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
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
- Carries around (on some segments) 30,000 veh/day
- A segment which carries 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

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

\[
WCSS^k = \arg \min_{\sum} \sum_{i=1}^{k} \sum_{x \in S_i} ||x - \mu_i||^2,
\]

• where \(\mu_i\) 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 \(WCSS^k = f(k)\).
Data Clustering – Where to “draw a line”? 

AM Peak hour starts at 8:15 AM

Point where gain of introducing another cluster diminishes

The inflection point
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?

Travel time – outside circle
Volume – inside circle
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
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

\[ Y = 0.938 \cdot X + 70.959 \]

\[ R^2 = 0.994 \]

(b) High Traffic

\[ Y = 0.933 \cdot X + 65.201 \]

\[ R^2 = 0.993 \]

(c) Moderate Traffic

\[ Y = 0.913 \cdot X + 67.780 \]

\[ R^2 = 0.991 \]

(d) Holiday Traffic

\[ Y = 1.083 \cdot X + 12.460 \]

\[ R^2 = 0.978 \]
Vol&TT-based Clusters of AM Peak Traffic

- Peak traffic
- High traffic
- Moderate traffic
- Low/Holiday 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

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Volume</th>
<th>Travel Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Year</td>
<td>2016</td>
</tr>
<tr>
<td>Number of workdays</td>
<td>242</td>
<td>247</td>
</tr>
<tr>
<td># of changes</td>
<td>101</td>
<td>108</td>
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<tr>
<td>% of changes</td>
<td>42%</td>
<td>44%</td>
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<tr>
<td>Period 1</td>
<td>Jan 4 - Mar 11</td>
<td>5 Jan - 5 Jun</td>
</tr>
<tr>
<td># of workdays</td>
<td>48</td>
<td>102</td>
</tr>
<tr>
<td>Correctly assigned</td>
<td>32</td>
<td>78</td>
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<tr>
<td>% of correctly assigned</td>
<td>67%</td>
<td>76%</td>
</tr>
<tr>
<td># of workdays</td>
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<td>53</td>
</tr>
<tr>
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<td>41</td>
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<td>% of correctly assigned</td>
<td>58%</td>
<td>77%</td>
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<tr>
<td>Period 3</td>
<td>16 Apr - 23 Dec</td>
<td>24 Avg - 6 Nov</td>
</tr>
<tr>
<td># of workdays</td>
<td>155</td>
<td>43</td>
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<tr>
<td>Correctly assigned</td>
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<td>35</td>
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<tr>
<td>% of correctly assigned</td>
<td>74%</td>
<td>81%</td>
</tr>
<tr>
<td>Period 4</td>
<td>24 Dec - 3 Jan</td>
<td>9 Nov - 20 Dec</td>
</tr>
<tr>
<td># of workdays</td>
<td>4</td>
<td>24</td>
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<tr>
<td>Correctly assigned</td>
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<td>100%</td>
<td>58%</td>
</tr>
<tr>
<td>Total (all periods)</td>
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<td>222</td>
</tr>
<tr>
<td># of workdays</td>
<td>165</td>
<td>168</td>
</tr>
<tr>
<td>Correctly assigned</td>
<td>71%</td>
<td>76%</td>
</tr>
</tbody>
</table>

Many fluctuations – good case for ATCS?
How many AM Peak patterns and when to implement?

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.

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

| A   | B   | C   | D   | E   | F   | G   | H   | I   | J   | K   | L   | M   | N   | O   | P   | Q   | R   | S   | T   | U   | V   | W   | X   | Y   | Z   | AA  | AB  | AC  | AD  | AE  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|     | 226 | 340 | 0   |     |     | 2   | 9   |     |     |     |     |     |     | 331 |     |     |     |     |     |     |     | 35  | 241 | 69  | .343 | 190 |
| 28  | 467 |     | 37  |     |     | 383 | 4   |     |     |     |     |     |     | 505 |     |     |     |     |     |     |     |     |     | 400 |     | 326 | 493 |
| 77  | 621 | 29.9 | 24  |     |     | 248 | 18  |     |     |     |     |     |     | 527 |     |     |     |     |     |     |     |     |     |     | 325 |     | 392 |
| 30  | 219 | 25  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 14.94 | 14.91 | 47.22 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|     |     |     | 37  |     |     |     | 1   | 29  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|     |     |     |     |     |     | 510 | 139 | 149 | 134 | 392 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|     |     |     |     |     |     |     | 535 | 679 | 366 | 311 | 279 | 405 |     | 342 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|     |     |     |     |     |     |     |     |     |     |     |     |     |     | 510 | 216 | 104 |     |     |     |     |     |     |     |     |     |     |     |     |     |

Sheet1

Florida Atlantic University
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.
  – 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.
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• Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Florida Department of Transportation
THANK YOU!

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