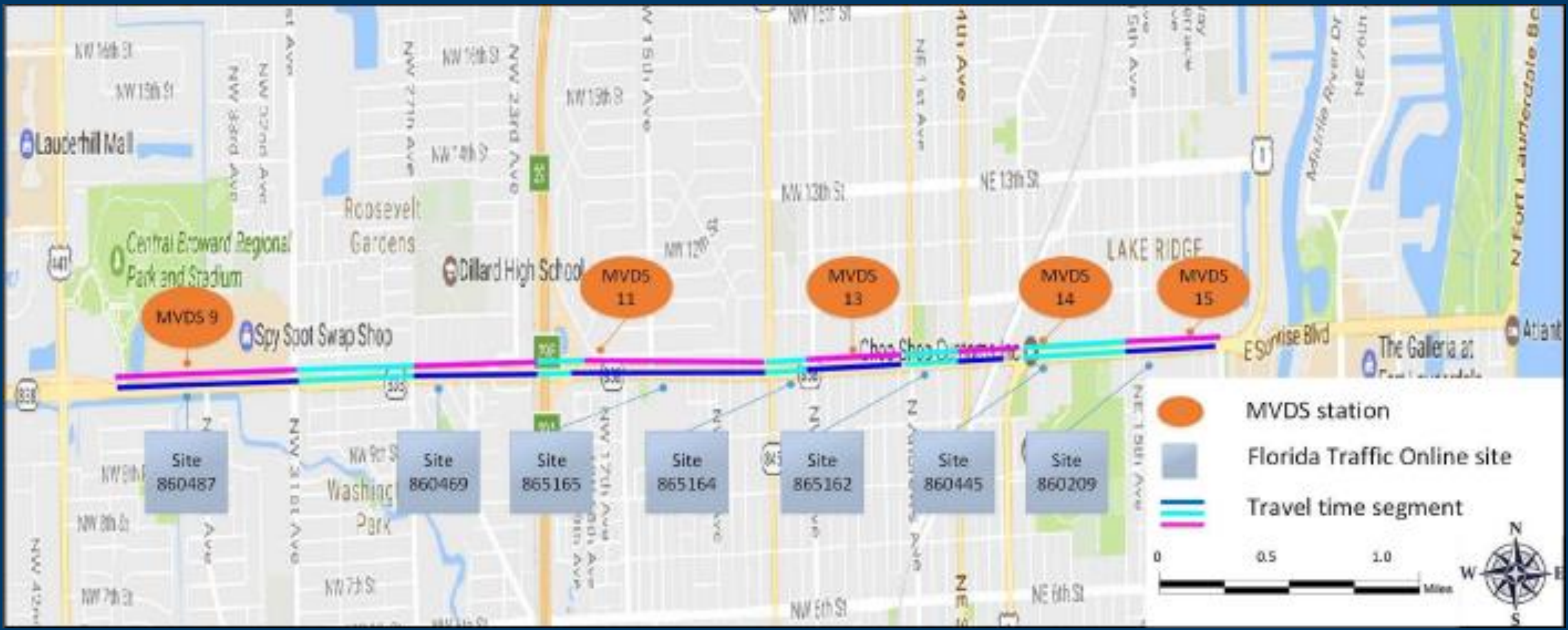
Focus of this Research Subsection

- We know how many TOD signal patterns we need
- How many (off)peak patterns we need per year (DOY)?
- There is no research on this topic
  - Difficult to address without having a lot of data
  - Methods are not developed/known
  - Retiming is costly – making a point that more patterns are needed may not be received well by the community
- This research addresses this problem by:
  - Presenting a method to estimate distinctive traffic patterns
  - Assigning signal timing plans to those distinctive patterns
  - Validating the above assignment through signal optimization
  - As a bonus – we get to discuss if we have a case for adaptive system

Research Method

- Collect field data (mid-block volumes & travel times)
- Store and group data in proper format
- Apply clustering methods
- Identify peak-hour and # of clusters (based on inflection point)
- Decide on data type to use (volumes, travel times or both)
- Identify a representative day for each cluster
- Develop full set of volumes for each representative day (flow-balancing of measured volumes and historical TMCs)
- Populate signal optimization model and optimize signal timings
- Analyze results of signal timing optimization & discuss benefits
- Analyze DOY application patterns
- Make a case for/against Adaptive Traffic Control

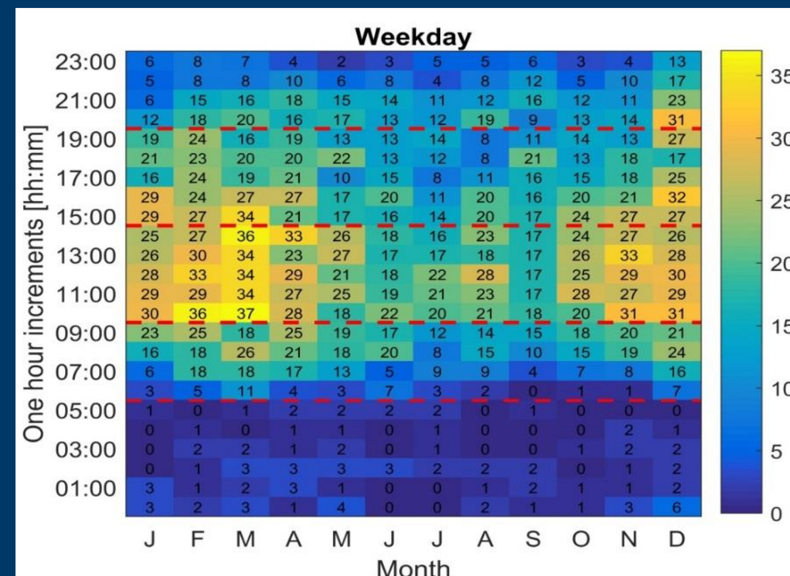
Sunrise Blvd – A1A to SR7



- One of the busiest corridors in Broward County
- Caries around (on some segments) 30,000 veh/day
- A segment which caries heavy traffic from another major arterial (US1)
- Prone to multiple preemption events (railroad & drawbridge)
- Beach access and freeway interchange, a lot of commercial activities

Data – Collection and Handling

- Turning movement counts (historical and some new)
- Travel time – trajectories; probe vehicles with GPS
- Travel time – segments; RITIS platform with INRIX & HERE data sources
- Speeds – point-based – MVDS
- Mid-block volumes – MVDS
- Occupancies – MVDS
- Split history data – ATMS.now
- Preemption events – ATMS.now
- Signal timing sheets (basic & coordination)
- Signal design plans
- Google earth images
- AADT volumes – Florida Traffic Online
- Video recordings (used for saturation flow rate observations)
- Drawbridge activations



# of drawbridge openings (weekdays in 2016)

- 230-page report just to show the trends from analyzed data

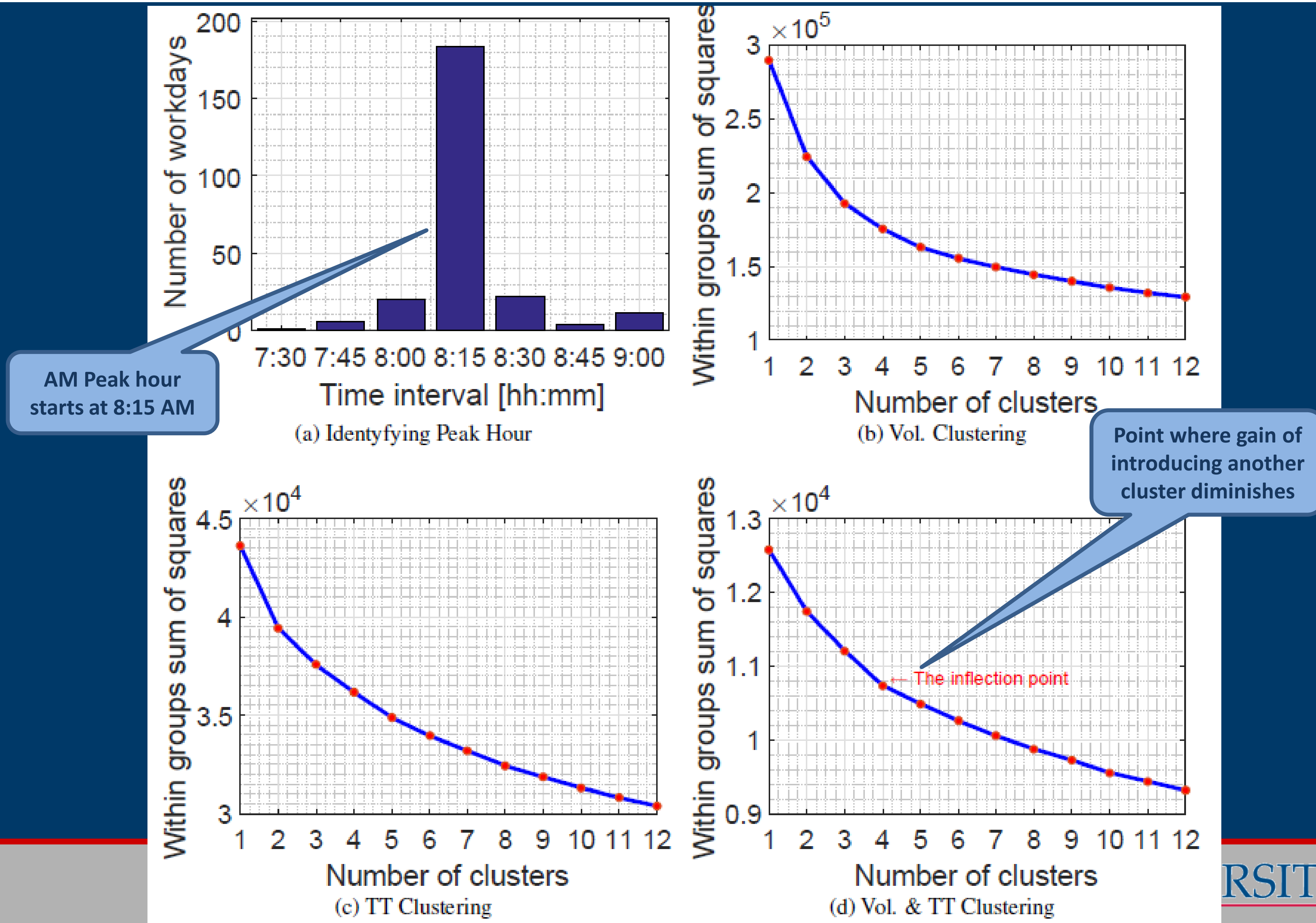
Data Clustering – Representative Days

- K-means clustering is an unsupervised clustering method whose goal is to partition a given set of observations (data points) (x_1, x_2, …, x_{md}) into k clusters by minimizing the within-cluster sum of squares (WCSS):

$$WCSS^k = \arg\min_S \sum_{i=1}^{k} \sum_{\mathbf{x} \in S_i} \| \mathbf{x} - \mu_i \|^2,$$

- where μ_i is mean point of S_i or centroid of cluster i (i = 1, 2,…, k). For the k-means clustering, number of clusters k need to be specified beforehand. This number of clusters depends on the specific domain application and it can usually be inferred with the help of the “elbow” curve WCSSk = f (k).

Data Clustering – Where to “draw a line”?



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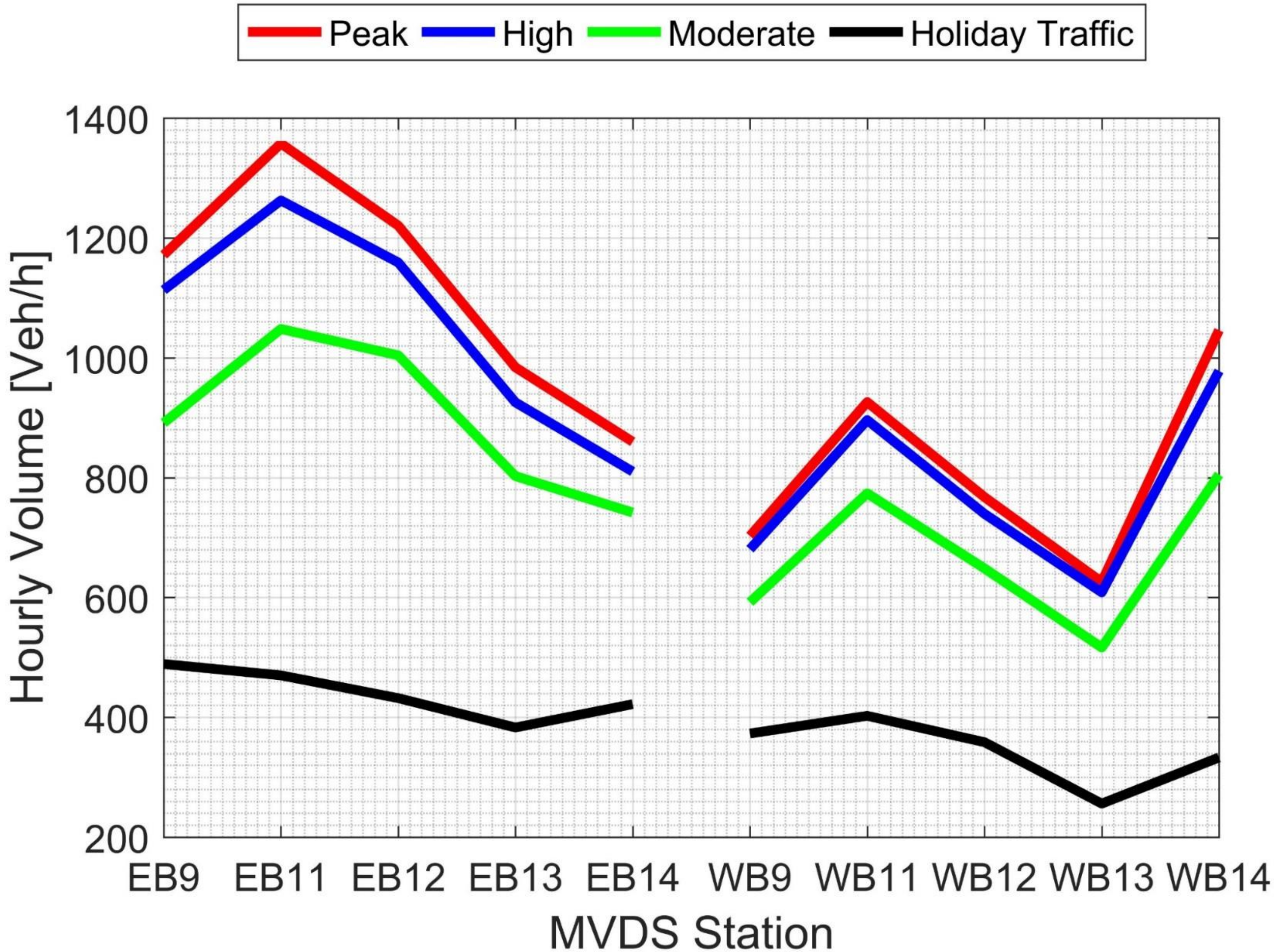
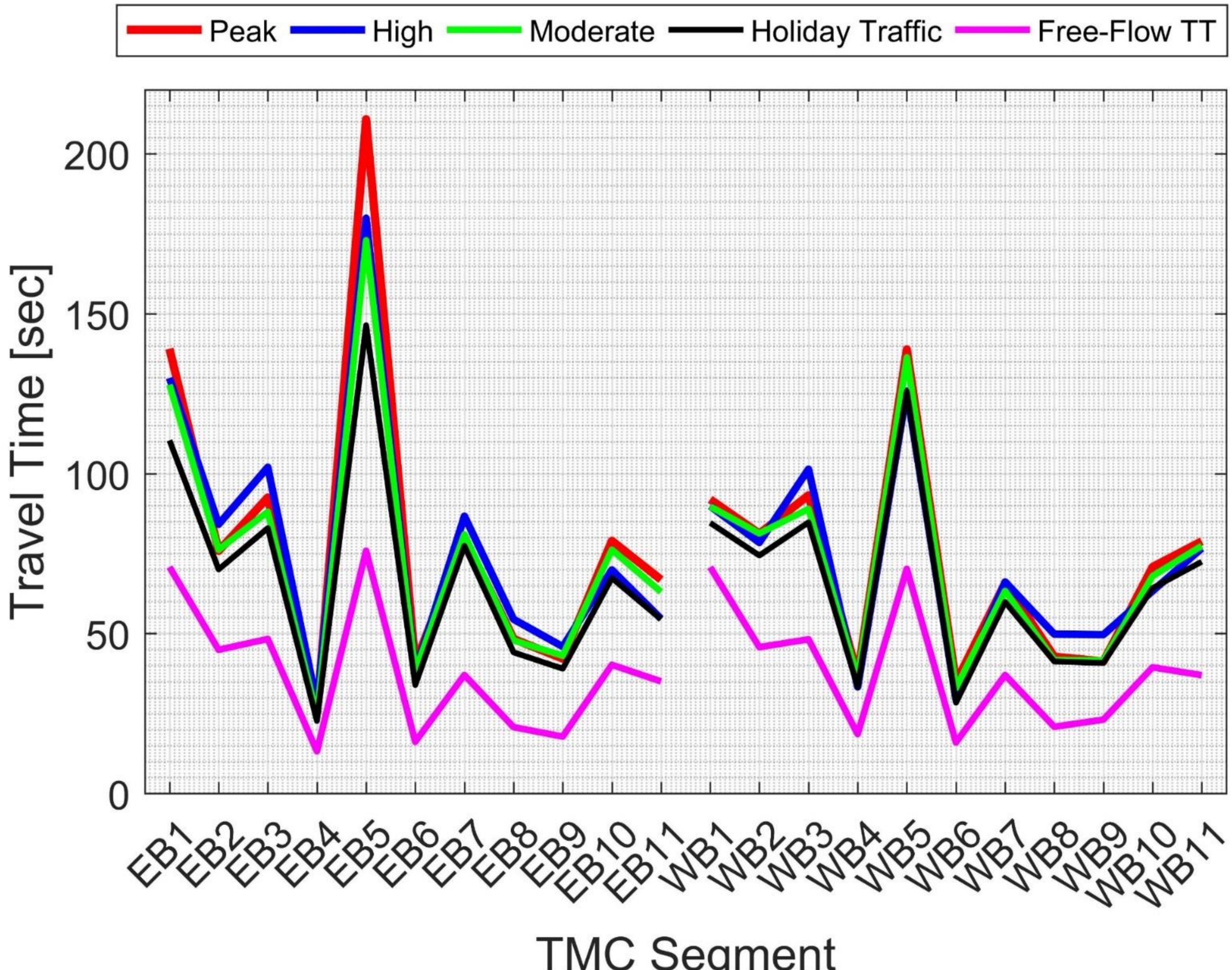
Cluster Analysis Results – Volumes

- System inputs
- Distinctive patterns
- Reflect common /group behavior

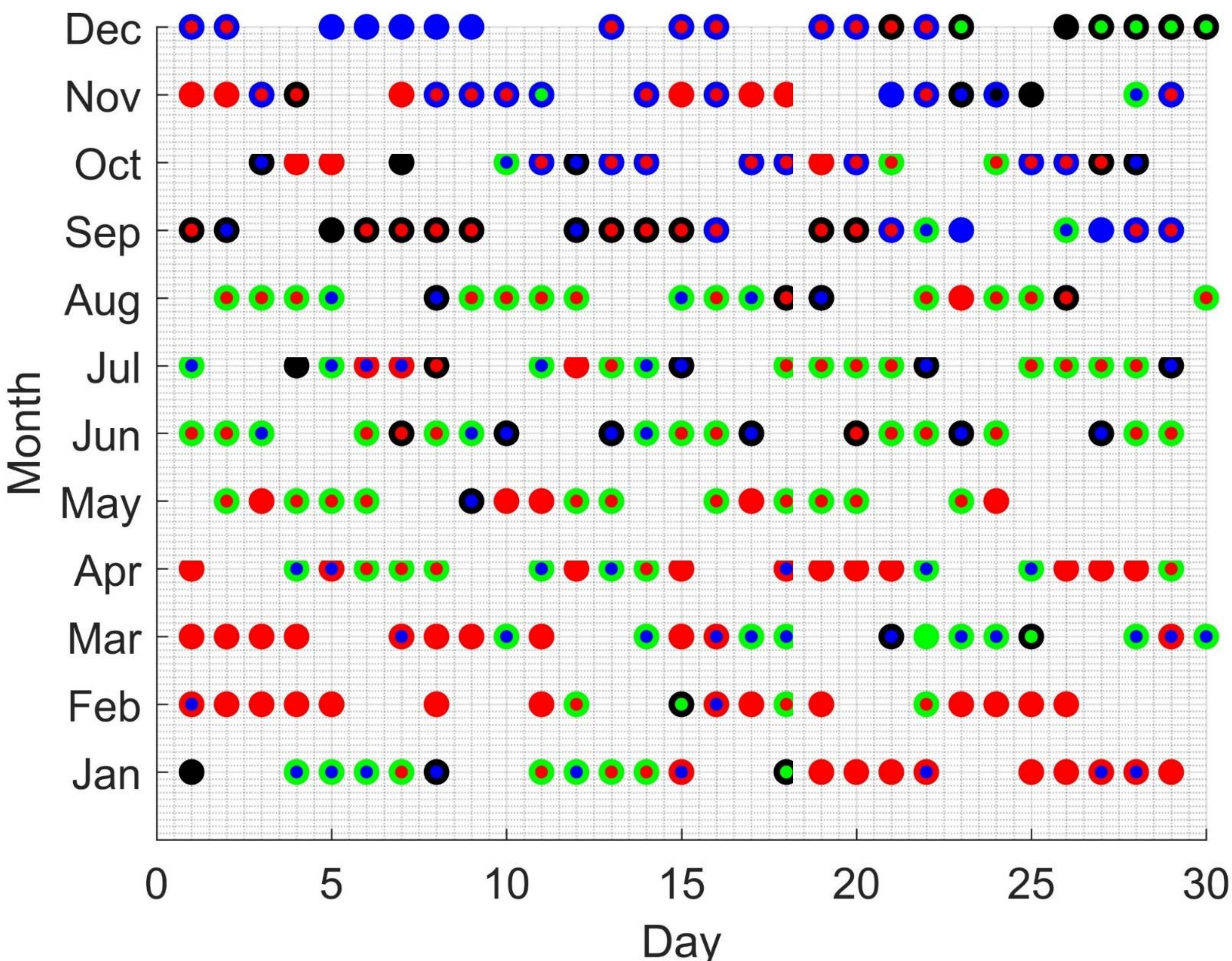


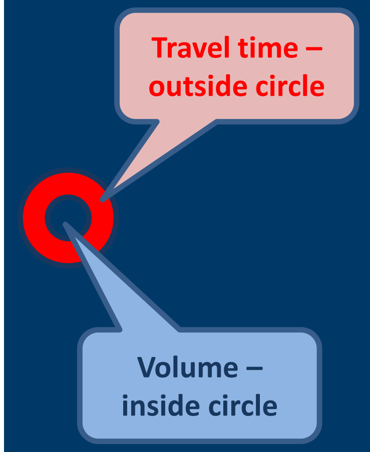
Cluster Analysis Results – Travel Times

- System outputs
- Not very distinctive patterns
- Less of causal group behavior

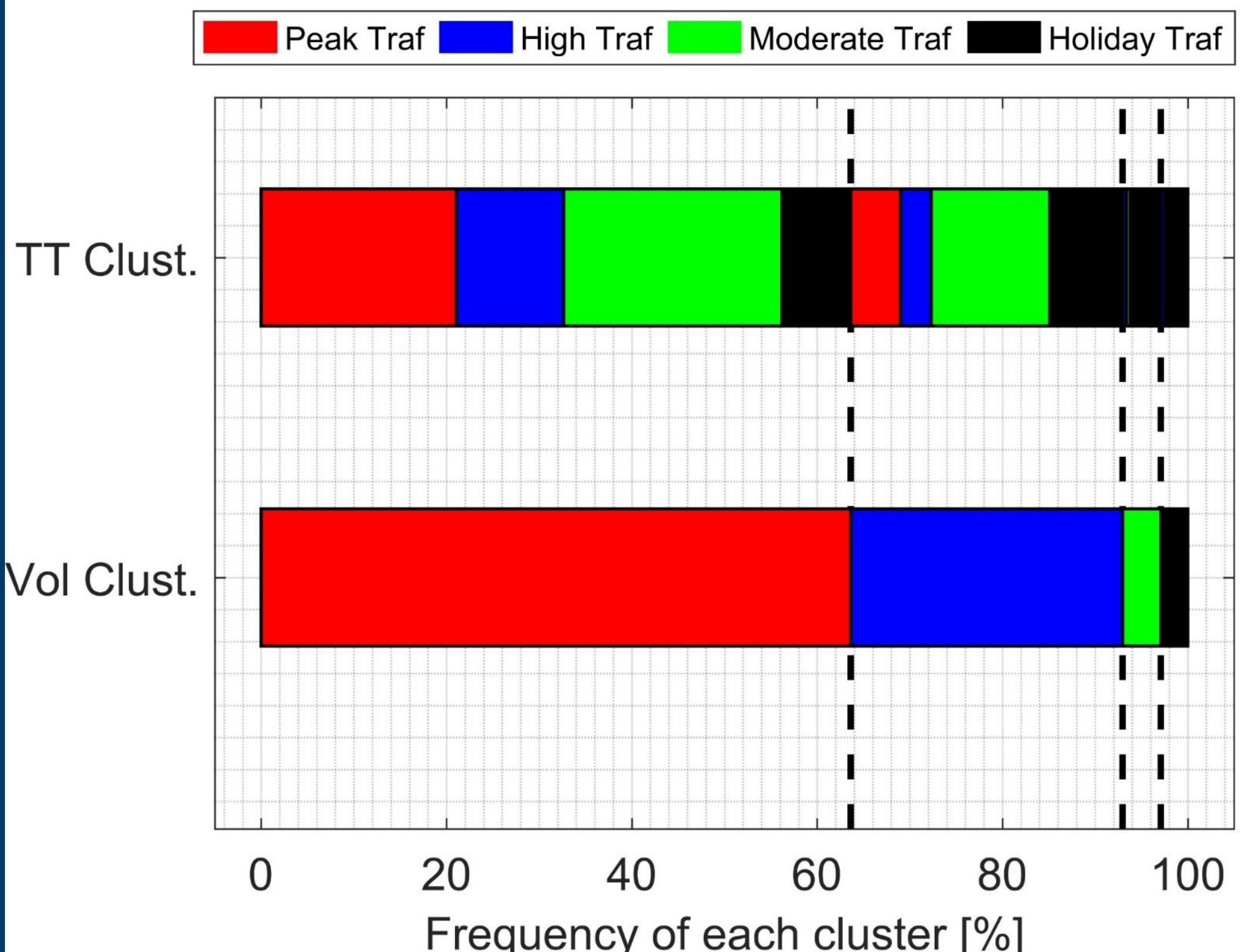


High Traffic Volumes == Long Travel Times?

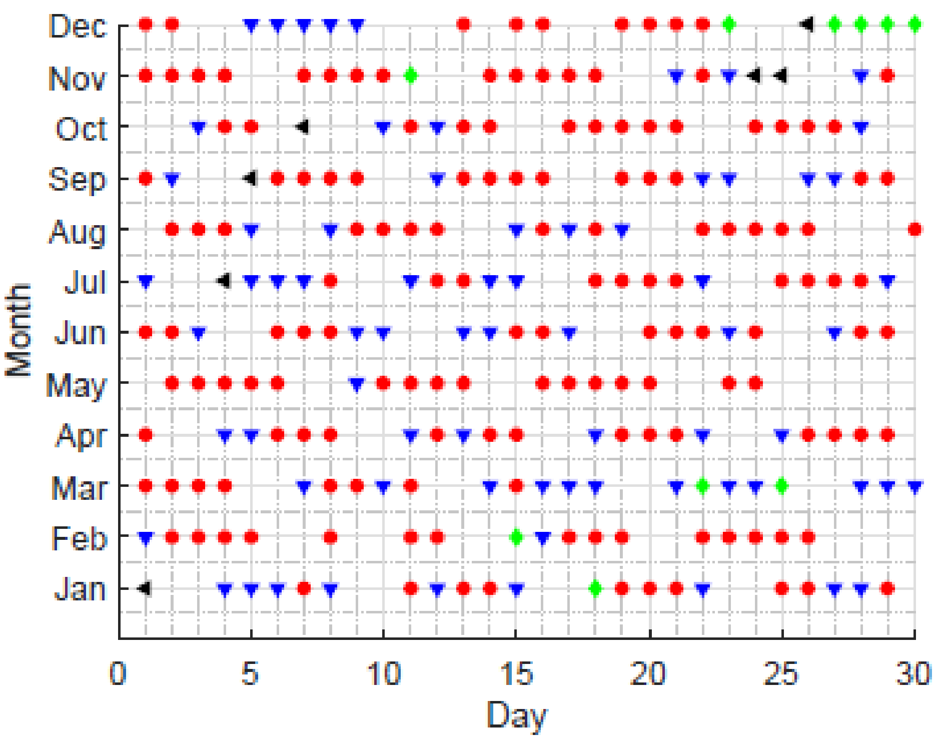




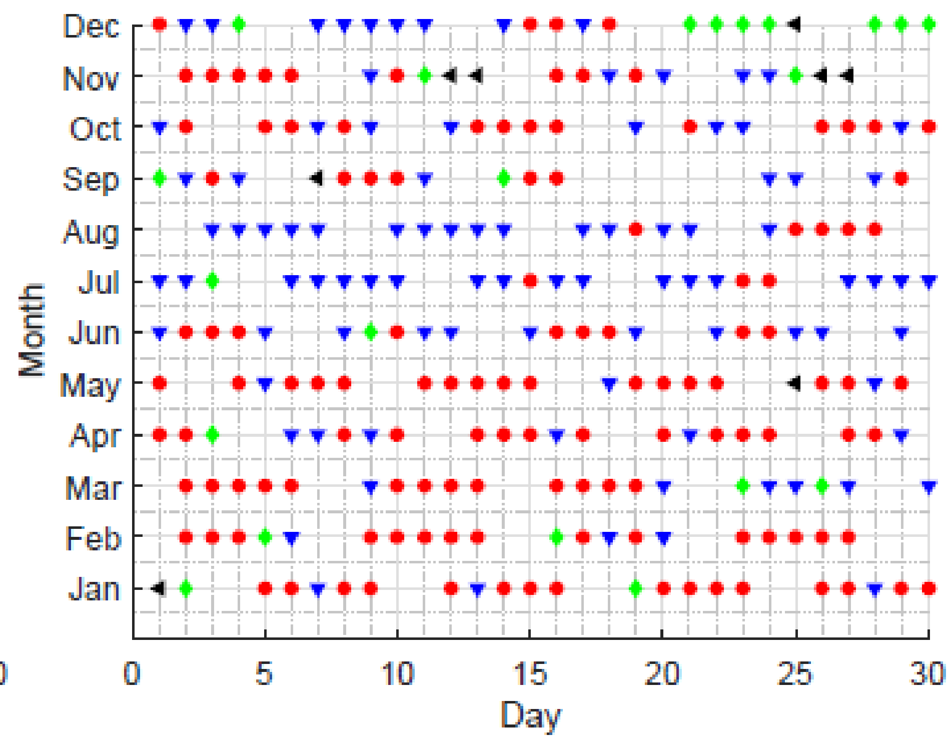
Varying of Travel Times for Given Volumes



Volume-based Clusters of AM Peak Traffic



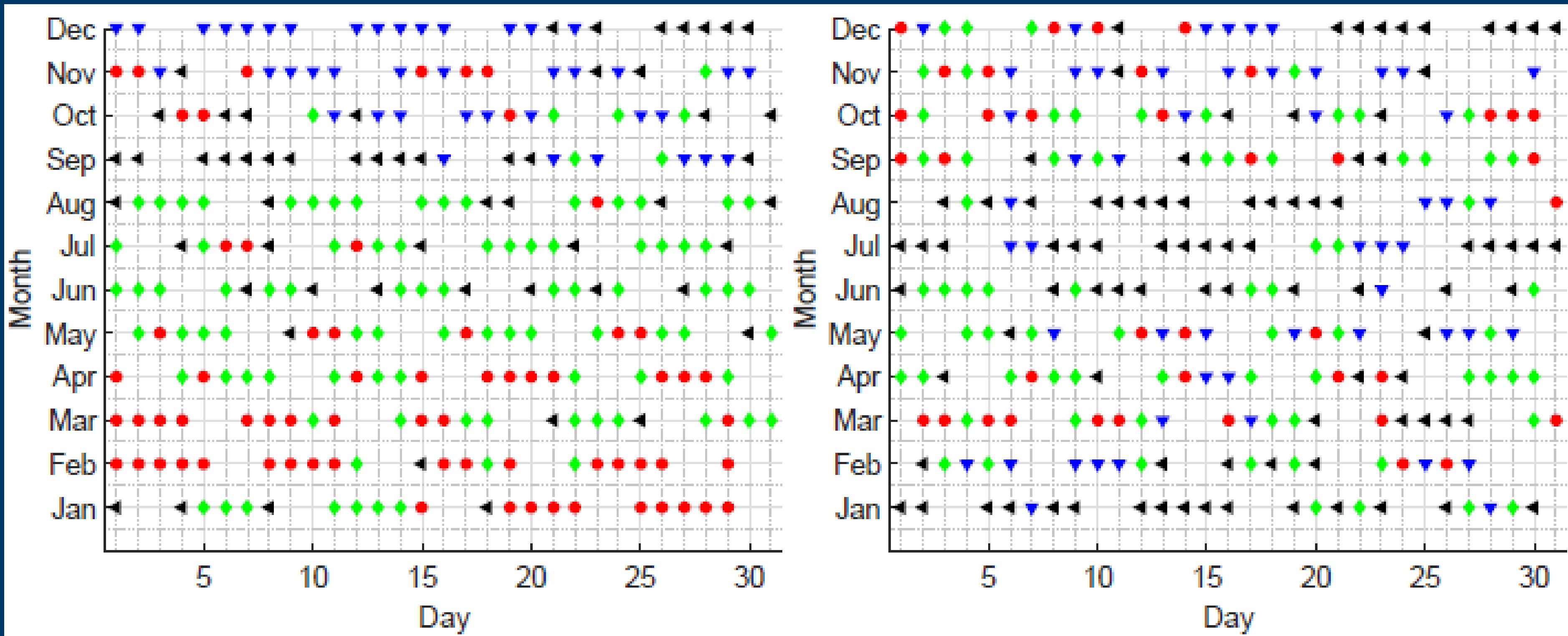
(a) Volume 2016



(b) Volume 2015

Peak traffic High traffic Moderate traffic Low/Holiday traffic

TT-based Clusters of AM Peak Traffic



(c) Travel Time 2016

(d) Travel Time 2015

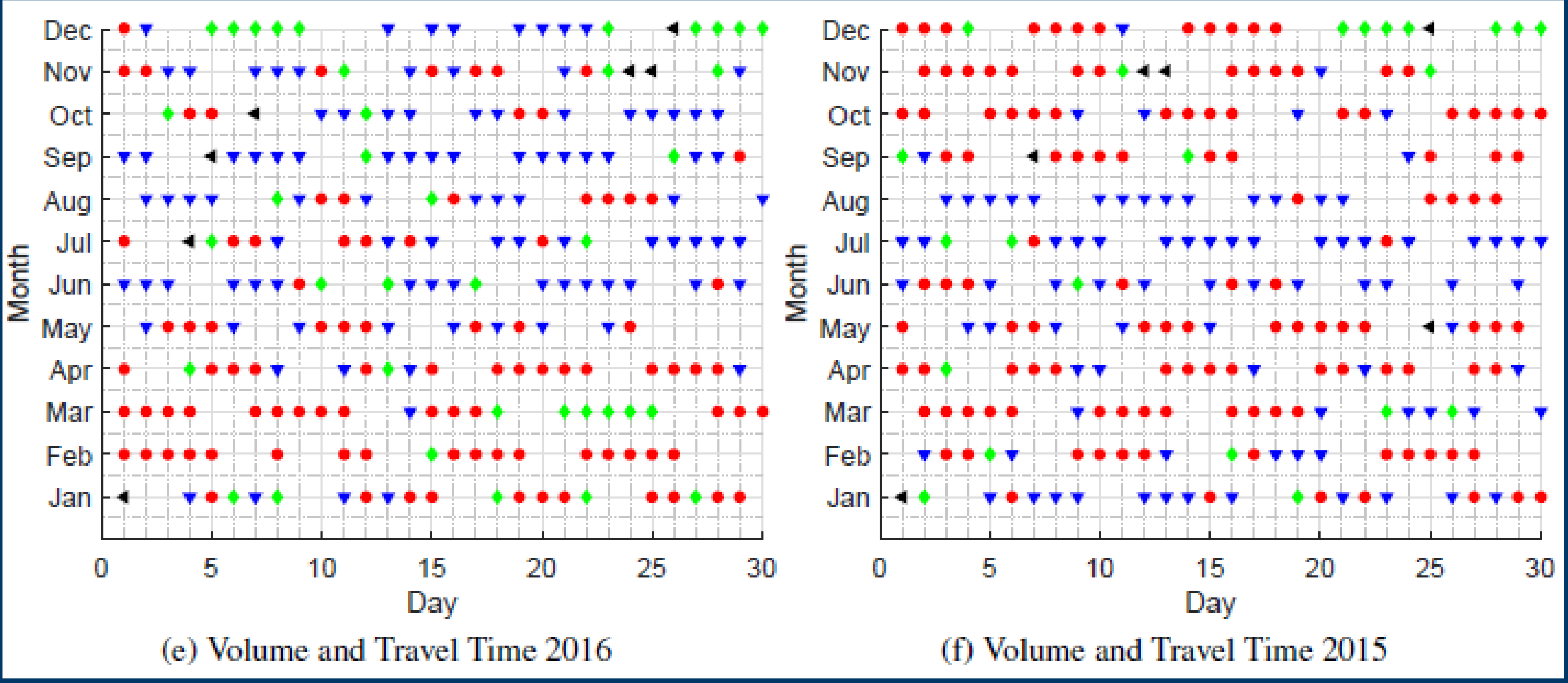
Peak traffic

High traffic

Moderate traffic

Low/Holiday traffic

Vol&TT-based Clusters of AM Peak Traffic



(e) Volume and Travel Time 2016

(f) Volume and Travel Time 2015

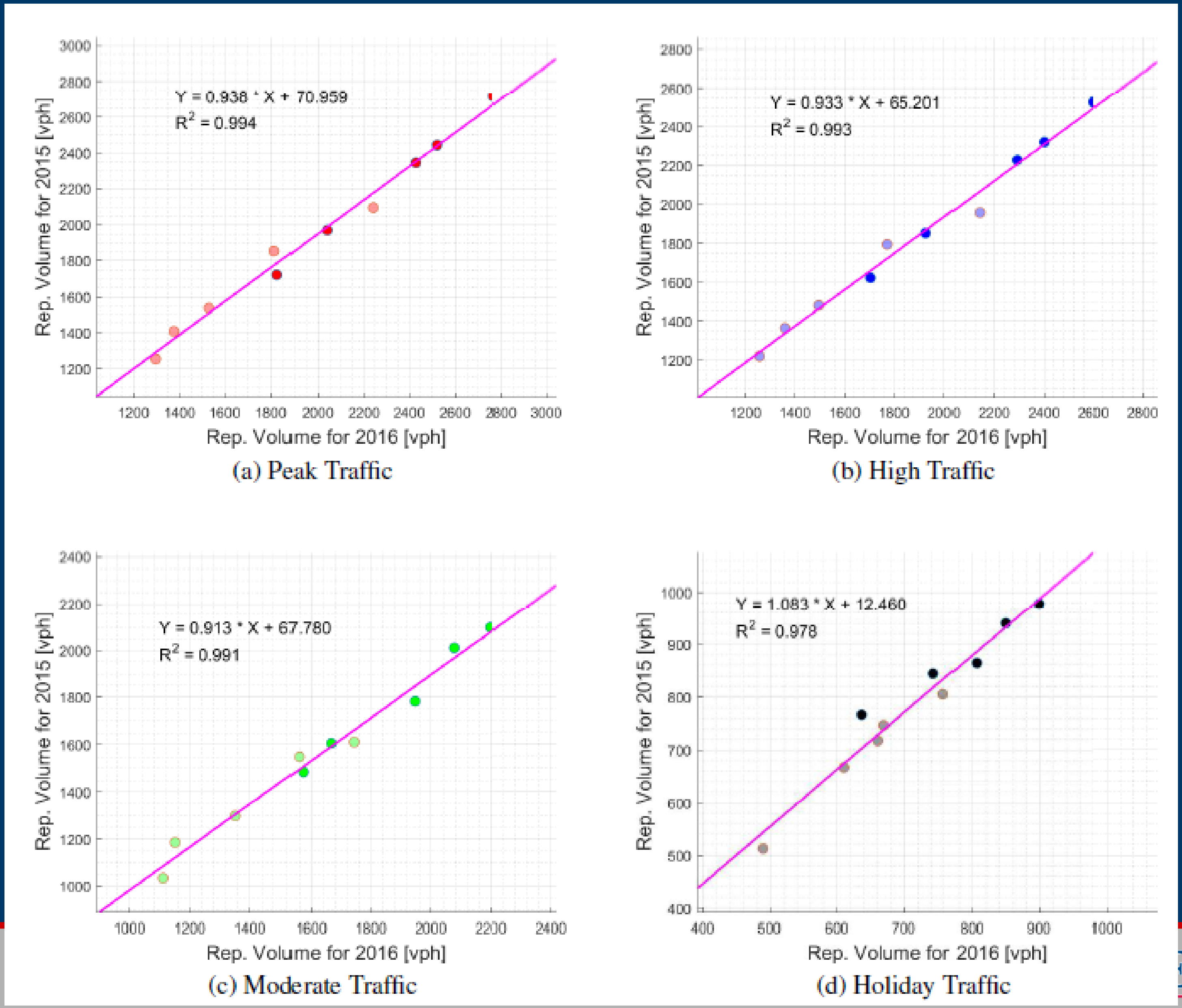
Peak traffic

High traffic

Moderate traffic

Low/Holiday traffic

Consistency of Clusters over Multiple Years



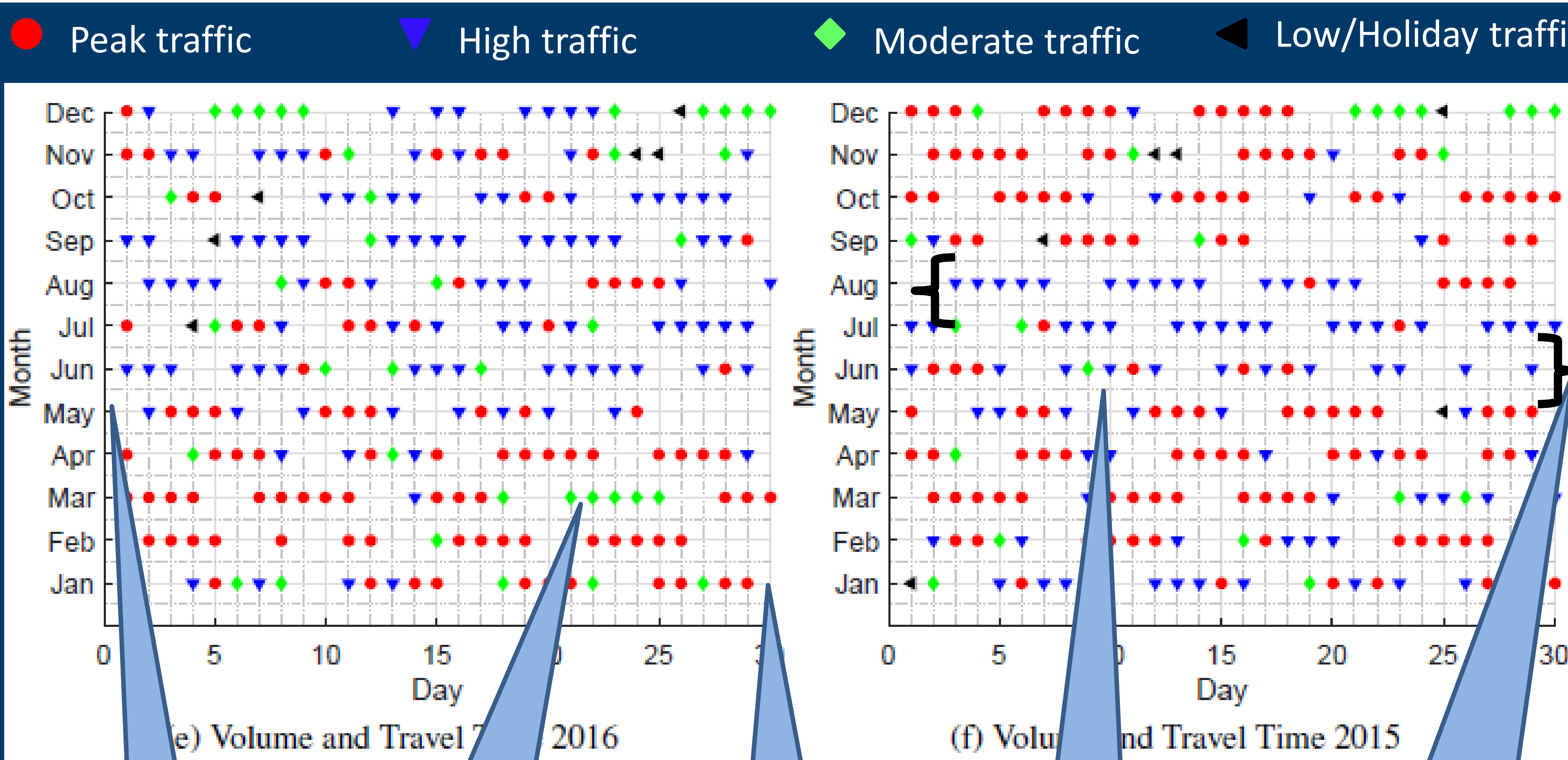
(a) Peak Traffic

(b) High Traffic

(c) Moderate Traffic

(d) Holiday Traffic

Vol&TT-based Clusters of AM Peak Traffic



End of Peak Traffic season?

Do we switch to a separate signal pattern only for a week?

Beginning of Peak Traffic season?

Distinctive traffic 'seasons' or leopard-fur-like pattern?

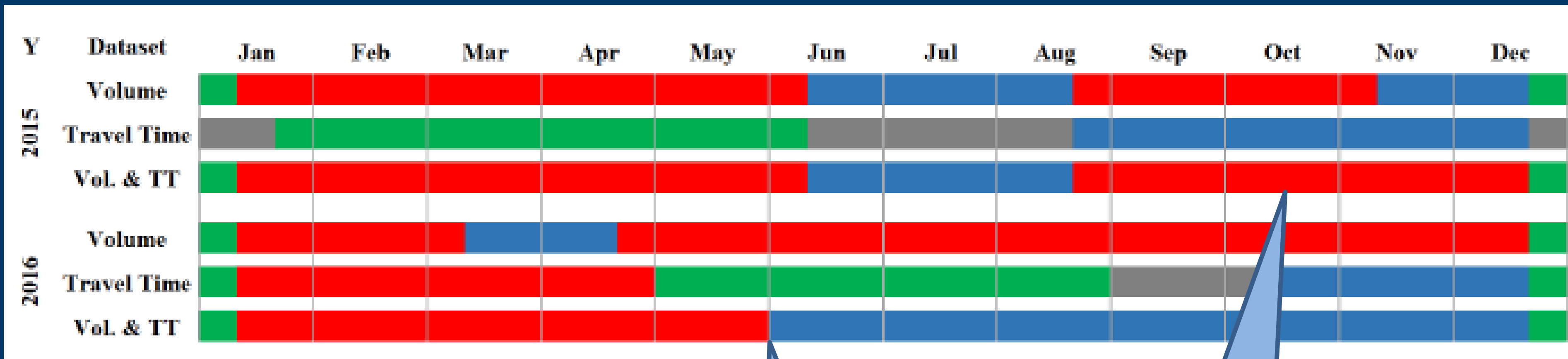
Define seasons as groups of days with minimal number of 'changes' – days when traffic patterns are different from a previous day

Identify Seasons for (DOY) Signal Patterns

Dataset	Volume		Travel Time		Volume & TravelTime	
Year	2016	2015	2016	2015	2016	2015
Number of workdays	242	247	261	259	242	242
# of changes	101	108	114	154	104	99
% of changes	42%	44%	44%	59%	43%	41%
Period 1	Jan 4 - Mar 11	5 Jan - 5 Jun	15 Jan - 30 Apr	19 Jan - 8 Jun	10 Jan - 1 Jun	5 Jan - 5 Jun
# of workdays	48	102	71	95	88	97
Correctly assigned	32	78	49	38	59	64
% of correctly assigned	67%	76%	69%	40%	67%	66%
Period 2	12 Mar - 15 Apr	6 Jun - 23 Avg	1 May - 31 Avg	9 Jun - 25 Avg	1 Jun - 25 Dec	5 Jun - 25 Avg
# of workdays	24	53	83	53	128	51
Correctly assigned	14	41	58	39	86	41
% of correctly assigned	58%	77%	70%	74%	67%	80%
Period 3	16 Apr - 23 Dec	24 Avg - 6 Nov	1 Sep - 9 Oct	25 Avg - 20 Dec	25 Dec - 10 Jan	25 Avg - 20 Dec
# of workdays	155	43	25	80	4	69
Correctly assigned	115	35	17	25	4	60
% of correctly assigned	74%	81%	68%	31%	100%	87%
Period 4	24 Dec - 3 Jan	9 Nov - 20 Dec	10 Oct - 25 Dec	20 Dec - 1[illegible] Jan		20 Dec - 4 Jan
# of workdays	4	24	55	18		8
Correctly assigned	4	14	33	17		8
% of correctly assigned	100%	58%	60%	94%		100%
Period 5		20 Dec - 2 Jan	25 Dec - 15 Jan			
# of workdays		7	13			
Correctly assigned		7	7			
% of correctly assigned		100%	54%			
Total (all periods)						
# of workdays	231	222	234	246	220	225
Correctly assigned	165	168	157	119	149	173
% of correctly assigned	71%	76%	67%	48%	68%	77%

Many fluctuations – good case for ATCS?

How many AM Peak patterns and when to implement?



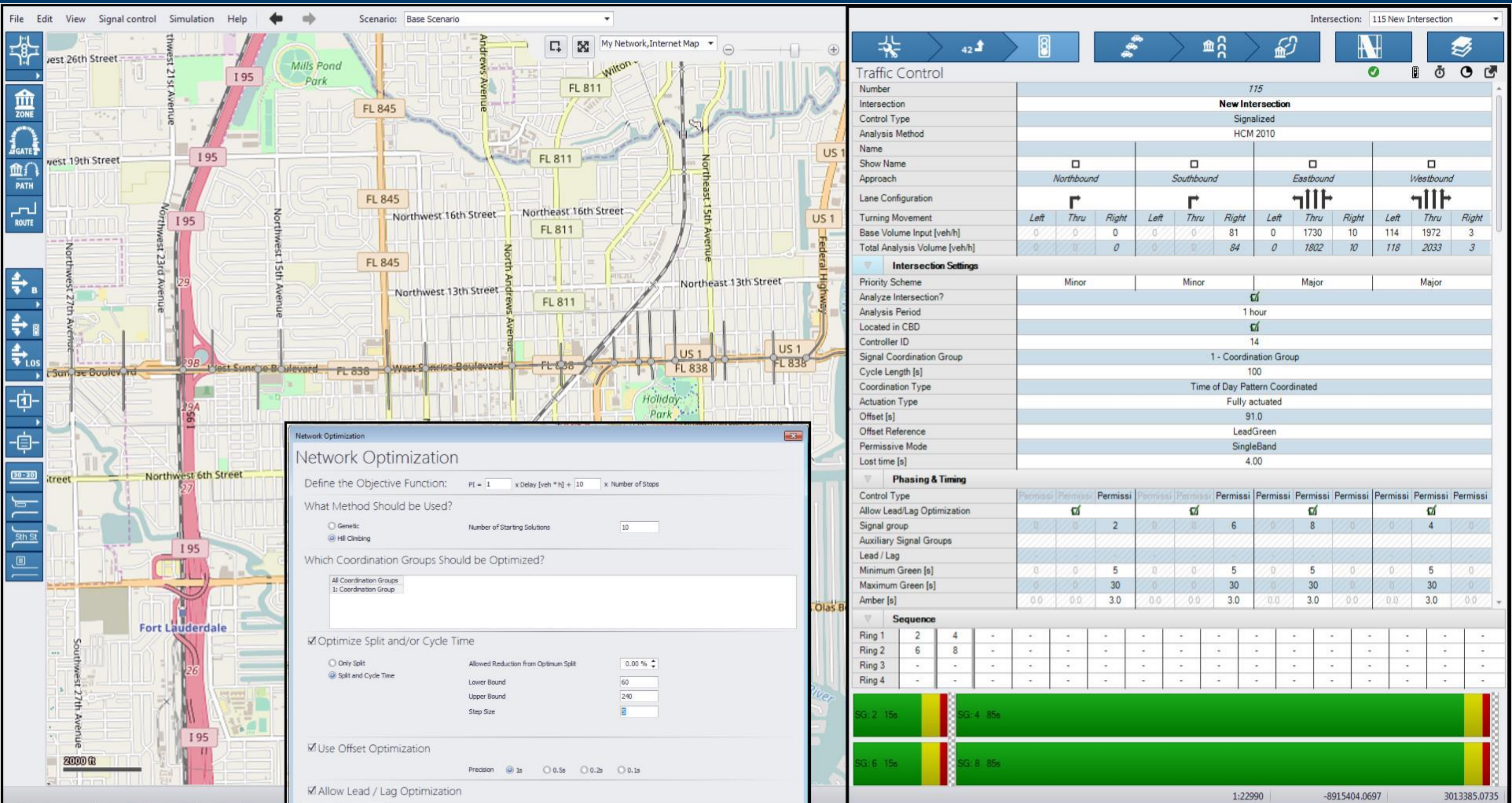
Data for 2016 show two major distinctive signal patterns for AM peak (+ holiday pattern in Dec/Jan)

Data for 2015 show two major distinctive signal patterns for AM peak (+ holiday pattern in Dec/Jan) but one of them is effective twice during the year

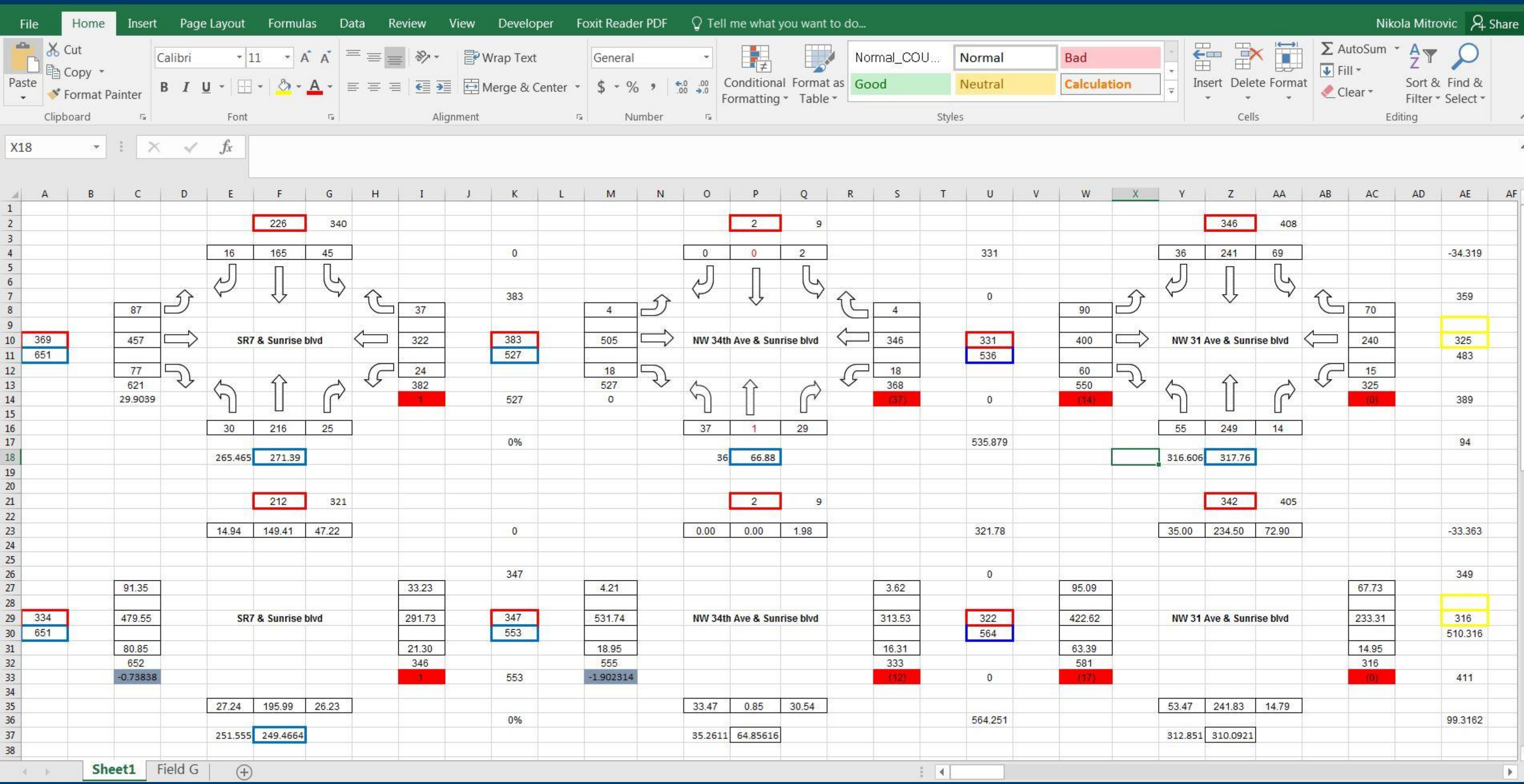
Signal Optimization

- Performed for one peak hour (AM)
- Traffic flow balanced based on mid-block volumes
- Historical TMC counts served as foundation for movement flows
- VISTRO – used for its compatibility with VISSIM
- One run performed (to optimize PI) for each set of traffic conditions
- Cross-comparisons were not made (e.g. optimized for low traffic but implemented in high traffic)
- Purpose - various traffic conditions deserve different signal timings – not to estimate benefits of retiming

Signal Optimization - Vistro



Balancing of Traffic Flows for Optimization



Benefits of Multiple Signal Patterns (% of PI)

Parameter		Volume				Travel Time				Vol. & Travel Time				
	Traffic Profile	Peak	Heavy	Moderate	Holiday	Peak	Heavy	Moderate	Holiday	Peak	Heavy	Moderate	Holiday	Current Tim. Plan
Volume	Peak	0.00%	0.68%	12.04%	55.74%	-24.21%	-22.55%	-17.49%	54.97%	-24.21%	0.00%	-0.87%	55.74%	-27.91%
	Heavy	-0.68%	0.00%	11.43%	55.44%	-25.05%	-23.38%	-18.29%	54.67%	-25.05%	-0.68%	-1.56%	55.44%	-24.83%
	Moderate	-13.68%	-12.91%	0.00%	49.69%	-41.20%	-39.31%	-33.57%	48.81%	-41.20%	-13.68%	-14.67%	49.69%	-15.70%
	Holiday	-125.96%	-124.43%	-98.77%	0.00%	-180.66%	-176.91%	-165.49%	-1.74%	-180.66%	-125.96%	-127.92%	0.00%	-7.16%
Trav. Time	Peak	19.49%	20.03%	29.18%	64.37%	0.00%	1.34%	5.40%	63.75%	0.00%	19.49%	18.79%	64.37%	-13.45%
	Heavy	18.40%	[illegible]8.95%	28.22%	63.89%	-1.35%	0.00%	4.12%	63.26%	-1.35%	18.40%	17.69%	63.89%	-14.48%
	Moderate	14.89[illegible]	[illegible]5.47%	25.13%	62.33%	-5.71%	-4.30%	0.00%	61.68%	-5.71%	14.89%	14.15%	62.33%	-15.10%
	Holiday	-122.0[illegible]	[illegible]0.58%	-95.36%	1.71%	-175.85%	-172.17%	-160.94%	0.00%	-175.85%	-122.09%	-124.02%	1.71%	-7.42%
Vol & TT	Peak	19.[illegible]	[illegible]03%	29.18%	64.37%	0.00%	1.34%	5.40%	63.75%	0.00%	19.49%	18.79%	64.37%	-13.45%
	Heavy	0.[illegible]	[illegible]8%	12.04%	55.74%	-24.21%	-22.55%	-17.49%	54.97%	-24.21%	0.00%	-0.87%	55.74%	-27.91%
	Moderate	[illegible]	[illegible]%	12.79%	56.13%	-23.14%	-21.49%	-16.48%	55.36%	-23.14%	0.86%	0.00%	56.13%	-18.93%
	Holiday	-[illegible]	[illegible]3%	-98.77%	0.00%	-180.66%	-176.91%	-165.49%	-1.74%	-180.66%	-125.96%	-127.92%	0.00%	-7.16%
Current Tim. Plan		[illegible]	[illegible]%	13.57%	6.69%	11.86%	12.65%	13.12%	[illegible]1%	11.86%	21.82%	15.92%	6.69%	

A signal timing plan developed for moderate traffic (recognized by volume data only) generates a PI which is 12.9% lower than a PI generated by an optimal signal timing plan for heavy traffic. This justifies a need for two different plans.

Grey cells indicate cases where the savings/costs are larger than 10%. This is (arbitrarily) chosen as a threshold to warrant development/implementation of different signal timing patterns.

Conclusions

- Traffic data (volumes and travel times) can be used to distinctively recognize traffic scenarios which may warrant different signal timing plans
- Multiple clustering methods revealed that the best results are achieved when both volumes (inputs) and travel times (outputs) are used to recognize distinctive traffic scenarios
- When signal plans are developed for those scenarios their relevant performance measures were distinctive enough to justify the applied clustering technique
- The compactness of the revealed traffic patterns can help when deciding on what type of traffic signal control should be deployed.
  - More compact patterns suggest that DOY signal plans are good solutions for weeks/months when respective patterns were historically observed.
  - Less compact patterns suggest investigation of the benefits of an adaptive traffic control system. T
  - In the case study of Sunrise Blvd the results show that use of three additional DOY plans would properly cover around 70% of the variability in day-to-day traffic.
- Resulting signal timing plans were distinctive enough to yield significantly different performance in majority of the cases (80%).
- Future research – try to generalize findings and find thresholds for some of the developed measures
- The proposed method could be embedded into a decision-support system to suggest periods/days of operations for various signal timing plans

Acknowledgement & Disclaimer

- Many thanks to Dr. Nikola Mitrovic and FAU GRAs: Djurdjija Mitrovic and Sharmin Chowdhury for their hard work in this study
- Special thanks to FDOT D4 project managers Melissa Ackert and Allison Glunt for their support and invaluable inputs

THANK YOU!

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