SAN FRANCISCO-OAKLAND BAY BRIDGE (SFOBB) METERING LIGHTS SYSTEM UPGRADE PROJECT

24TH ANNUAL ITS CALIFORNIA CONFERENCE
OCTOBER 1, 2018
Presentation Outline

• Introduction and Background
• Project Objectives and Scope
• Existing System
• Simulation Modeling
• Proposed System
• Project Challenges
• Project Status
SAN FRANCISCO - OAKLAND BAY BRIDGE

A Few Bridge Facts:
- 1936 Bridge opens to traffic
- 1958 Bridge lanes reconfigured (vehicles/upper and lower decks)
- 1974 metering sys installed to regulate traffic on the Bridge
- 2013 East Span Bridge open to vehicles
Toll Plaza Background

130,000 to 140,000 vehicles per day

Toll plaza has 20 approach lanes:
- 16 cash/ FasTrak® lanes
- 2 dedicated FasTrak®/ORT lanes
- 2 dedicated bus-only/HOV lanes

Metering Lane Configuration:
- 20 toll lanes converge to 16 lanes at metering lights approximately 1,000 feet west of the toll plaza
- 16 metered lanes further converge to 5 lanes across the bridge
- During HOV hours, 12 metered lanes converging to 4 lanes on bridge – 2 bus only lanes not metered that converge to 1 lane on bridge
Metering Lights Approach
Existing Metering Lights System

• System first deployed in 1974
• Basically the same metering system with few technology upgrades
• Metering rates are manually controlled and implemented from the District 4 TMC
• Not capable of automatically responding to changes in traffic conditions and queuing
• The back up system is to conduct manual operations from the controller cabinets in the field
Bay Area Toll Authority

Project Objectives

Implement a metering system that:

• optimizes the bridge’s current capacity
• adapts to changing traffic conditions (i.e. accidents, reoccurring and non-reoccurring)
• reduces queuing at the toll plaza
• accommodates differential metering rates for different lane configurations and classes of users (buses, HOV, FasTrak®, and cash lanes)
• improves traffic operations and vehicle flow along the corridor
• provides for redundancy in the event of component failures
Scope of Work Overview

• Replace and upgrade the existing metering system software and hardware system (cabinets, controllers, servers, CMS, etc.)
• Implement a fully automated and adaptive mainline metering system algorithm
• Provide redundancy via a backup TMC at the Toll Plaza Building
• Upgrade associated communications network and vehicle detection systems
• District 4 ATMS integration (ML System, CMS, loop detectors, CCTV)
• Utilize existing traffic monitoring stations in the vicinity of the Toll Plaza
• Repair or close existing gaps in the communications system
Project Flow Overview

- Evaluation Existing System
- Document Framework
- Design & Development of the Metering Algorithm
- System Software Design
- Graphical User Interface (GUI) Design
- System Integration & Implementation Plan
- Hardware & Software Procurement
- Center to Field Communication Integration
- Toll Plaza Workstation Upgrades
- Caltrans Camera Integration
- CMS Integration
- Caltrans D4 ATMS Modifications

Simulation Modeling

- Manuals
- Training
- System Testing
- Ongoing Maintenance and Support
Data Collection

• Toll Volume (BATA)
• Traffic Volume (Caltrans)
• Metering Logs (Caltrans)
• Travel Time/Delay – collected in 2016 and 2017
Bay Area Toll Authority

Existing Traffic Volumes

SFOBB Flow Rate at Toll Plaza

Toll Plaza Volumes
Simulation Modeling Process

Data
- Toll Volume (BATA)
- Traffic Volume (Caltrans)
- Metering Logs
- Travel Time/Delay

Analysis

Geometry & Metering

Calibration

Base Simulation Model

Simulation Modeling
- Recurring Congestion
- Non-Recurring Congestion

Metering Algorithm #1
- Refine Algorithm Parameters
- Refine Detector Locations
- Output Analysis (Performance Measures)
- Metering Algorithm Selection

Metering Algorithm #2

Metering Algorithm #3
Physical and Operational Considerations

To Consider
- Differential metering rates for FASTRAK and Cash
- Lane assignment based on TOD
- Traffic condition on the bridge
- Traffic condition at the merging area
- Traffic condition upstream and detectors
Metering Lights Algorithm Performance Measures

- Throughput
- Travel Time
- Delay
- Recurrent Congestion
- Non-Recurrent Congestion
## Simulation Results (Recurring Congestion)

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Throughput</th>
<th>Improvement</th>
<th>Delay</th>
<th>Improvement</th>
<th>Travel time</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>41099</td>
<td>--</td>
<td>10.54</td>
<td>--</td>
<td>24.23</td>
<td>--</td>
</tr>
<tr>
<td>Alinea</td>
<td>44059</td>
<td>7.2%</td>
<td>7.3</td>
<td>30.7%</td>
<td>18.14</td>
<td>25.1%</td>
</tr>
<tr>
<td>PI-Alinea</td>
<td>43919</td>
<td>6.9%</td>
<td>7.29</td>
<td>30.8%</td>
<td>18.1</td>
<td>25.3%</td>
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<tr>
<td>Fuzzy #1</td>
<td>43771</td>
<td>6.5%</td>
<td>7.04</td>
<td>33.2%</td>
<td>16.53</td>
<td>31.8%</td>
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<tr>
<td>Fuzzy #2</td>
<td>44293</td>
<td>7.8%</td>
<td>8.06</td>
<td>23.5%</td>
<td>19.22</td>
<td>20.7%</td>
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Simulation Results (Non-Recurring Congestion)

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Throughput</th>
<th>Impact</th>
<th>Delay</th>
<th>Impact</th>
<th>Travel time</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
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<td>43192</td>
<td>5.1%</td>
<td>7.1%</td>
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<td>--</td>
<td>--</td>
</tr>
<tr>
<td>PI-Alinea</td>
<td>42102</td>
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<td>10.2%</td>
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<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Fuzzy #1</td>
<td>42754</td>
<td>4.0%</td>
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<td>--</td>
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<tr>
<td>Fuzzy #2</td>
<td>44242</td>
<td>7.6%</td>
<td>8.8%</td>
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<td>--</td>
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</tr>
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</table>

Non-Recurring (1 lane blockage)

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Throughput</th>
<th>Impact</th>
<th>Delay</th>
<th>Impact</th>
<th>Travel time</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
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<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Alinea</td>
<td>43192</td>
<td>5.1%</td>
<td>7.1%</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>PI-Alinea</td>
<td>42102</td>
<td>2.4%</td>
<td>10.2%</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Fuzzy #1</td>
<td>42754</td>
<td>4.0%</td>
<td>7.2%</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Fuzzy #2</td>
<td>44242</td>
<td>7.6%</td>
<td>8.8%</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Non-Recurring (2 lane blockage)

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>Accident Location</th>
<th>Number of Lanes Closed</th>
<th>Duration of Lane Closure</th>
<th>Time of Day</th>
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<tbody>
<tr>
<td>1</td>
<td>Near YBI Tunnel</td>
<td>1</td>
<td>30</td>
<td>8:00-8:30 AM</td>
</tr>
<tr>
<td>2</td>
<td>Near YBI Tunnel</td>
<td>2</td>
<td>90</td>
<td>6:00-7:30 AM</td>
</tr>
<tr>
<td>3</td>
<td>Near YBI Tunnel</td>
<td>3</td>
<td>35</td>
<td>6:55-7:30 AM</td>
</tr>
</tbody>
</table>

Non-Recurring (3 lane blockage)

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Throughput</th>
<th>Impact</th>
<th>Delay</th>
<th>Impact</th>
<th>Travel time</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Alinea</td>
<td>39650</td>
<td>-3.5%</td>
<td>12.03</td>
<td>-14.1%</td>
<td>33.29</td>
<td>-37.4%</td>
</tr>
<tr>
<td>PI-Alinea</td>
<td>39210</td>
<td>-4.6%</td>
<td>11.15</td>
<td>-5.8%</td>
<td>28.15</td>
<td>-16.2%</td>
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<tr>
<td>Fuzzy #1</td>
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<td>-4.2%</td>
<td>10.3</td>
<td>2.3%</td>
<td>25.57</td>
<td>-5.5%</td>
</tr>
<tr>
<td>Fuzzy #2</td>
<td>39983</td>
<td>-2.7%</td>
<td>11.51</td>
<td>-9.2%</td>
<td>29.02</td>
<td>-19.8%</td>
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</tbody>
</table>
Mainline Metering Controller Firmware

Minimum Requirements

1. Independently control up to 16 metered lanes
2. Open interface for control from central system
3. Supports national standard (i.e., NTCIP)
4. Support for Local Traffic Responsive mode by time of day
5. Support logging volume, occupancy and speed data to the local controller database
6. Provide reporting capability - status, collected data, health
7. Pre-configured or user defined cabinet support
## Software/Firmware Candidates

<table>
<thead>
<tr>
<th>Controller Software/Firmware</th>
<th>Max Metered Lanes Supported</th>
<th>NTCIP (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Systems / Siemens</td>
<td>16</td>
<td>YES</td>
</tr>
<tr>
<td>Western Systems / Siemens</td>
<td>16</td>
<td>YES</td>
</tr>
<tr>
<td>Wapiti Micro Systems</td>
<td>16</td>
<td>YES</td>
</tr>
<tr>
<td>Intelight</td>
<td>16</td>
<td>YES</td>
</tr>
<tr>
<td>Econolite/Safetrans</td>
<td>4 Meters x 4 Controllers</td>
<td>YES</td>
</tr>
<tr>
<td>Trafficware/Naztec</td>
<td>4 Meters x 4 Controllers</td>
<td>YES</td>
</tr>
<tr>
<td>McCain</td>
<td>4 Meters x 4 Controllers</td>
<td>YES</td>
</tr>
</tbody>
</table>
Proposed System

- Metering Lights Server - Fuzzy Logic #1
- Metering Lights Controller - ATC 2070 with Intelight Firmware
- NTCIP 1207 (ramp meter systems) and 1209 (transportation sensor systems)
- Merge Area Detection (direct connect)
- Lane Group Metering Rate by Metering Lights Server
- Metering Rate implementation by Metering Lights Controller
Systems Engineering Process

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 0</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>Phase 5</th>
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</thead>
<tbody>
<tr>
<td>Interfacing with</td>
<td>Concept Exploration</td>
<td>Project Planning and</td>
<td>System Definition</td>
<td>System Development and</td>
<td>Validation, Operations</td>
<td>System Retirement /</td>
</tr>
<tr>
<td>Planning and the</td>
<td>and Benefits</td>
<td>Concept of Operations</td>
<td>and Design</td>
<td>and Implementation</td>
<td>and Maintenance,</td>
<td>Replacement</td>
</tr>
<tr>
<td>Regional Architecture</td>
<td>Analysis</td>
<td>Development</td>
<td></td>
<td></td>
<td>Changes &amp; Upgrades</td>
<td></td>
</tr>
<tr>
<td>Project Planning and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systems Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management Planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cross-Cutting Activities:
- Stakeholder Involvement
- Elicitation
- Project Management Practices
- Risk Management
- Program Metrics
- Configuration Management
- Process Improvement
- Decision Gates
- Trade Studies
- Technical Reviews
- Traceability

Systems Validation
- Initial Deployment
- System Verification
- Subsystem Integration
- Subsystem Validation
- Subsystem Integration

We are here
Project Challenges

• Technical Complications
  • Replacing/Enhancing five interconnected systems
    - Metering Lights System Software
    - Controller Firmware
    - Changeable Message Signs
    - Communications
    - Detection
  • No other examples in the world
  • Lane assignments (Fastrak, cash, HOV)
  • “Merge” area

• System Cutover
  • Redundant Systems
  • Significant Testing/Burn-in Period
Key Activities Remaining

- Design and Development of Firmware in progress
- Detailed Design (PS&E) in progress 70% done
  - Additional Detection
  - Communications infrastructure
  - CMS installation
  - TMC in Toll Plaza Building
- Caltrans Encroachment Permit (PEER) in progress
- Environmental Revalidation winter 2018
- Prepare Integration, Implementation and Cutover Plans in progress
- CMS Procurement early summer 2019
- BCDC Permits
- Construction Manager Procurement early summer 2019
- Construction and Implementation early summer 2019
  - System Testing
  - Training
- Ongoing Maintenance & Support
Questions?
# Algorithms Considered

<table>
<thead>
<tr>
<th>Conditions considered</th>
<th>Old Algorithm</th>
<th>ALINEA</th>
<th>PRIALINEA with RBL</th>
<th>Bottleneck</th>
<th>CARMA</th>
<th>COMPASS</th>
<th>Fuzzy Logic Caltrans</th>
<th>Fuzzy Logic (Chen et al.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Local</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ramp</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measure</th>
<th>HOV Lanes</th>
<th>local</th>
<th>downstream</th>
<th>upstream</th>
<th>Local/ramp</th>
<th>Local/ramp</th>
<th>Local/downstream</th>
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</thead>
<tbody>
<tr>
<td>Volume</td>
<td>✗</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Occupancy</td>
<td>local</td>
<td>local</td>
<td>Local/downstream</td>
<td>local</td>
<td>downstream/ramp/local</td>
<td>Local/ramp</td>
<td>Local/downstream</td>
</tr>
<tr>
<td>Speed</td>
<td>✗</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Approach</th>
<th>Operates at a predefined capacity based on measured HOV lanes flow</th>
<th>Maintains the merge area occupancy below a critical value using a feedback mechanism</th>
<th>Adjusts metering rates to maintain occupancies of local and several downstream stations below critical values using a feedback mechanism</th>
<th>Adjusts metering rates using offline optimized rates for local condition, and using a feedback mechanism considering downstream capacity</th>
<th>Adjusts metering rates based on downstream speed</th>
<th>Adjusts metering rates considering local and downstream occupancies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extendible to mainline metering</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sufficient information available</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Recommended for Evaluation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Rationale</td>
<td>Base line algorithm</td>
<td>Robust algorithm based on feedback control.</td>
<td>Extension of ALINEA which considers the downstream capacity (traffic condition on the bridge)</td>
<td>Two level optimization technique as combination of offline rates and feedback mechanism</td>
<td>Only based on downstream speed</td>
<td>Requires calibration of a lookup table based on detector inputs from three different locations. Limited information is available on the algorithm</td>
</tr>
</tbody>
</table>

Bay Area Toll Authority
Bay Area Toll Authority

Existing System Elements