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

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Outline

- Objectives
- MOEs
- Procedures
- Tools
- Next Steps
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

Guidance Document

- Parts B & C: Description of Process
- Part D: Con Ops Guidance
- Part E: Requirements Guidance
- Part F: Verification Guidance
- Part G: Validation Guidance

Con Ops Statements (Table) → Con Ops Template → Con Ops Document

Requirements Statements (Table) → Requirements Template → Requirements Document

Verification Template → Verification Document

Validation Template → Validation Document
Systems Engineering Process

Guidance Document
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- Con Ops Statements (Table)
- Requirements Statements (Table)
- Con Ops Template
- Requirements Template
- Verification Template
- Validation Template
- Con Ops Document
- Requirements Document
- Verification Document
- Validation Document
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
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

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<th>MOEs</th>
<th>Data Sources</th>
<th>Operational Objectives</th>
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<td>Route travel time</td>
<td>Import travel time data from Bluetooth scanner</td>
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<td>Import trajectory data from GPS probe</td>
<td>Multiple objectives by TOD</td>
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<td>Number of stops per mile on route</td>
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<td>Traffic volume on route (throughput)</td>
<td>Import count data from tube counter file</td>
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<td>Time to process equivalent volume</td>
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<td>Handle incidents and events</td>
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<td>Percent arrivals on green, by link</td>
<td>Import high-resolution signal timing and detector data</td>
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<td>V/C ratio by movement</td>
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<td>Platoon ratio, by link</td>
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<td>Phase green to occupancy ratio by movement</td>
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<tr>
<td>Reliability of phase metrics</td>
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</table>
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

![Graph showing travel time reliability improvements over years.](image)
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

- GPS runs
- Vehicle Re-ID
- Phase Timing Data
- Signal Detector Data

Analysis Tools

MOEs

Processing layer

Flow Detector Data

GPS runs

Vehicle Re-ID

Phase Timing Data

Signal Detector Data
Components of Tools

- Flow Detector Data
- GPS runs
- Vehicle Re-ID
- Phase Timing Data
- Signal Detector Data

Analysis 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
GPS probe data

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

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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
GPS probe data interface
Import data files

---

**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.

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Validate performance
- Select “before” days
- Select “after” days
- Run analysis
- Numerical results
- Open source
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### Reports

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<th>GOR</th>
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**Averaged over a 15 minute interval**

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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
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