



FHWA Every Day Counts Program

Measures of Effectiveness and Performance Evaluation Procedures to Validate Traffic Signal Operational Objectives

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T3 Webinar
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Kimley-Horn and Associates, Inc.

Outline

- Objectives
- MOEs
- Procedures
- Tools
- Next Steps

U.S. Department of Transportation
Federal Highway Administration

ASCT PERFORMANCE EVALUATION SYSTEM

Home Google Earth Google Maps Reports Contact Us Configuration Logout

Welcome to ASCT Performance Evaluation!

Account Information

Username:

Password:

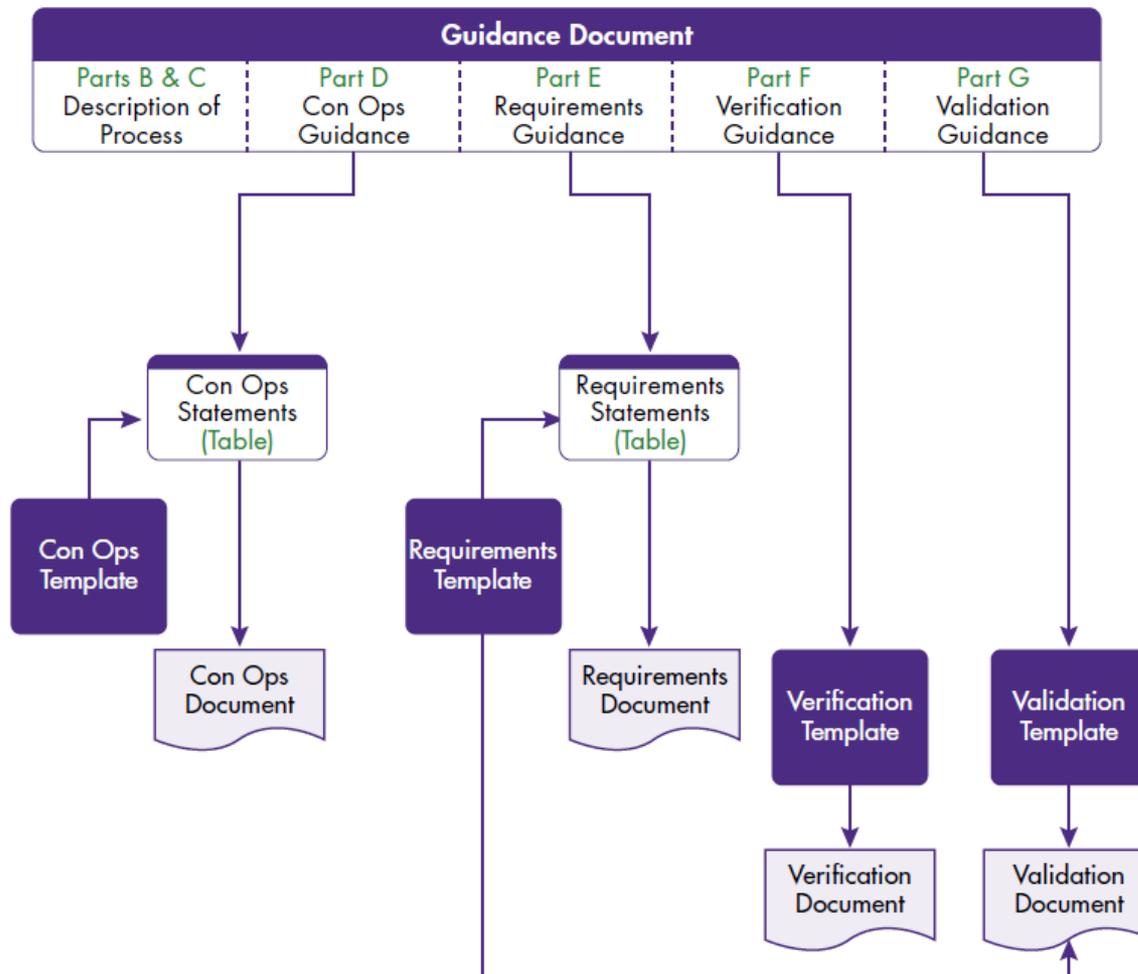
Keep me logged in

[Register](#) if you don't have an account.

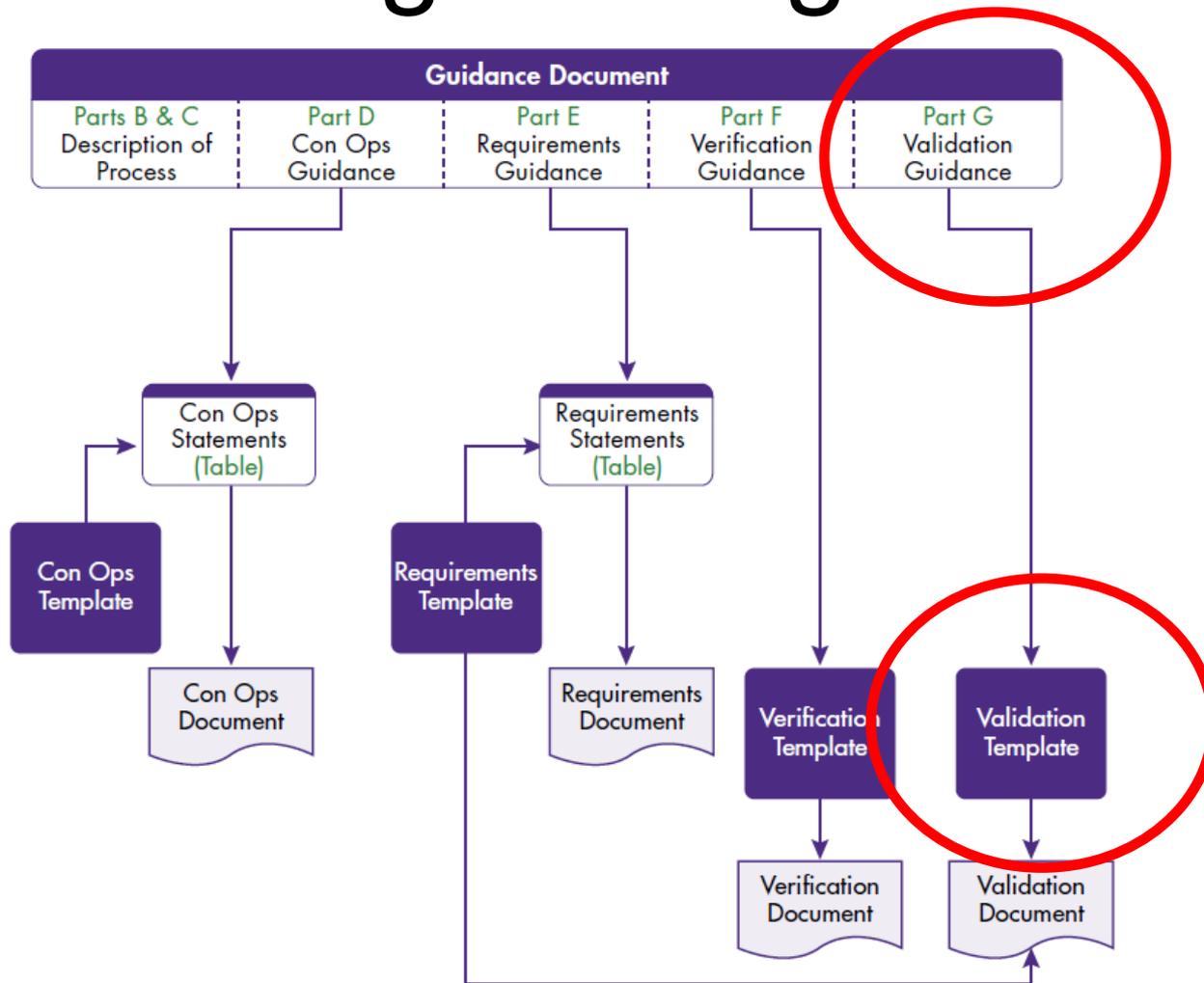
Uncertainty about benefits

- Limited articulation of operational objectives
- Sometimes measure the wrong metrics for a given objective
- Differences in baseline performance of existing signal timings
- Lack of common validation process

Systems Engineering Process



Systems Engineering Process



Goals for this project

- Identify common operational objectives for ASCT (and signal timing in general)
- Identify MOEs to validate ASCT meet the objectives
- Develop computation methods for those MOEs
- Develop recommended procedures for validation of ASCT

Objectives for ASCT

- Pipeline
- Access equity
- Manage queues
- Prevent or delay oversaturation
- Accommodate long-term variability
- Manage incidents and events
- Operational objectives, not outcomes like B/C ratios



The Silver Bullet Roller Coaster
Knott's Berry Farm Amusement Park, USA

Pipeline

- Uninterrupted, smooth flow on a route
- Typically on an arterial street
- Optional: two-way progression flow
- Maximizes throughput by limiting time to side-street and minor phases

Provide Equitable Access

- Side streets considered as important as main street
- Manage surge flows from side streets
- Signals may still be in coordination, but smaller greenband
- Also typically applies to “isolated” signals
- Typically an effect of ASCT

Manage Queues

- Closely spaced intersections
- Ensure that downstream queues do not block flows from upstream movements
- Ensure that queues on some movements do not starve others
 - Left turn blocking through or vice versa
- May require creating queues elsewhere
- Most ASCT do not explicitly address

Prevent or Delay Oversaturation

- Manage green times before oversaturation begins
- Delay the occurrence and limit the duration
- More quickly clear oversaturated queues when demands are reduced
- Typically an effect of ASCT

Changing Objectives by TOD

- Pipeline in AM and PM peaks
- Equity access in off peak
- Manage incidents when they occur
- Most ASCT do not have explicit configurability for changing objectives

Accommodate long-term variability

- Adjust to monthly, seasonal, and yearly fluctuations
 - Changes in land use
 - School schedules
- Provide less deterioration in performance versus periodic re-timing
- Typically an effect of ASCT, but difficult/costly to measure

Manage Incidents and Events

- Reduce delays induced by anomalies
 - Crashes, blockages
- Reduce delays during planned events
 - Ingress/Egress
 - Start time of egress typically less predictable
- Reduce the variance between the worst and the best performance
- Not typically evaluated

Validation methodology & tools

- Provide key recommendations to improve state of practice in validation
- Provide tools to reduce cost of validation
- Provide generic MOEs that have no bias to any ASCT
- Provide free open-source software

ASCT validation

- If any signal timing strategy meets the operational objectives for your agency, it is a valid methodology
- ASCTs don't mitigate the need for traffic engineering
 - Can supplement limited staff
 - Cannot make traffic demand disappear
 - Cannot eliminate need for maintenance

Review of validation methods

- Variety of evaluation reports
 - Consultants, academics, agency staff
 - Vendors/developers
- Most reports provide detail of system characteristics
 - Geometrics, land uses, AADT, demands
- Fewer reports provide existing timings, phasing and what the ASCT actually did differently

ASCT Performance

- If an ASCT doesn't improve MOE X by X%, what could that mean?
 - The existing timings were already good
 - The traffic situation isn't that challenging
 - The traffic situation is really oversaturated
 - The evaluation was limited

ASCT Performance

- If ASCT improves MOE X by X%, what could that mean?
 - The existing timings were not appropriate
 - The traffic situation was fluctuating
 - the “sweet spot” for ASCT
 - The evaluation was limited

Limitations of evaluations

- Limited articulation of operational objectives
- Low number of probe runs due to cost
 - This is OK when comparing averages
 - Not OK to compare variances
 - Variances are typically not evaluated

Limitations of evaluations

- Probe data collected only in peak periods
 - Can potentially miss benefits available during off-peak times
 - Can potentially skew results if PM peak is excessively saturated

Limitations of evaluations

- Side street performance measured manually via observers
 - Limited amount of time due to cost
- Limited or no focus on abnormal conditions
 - Difficult to replicate in both “before” and “after”
- Limited or no focus on pre- and post-peak period performance

Limitations of evaluations

- Data collection in “before” and “after” periods are separated by long time period
- Limited use of volume data for aggregate performance assessment
 - Relationship of travel time to route volume

Limitations of evaluations

- Extrapolation methods in B/C estimation make many assumptions
 - ASCT benefits will accrue linearly and forever
 - Signal timings will never be retimed
- Limited focus on reliability of ASCT performance measures

Validation recommendations

- Articulate operational objectives
- Identify MOEs that map to those objectives
- Consider ON/OFF study
 - Similarity in traffic conditions
 - Measure the performance during “failure” conditions
- Use high-resolution phase/detector data to assess generic MOEs

Validation recommendations

- Consider measurement of reliability metrics
- Consider data collection in pre and post peak periods
- Consider data collection during “incidents” and events

Mapping MOEs to objectives

MOEs	Data Sources	Operational Objectives
<ul style="list-style-type: none"> Route travel time Route travel delay Route average speed Route travel time reliability 	<ul style="list-style-type: none"> Import travel time data from Bluetooth scanner Import trajectory data from GPS probe 	<ul style="list-style-type: none"> Pipeline Multiple objectives by TOD Accommodate long-term variability
<ul style="list-style-type: none"> Link travel time, delay Number of stops per mile on route 	<ul style="list-style-type: none"> Import trajectory data from GPS probe 	<ul style="list-style-type: none"> Pipeline Manage queues Prevent oversaturation Handle incidents and events Multiple objectives by TOD
<ul style="list-style-type: none"> Traffic volume on route (throughput) Time to process equivalent volume 	<ul style="list-style-type: none"> Import count data from tube counter file 	<ul style="list-style-type: none"> Pipeline Manage queues Prevent oversaturation Handle incidents and events Multiple objectives by TOD
<ul style="list-style-type: none"> Percent arrivals on green, by link V/C ratio by movement Platoon ratio, by link Phase green to occupancy ratio by movement Reliability of phase metrics 	<ul style="list-style-type: none"> Import high-resolution signal timing and detector data 	<ul style="list-style-type: none"> Pipeline Access equity Multiple objectives by TOD Accommodate long-term variability

MOEs for ASCT Objectives

- Route travel time, delay
- Number of stops per mile
- Throughput
- Time to process equivalent volume
- % arrivals on green, platoon ratio
- Green Occupancy ratio
- Served V/C ratio

Oversaturation and incident MOEs

- Queue lengths are ideal
 - Instrumentation can be costly
 - Theory is available for advance loops/zones
 - U of Minnesota / MnDOT / NCHRP 03-90
 - Future
- Route throughput
- Time to process equivalent volume

Route travel volume

- Screen line volumes validate that conditions are “equal”
 - State of the practice
 - Approximate by total flow at begin and end
 - Approximate by re-identification volume, assuming a saturation percentage of bluetooth/WiFi devices

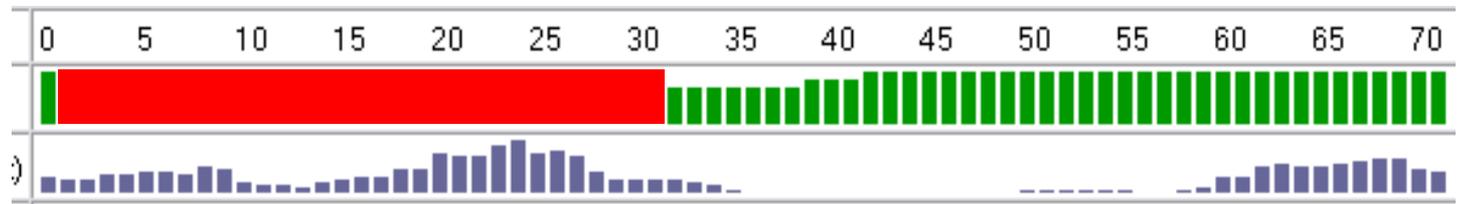
Throughput

- Cumulative volume at a point over a time period
- “Total” throughput in a system is only measurable with every OUT point covered
 - Not to be recommended (cost)
- Confounded by fluctuations in traffic on a particular day
- Need R&D and standards for baselines

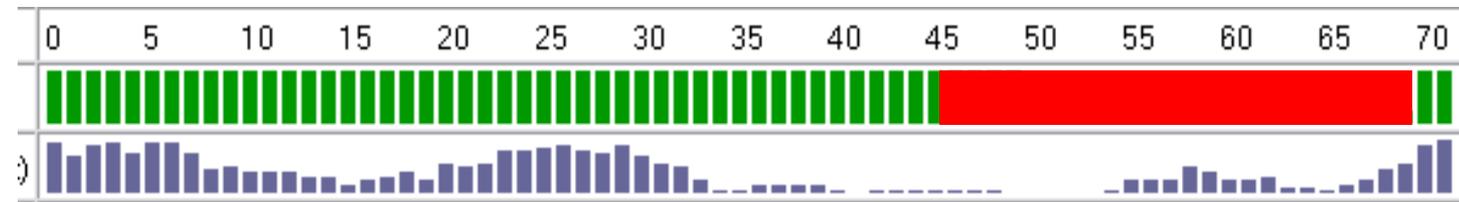
Time to process volume

- Time required by system to process a fixed amount of volume
 - Before: 45 minutes to generate 10,000 volume
 - After: 35 minutes to generate 10,000 volume
 - → validated
- Confounded by fluctuations in traffic on a particular day
- Need R&D and standards for baselines

% Arrivals on green

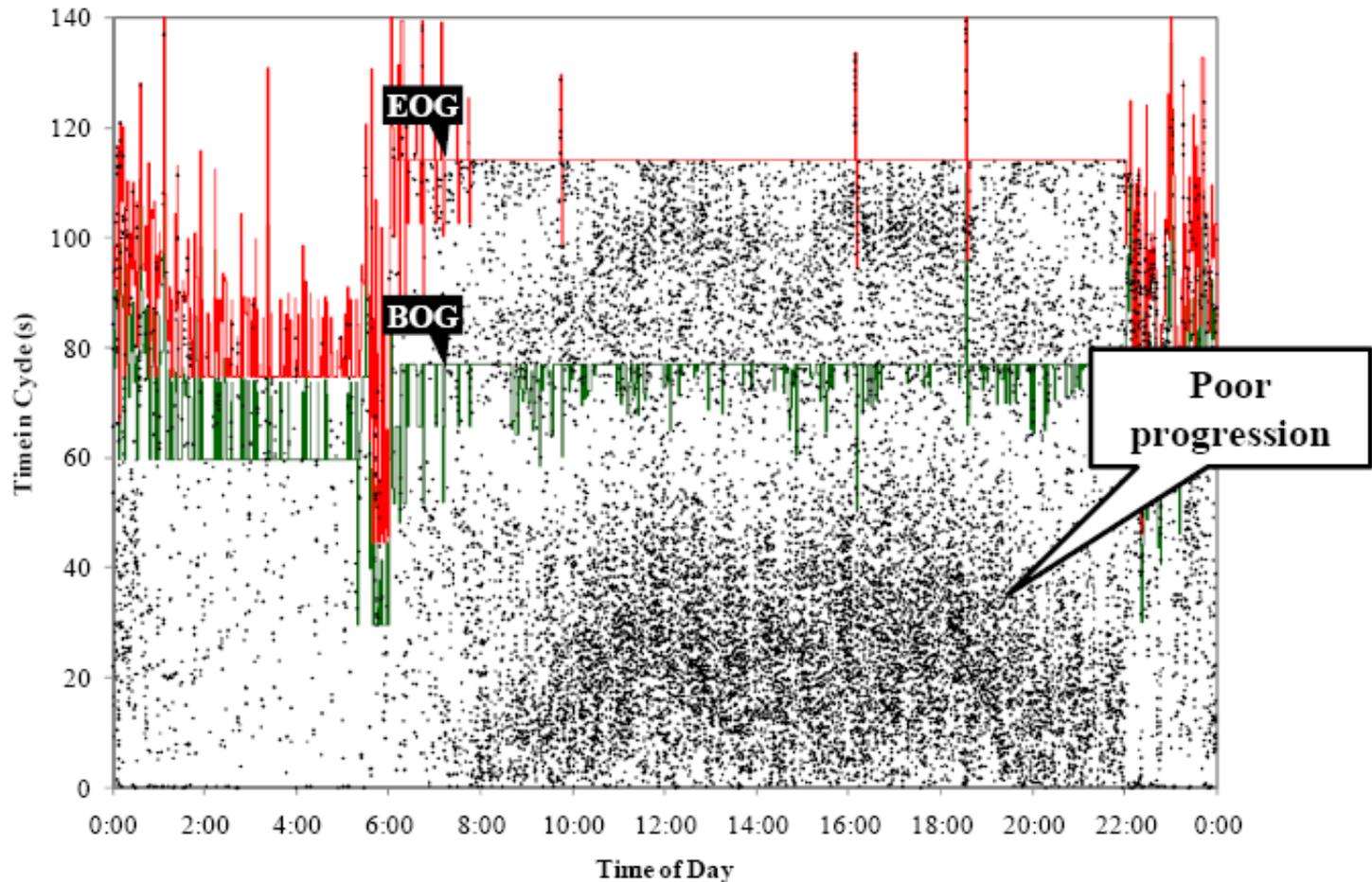


POOR PROGRESSION

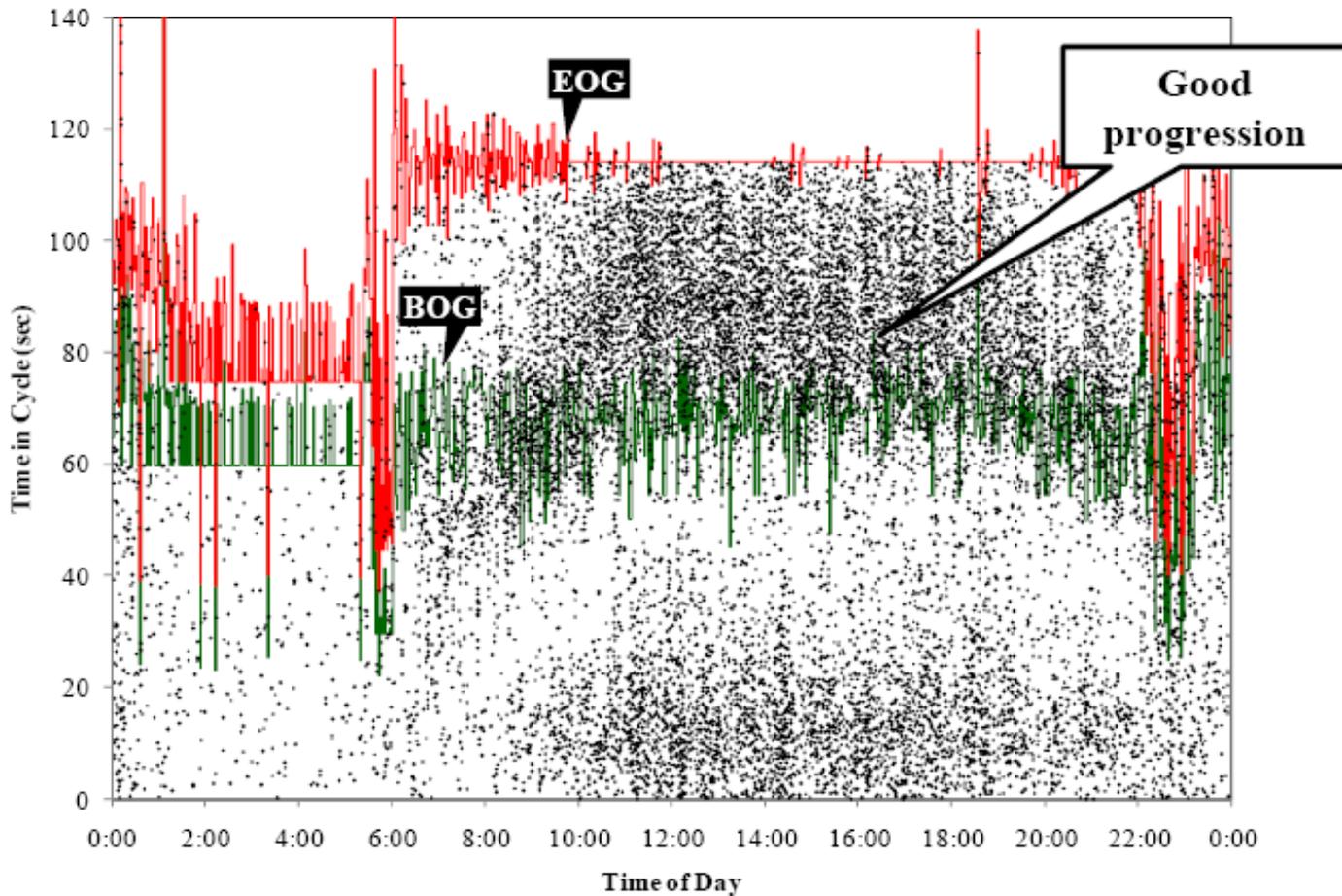


GOOD PROGRESSION

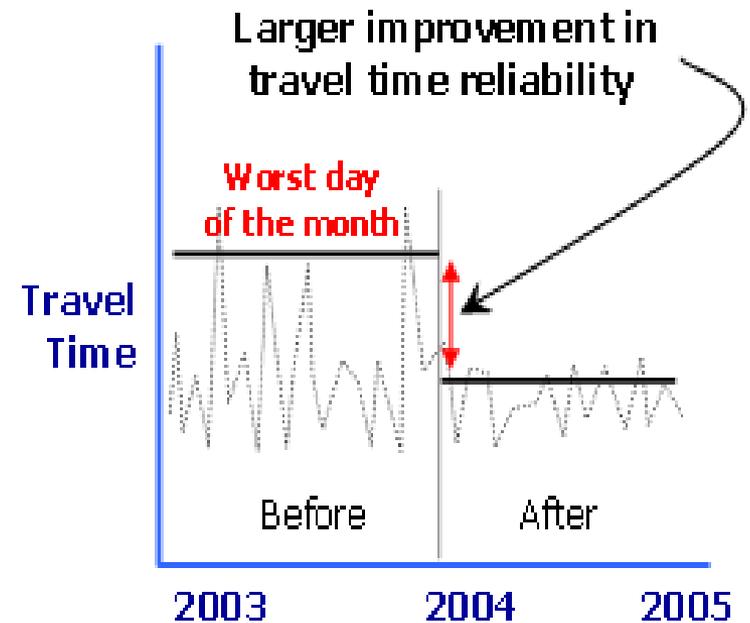
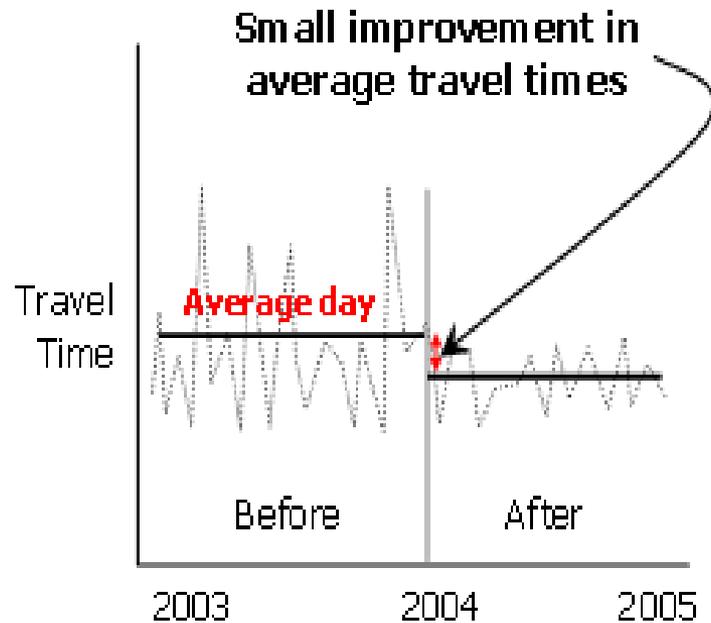
% arrivals on green



% arrivals on green



Travel time reliability



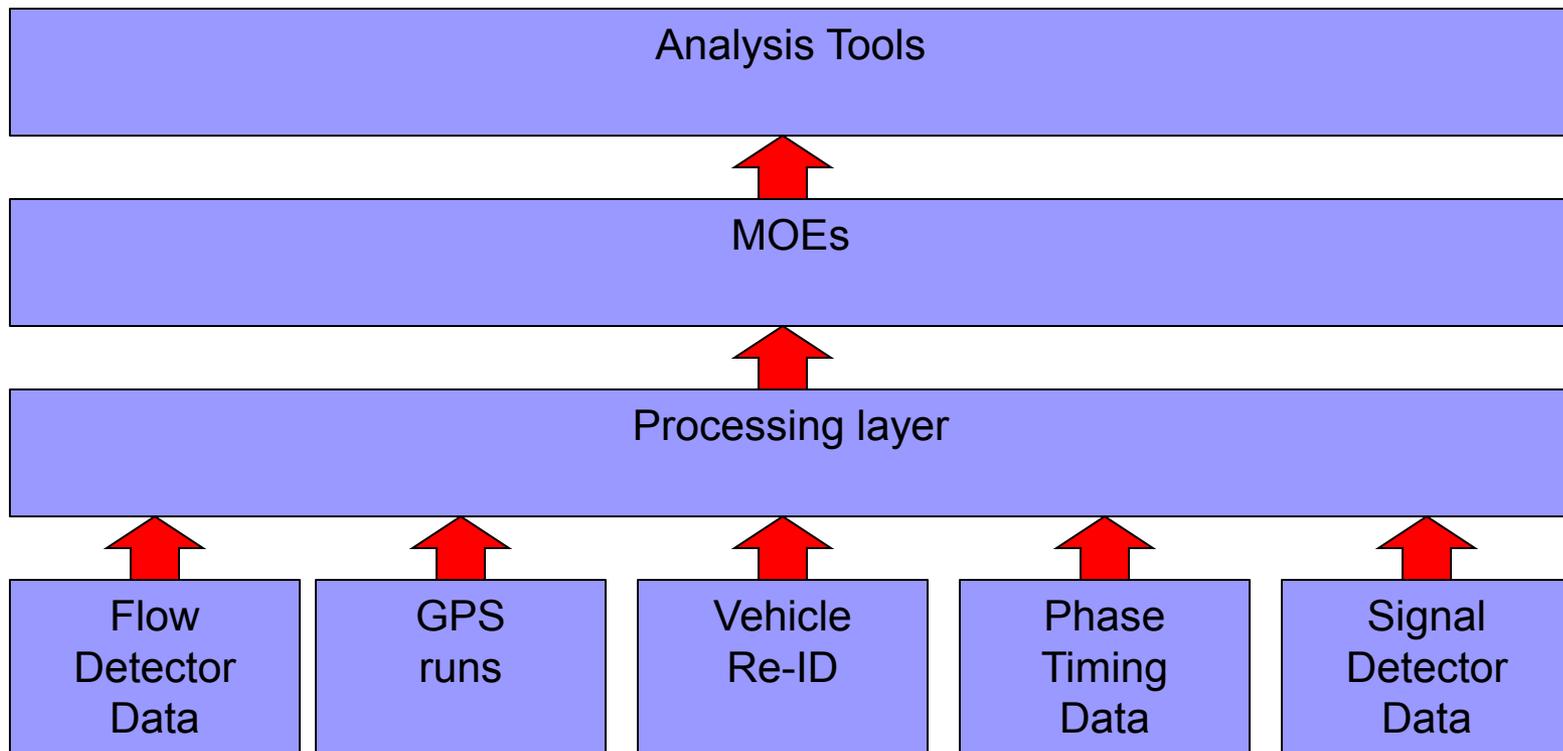
Performance Measures

- Ed Smaglik, Northern Arizona University
- Green Occupancy Ratio
- Arrival type estimation

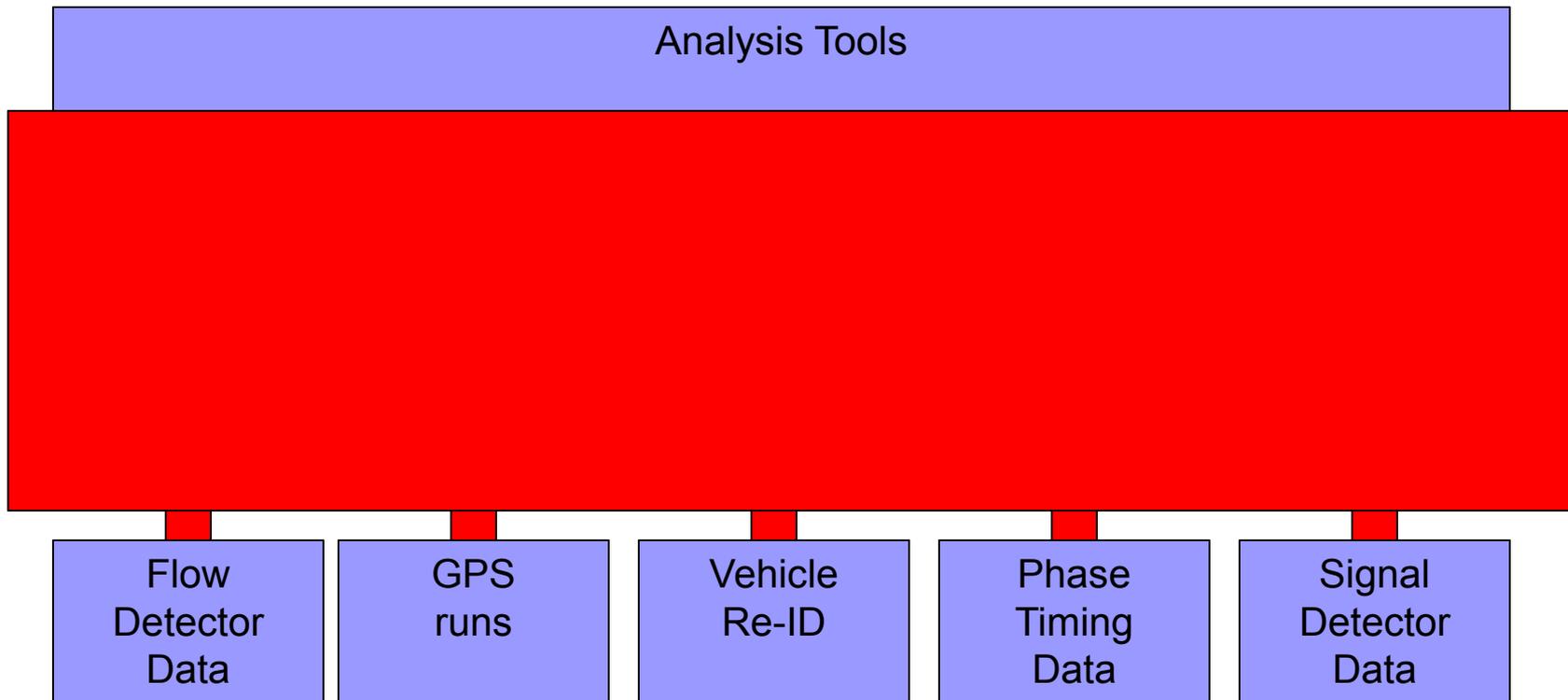
Technical Tools

- All data are generic and not require a specific technology or vendor
- Derive MOEs from data
- Provide tools for validation
 - Averages, variances, trends, etc.
 - By pattern, route, TOD/DOW

Components of Tools

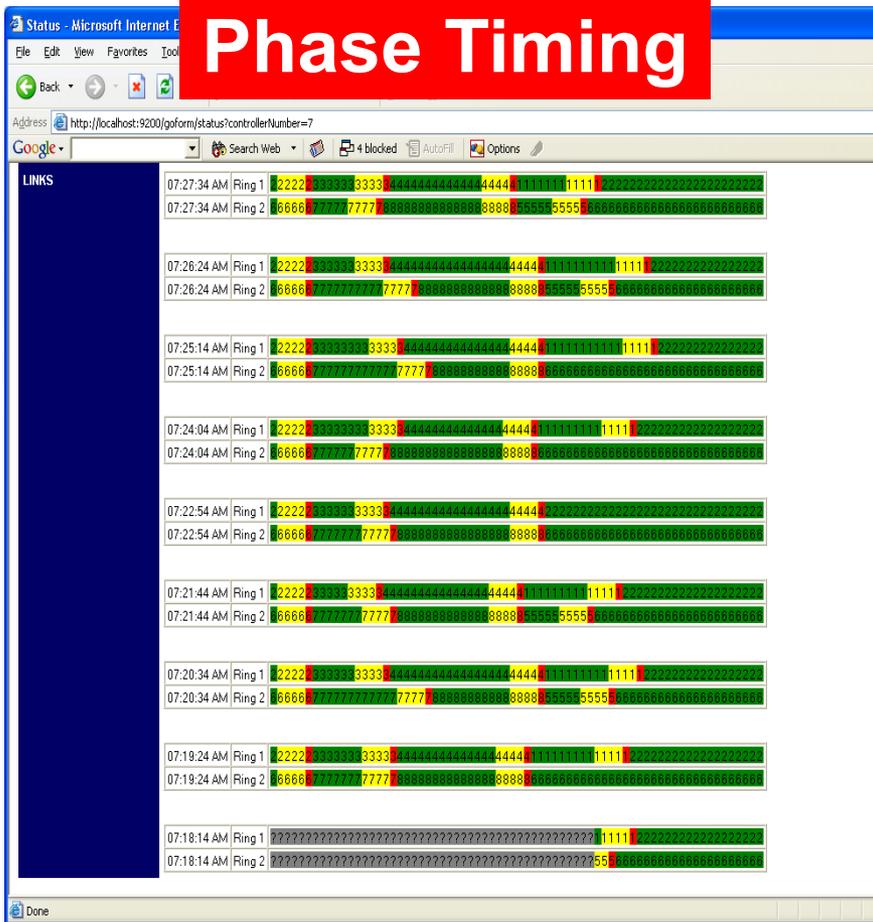


Components of Tools

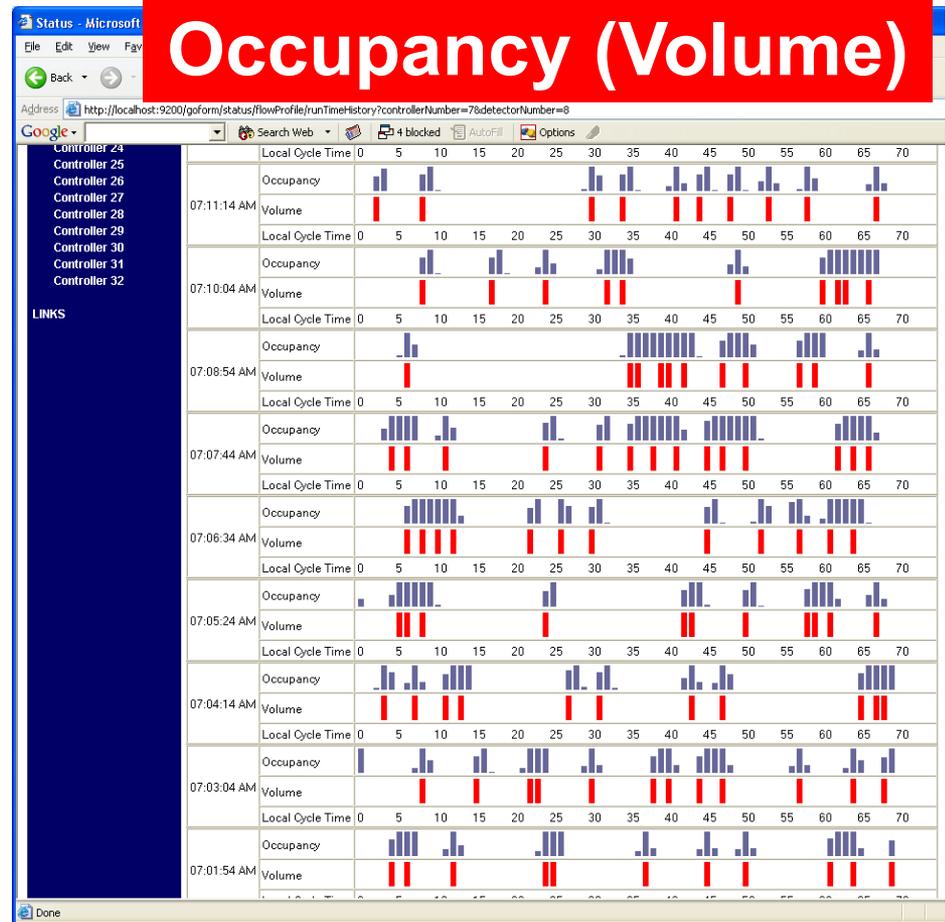


Key: cycle-by-cycle data from ASCT

Phase Timing



Occupancy (Volume)



Phase timing and detectors

- Several vendors have log files on controller (1 hour summaries with 0.1s accuracy)
 - All phase interval events
 - All detector interval events
 - Periodically upload/FTP the data
- Several ASCT and signal systems store log files of all events from polls

Vehicle re-identification data

- Bluetooth
- License plate readers
- Magnetometers and some loops
- Identify a vehicle at one point
- Re-identify at different point
- Calculate end-to-end travel time

Vehicle re-ID reader data file

- Summarized by O-D pair
- Travel time, average speed
- Some devices report number of matches in each time bin

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- <PAIRDATA>
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  <Pairing>Hwy 93 & Paradise Hills Dr (u170) to Hwy 93 & West of Veterans Memorial Dr (u179)</Pairing>
  <Direction>East Bound</Direction>
  <Origin>Hwy 93 & Paradise Hills Dr</Origin>
  <Destination>Hwy 93 & West of Veterans Memorial Dr</Destination>
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  <Direction>West Bound</Direction>
  <Origin>Hwy 93 & West of Veterans Memorial Dr</Origin>
  <Destination>Hwy 93 & Paradise Hills Dr</Destination>
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  <TravelTime>229</TravelTime>
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  <Speed>53.4497816593886</Speed>
  <Status>Active</Status>
</PAIRDATA>
- <PAIRDATA>
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GPS probe data

- Needs to be allocated to a particular route
- Implemented in this project for Android smartphones

ID	GPS_Latitude	GPS_Longitude	GPS_Heading	GPS_Speed	CurrDate
111487	33.69277	-111.993959	219.860489	5.31794917	9/26/2010 11:52
111488	33.692752	-111.993965	181.928696	6.24787267	9/26/2010 11:52
111490	33.692723	-111.993929	125.099113	7.78643297	9/26/2010 11:52
111491	33.692704	-111.993895	123.486015	8.40994317	9/26/2010 11:52
111492	33.692696	-111.993838	101.273514	11.6412178	9/26/2010 11:52
111493	33.692691	-111.993776	98.277725	12.5670902	9/26/2010 11:52
111494	33.692701	-111.993709	81.535233	13.8963963	9/26/2010 11:52
111495	33.692724	-111.993643	66.944435	14.8369273	9/26/2010 11:52
111496	33.692762	-111.993581	54.206722	15.6183272	9/26/2010 11:52
111497	33.692805	-111.99352	50.887997	16.3502662	9/26/2010 11:52
111498	33.692854	-111.993464	47.099316	16.6893835	9/26/2010 11:52
111499	33.692906	-111.993413	44.1329	16.3861534	9/26/2010 11:52
111500	33.692957	-111.993368	42.131786	15.7182265	9/26/2010 11:52
111501	33.693006	-111.993327	40.809139	14.4465596	9/26/2010 11:52
111502	33.693053	-111.993289	39.549496	13.5948081	9/26/2010 11:52
111503	33.693098	-111.993254	38.1418	12.8541629	9/26/2010 11:52
111504	33.69314	-111.993223	36.809719	11.8972844	9/26/2010 11:52
111505	33.693172	-111.993192	38.736008	9.29935352	9/26/2010 11:52

Volume data recorders

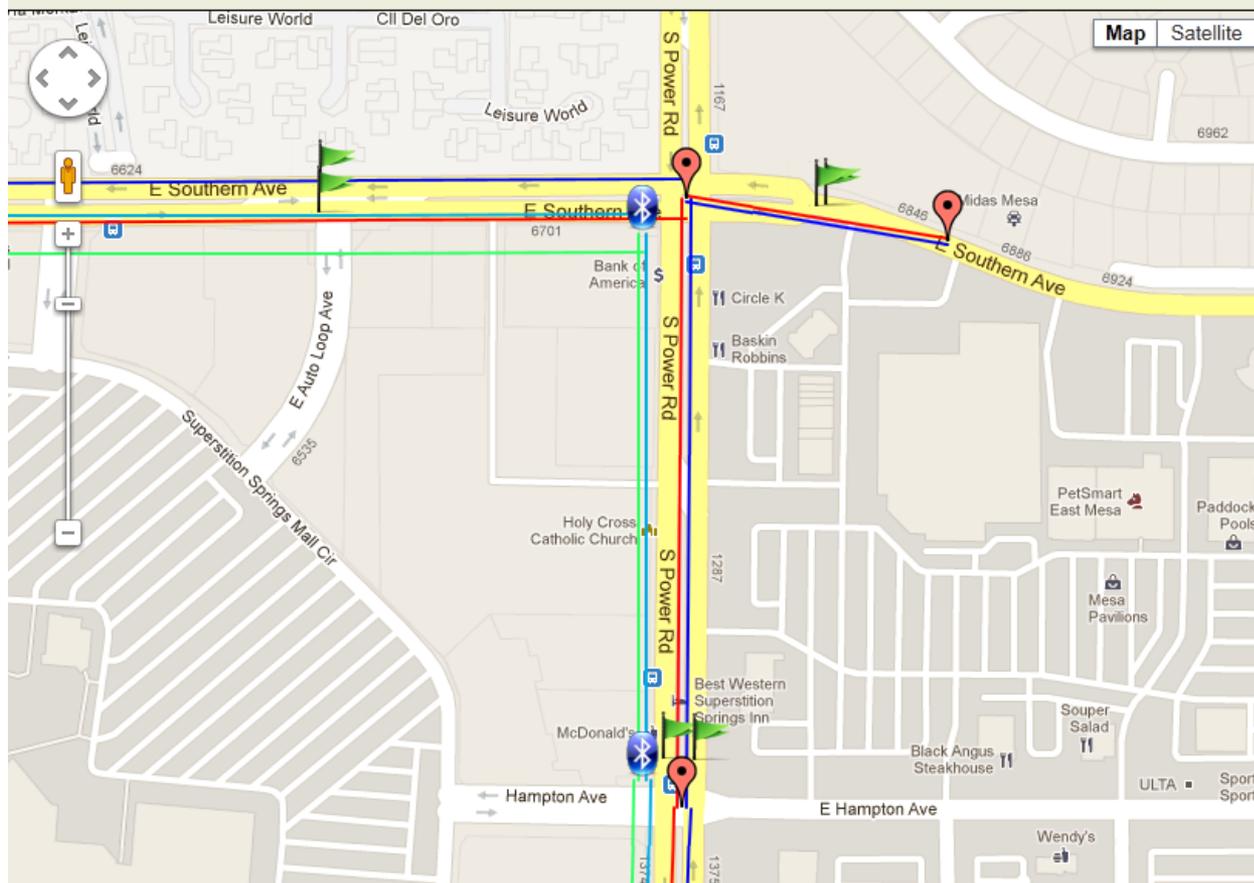
- Tube counters
- Stand-alone detection stations
 - X3 standard for freeways
 - Other vendor-specific methods (e.g. Sensys)
- System detectors connected to traffic controllers
 - NTCIP, AB3418E, vendor-specific
- Import data from tabulated files

Validation system configuration

- Add intersections
- Add links
- Add Vehicle re-ID readers
- Add volume counters
- Create routes
- Manually import files from data sources
 - Mark times as ON or OFF

Configure routes and readers

Configuration

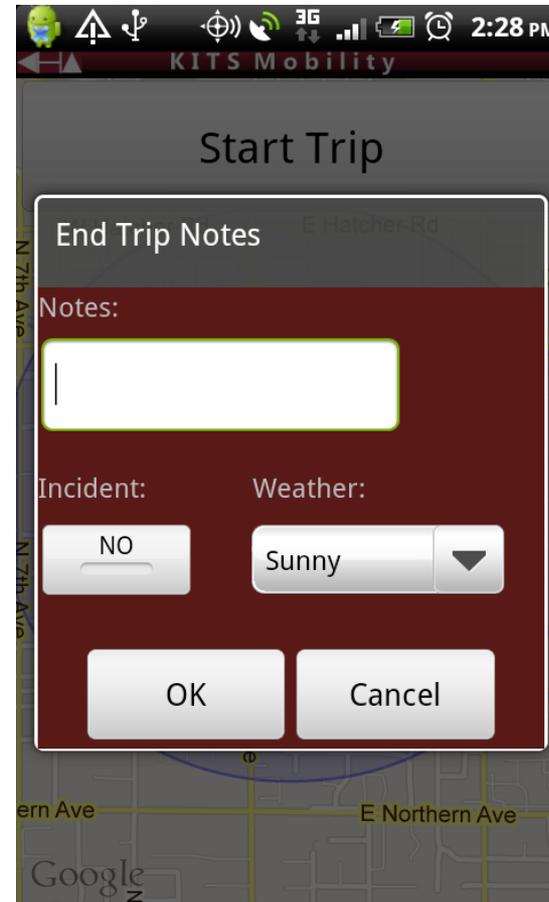
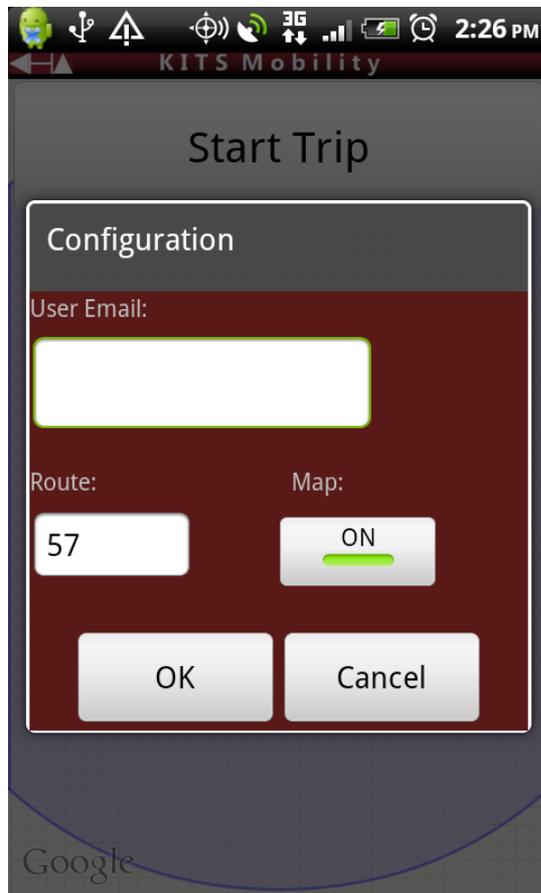


Configure Region

Region: Mesa

- + Intersections
- + Bluetooth Scanners
- + Tube Counters

GPS probe data interface



Import data files

Import

File Type:

- Phase Timing and Detector Data
- Bluetooth Scanner Data
- Tube Counter Data

Intersection:

Scottsdale Rd & McDonald Dr ▼



Select files

Add files to the upload queue and click the start button.

Filename	Adaptive State	Status	Size
INT_10.40.7.206_2012_08_30_1441.csv	<input checked="" type="checkbox"/>	0%	9 KB
INT_10.40.7.206_2012_08_30_1500.csv	<input checked="" type="checkbox"/>	0%	12 KB
INT_10.40.7.206_2012_08_31_0600.csv	<input checked="" type="checkbox"/>	0%	8 KB
INT_10.40.7.206_2012_08_31_0700.csv	<input checked="" type="checkbox"/>	0%	8 KB

4 files queued

Start Upload

Clear List

0% 36 KB



Validate performance

- Select “before” days
- Select “after” days
- Run analysis
- Numerical results
- Open source

Reports

Report Type:

Compare Speed vs Distance Report

Region:

ADOT

Before

Time Range Start:

Time Range End:

Select All Select All Pages 4 selected

Time	Weekday	Group	User	Route	Pattern
04/10/2012 18:47:11	Tuesday	ADOT	Camila.weckerly@kimley-horn.com	1	o
04/10/2012 07:42:26	Tuesday	ADOT	Camila.weckerly@kimley-horn.com	1	o
04/10/2012 07:35:39	Tuesday	ADOT	Camila.weckerly@kimley-horn.com	1	o

Search Time: tu Search Group: Search User: 1 Search Pattern:

Go to page: of 1 Show rows: 10 < > 1 - 3 of 3

After

Time Range Start:

Time Range End:

Select All Select All Pages 6 selected

Time	Weekday	Group	User	Route	Pattern
04/06/2012 15:05:09	Friday	ADOT	Camila.weckerly@kimley-horn.com	1	o
04/06/2012 14:41:07	Friday	ADOT	Camila.weckerly@kimley-horn.com	1	o
04/06/2012 14:05:17	Friday	ADOT	Camila.weckerly@kimley-horn.com	1	o
04/06/2012 13:58:08	Friday	ADOT	Camila.weckerly@kimley-horn.com	1	o
04/13/2012 05:38:57	Friday	ADOT	Catherine.occhiline@kimley-horn.com	51	o

Search Time: fr Search Group: Search User: 1 Search Pattern:

Go to page: of 1 Show rows: 10 < > 1 - 5 of 5

[View Average](#) [View Multiple](#) [Export](#)

Reports

Report Type: Region: Controller:

Time Range Start: Time Range End:

Date/Time	Weekday	Pattern	Phase	Cycle	Split	Green	GOR	Served V/C	% Green Arrival	Platoon Ratio	Adaptive On
2010-10-19 01:11:39.0	Tuesday	0	1	83.1	11	7	0	0	0	0	True
2010-10-19 01:11:39.0	Tuesday	0	2	83.1	39.5	33.2	1.05	20.86	0.56	1.4	True
2010-10-19 01:11:39.0	Tuesday	0	3	83.1	16.7	12.7	0.79	10.91	0	0	True
2010-10-19 01:11:39.0	Tuesday	0	4	83.1	15.9	8.9	1.62	31.12	0	0	True
2010-10-19 01:11:39.0	Tuesday	0	6	83.1	50.5	44.2	0.66	11.49	0.89	1.67	True
2010-10-19 01:11:39.0	Tuesday	0	7	83.1	15.4	11.4	0.86	16.2	0	0	True
2010-10-19 01:11:39.0	Tuesday	0	8	83.1	17.2	10.2	0.96	13.58	0	0	True
2010-10-19 01:10:19.0	Tuesday	0	2	80.1	34.4	28.1	0.68	14.25	0.42	1.2	True
2010-10-19 01:10:19.0	Tuesday	0	3	80.1	23.2	19.2	0.73	11.59	0	0	True
2010-10-19 01:10:19.0	Tuesday	0	4	80.1	22.5	15.5	1.48	28.71	0	0	True

Search Date/Time Search Weekc Search Patter Search Phas Search Adapt

Go to page: of 3 Show rows: < > 1 - 10 of 27

Averaged over a 15 minute interval

Copy Show entries

Date/Time	Pattern	Phase	Statistic	GOR	Served V/C	% Green Arrival	Platoon Ratio
10/19/2010 00:00:00	0	2	Average	0.5	6.725	0.62	1.43
			Min	0.3	0.9	0.6	1.05
			Max	0.7	12.55	0.64	1.81
			Std Dev	0.283	8.238	0.028	0.537
10/19/2010 00:00:00	0	3	Average	0.247	0.57	0	0
			Min	0.08	0.1	0	0
			Max	0.37	1.21	0	0
			Std Dev	0.15	0.574	0	0
10/19/2010 00:00:00	0	4	Average	0.61	1	0	0
			Min	0.61	1	0	0

Showing 1 to 10 of 52 entries

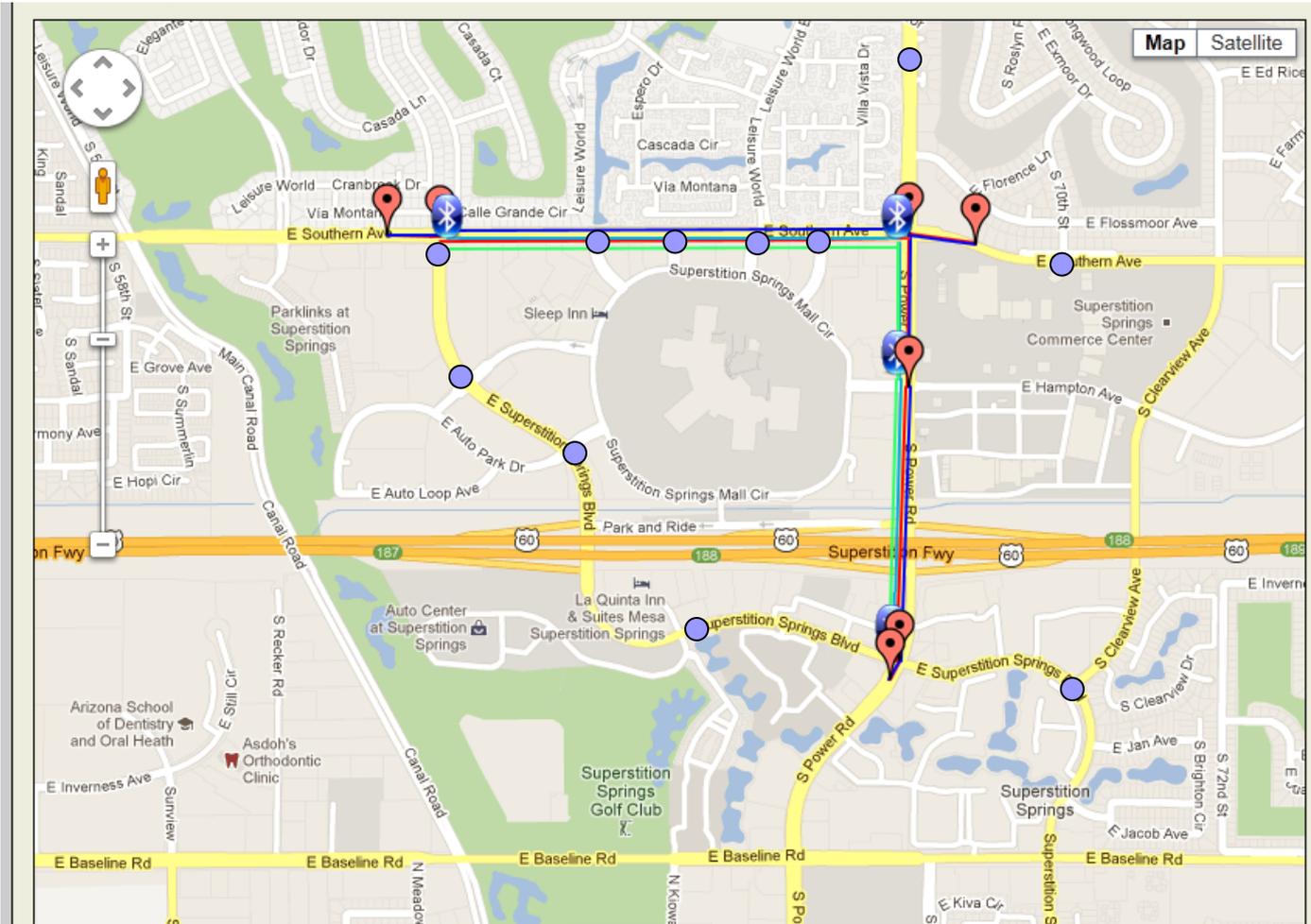
Reliability estimation

- Max, Min, and Standard Deviation
 - % arrivals on green
 - Platoon ratio
 - GOR per phase
 - Served V/C per phase
 - Throughput
 - Time to process equivalent volume

Testing the Validation Methodology

- City of Mesa, Arizona ASCT
- This ASCT has been previously evaluated
- One month of ASCT ON/OFF
 - Vehicle Re-identification readers
 - Volume counters
 - Event data from controllers
 - GPS probe runs

Mesa, Arizona Field Site



Status



- Validation testing – Fall 2012
- Validation guidance – Fall 2012
- Tools available – Winter 2012

Acknowledgements

- Jim Sturdevant & Tim Overman, Indiana DOT
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- Ed Smaglik, Northern Arizona University
- Montasir Abbas, Virginia Tech
- Cambridge Systematics