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Pennsylvania Turnpike Commission (PTC)
Fog Detection, Traveler Information and Dynamic Traffic Control System

Joerg ‘Nu’ Rosenbohm
nu.rosenbohm@telvent.abengoa.com
Reason for Project

5 dead, 25 injured in two crashes on fog-shrouded PA Turnpike...

Associated Press

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Why the Need for a Fog Warning System?

- Goal – Zero Fog-Related Crashes
- Issues
  - Large Variations In Travel Speed
  - Driver Uses His/Her Own Judgment
  - Standard warning signs ineffective
- Existing Equipment in Project Area
  - One RWIS site in fog prone area
  - One camera for verification
  - One DMS within one and four miles outside of Project Area
  - Existing Central Control Software
- Inspired by Effective System on I-75 in TN
Project Location within Pennsylvania
System Development

- Based on System Engineering Process (SEP)
  - Required National ITS Architecture
  - Requires NTCIP for DMS, VSLS, RWIS
- Concept of Operations
- Functional Requirements based on ConOps Needs
- Turn-key System
  - Designer of System was also Project Manager
  - General Contractor = Sub
  - DMS / VSLS / RWIS vendors = 2nd tier Subs to General Contractor
  - Central System Developer = Sub
• Note: existing DMS at Site 10 (Milepost 175.4) is not shown
Site Configurations

- 10 field device sites over 19 km (12 mile) stretch with all sites spaced at approx. 1 mile, except the most eastern site at approx. 3 miles.
- Nine of the sites house
  - 1 road weather information system (RWIS) sensor system
  - 1 radar-based speed detector
  - 1 CCTV camera providing a snapshot every 30-seconds
  - Up to 3 variable speed-limit signs (VSLS) at each site
    - 1 VSLS facing each direction of traffic; Sometimes 2 in one direction, if there are 3 lanes
    - VSLS spaced at 1.6 km (1 mile) intervals to encourage drivers to reduce their speed when approaching a fog bank.
    - A total of 25 VSLS throughout the project.
- 11 dynamic message signs are placed at every other site and the tenth site to inform approaching vehicles
Typical Site Layout w/ DMS

- RWIS Station
- CCTV
- RTMS
- Fog Detector
- PTC TEST MSG
- SPEED LIMIT 30
- Median
- Approx. 1000 ft
Hybrid Communications Infrastructure

- **Level 1:** Existing high-speed, wireless communications backbone
  - From Harrisburg TMC to 54m (180 foot) Tower in Project Area
  - 154 km (90 miles) distance
  - Level 1 proven to be extremely reliable
- **Level 2:** Mix of Spread Spectrum and Fiber-Optics
  - 2 separate spread spectrum paths from Tower to 2 roadside receivers
  - Fiber Optics backbone between the 2 roadside receivers
  - Fiber Optics drops to each of the 9 individual device sites
  - Level 2 designed for Redundancy
Central Control Software

- PTC has an existing Central System (MIST©) managing other devices along the Turnpike
- PTC wanted to expand MIST© to manage the Fog Warning System
- MIST© already supported:
  - NTCIP-compliant DMS (VSLS are considered DMS, but with limited functionality enforced by MIST©)
  - Radar Detection Units (RTMS) for Speed Detection
  - CCTV for Verification
- MIST© software development for:
  - FWS algorithms
  - RWIS interface
**Road Weather Information System (RWIS) Interface**

- Different ways to integrate RWIS:
  - Direct interface with each RWIS station
  - Indirect interface with existing RWIS Central System
- Decided on Indirect Interface
  - Lower Software development costs
  - Existing RWIS Central System located in TMC
  - MIST© uses operational data, i.e., fog (reduced visibility) values and display of other sensor data
  - Retaining of Existing RWIS Central System
    - RWIS station diagnostics capabilities
    - Extensive History displays / reports build-in
- The CCTV cameras are snapshot cameras connected to the RWIS Central System
- 30 sec polling of RWIS field devices by RWIS Central Software and 30 sec polling of RWIS – MIST© interface
Fog Warning System Module - Design

- Designed for maximum flexibility - Examples
  1. Respond with a single response to fog detected anywhere within the system
  2. Suggest different responses for each RWIS site
     Example 2 is the current configuration.

- 2 methods to address competing FWS and Incident responses:
  - Assignment of Priority Levels to each message
    - Example: “Accident Ahead” message has higher priority than “Reduced Vision Ahead” message.
    - Situation and FWS reaction: Fog appears / Accident Exists ⇒ FWS wants to display “Reduced Vision Ahead” message but cannot override existing “Accident Ahead” message.
  - Manual Operator decision (computer cannot determine severity of incidents) – function can be disabled
Fog Warning System Module - Logic

- **Sequence of Events when Fog is detected:**
  - Perform Evaluation for each Site separately
  - Consideration of any device and communications failures.
    - If existing:
      - At least 1 DMS operational within 6 miles $\Rightarrow$ If not, blank VSLS
      - RWIS prior to detecting site is failed, display of ‘special’ message on DMS (cannot determine where fog starts)
  - If no Failures, determine which of 3 user-definable thresholds has been exceeded
    - Select and display associated VSLS speed limit at site in both directions
    - Select and display associated DMS message for all DMS within 6 miles in both directions
  - Overlay suggested Messages for each DMS and VSLS and display the Messages with the Highest Priority
Fog Warning System Module – Special Functions

- VSL Smoothing Algorithm
  - VSL in between 2 VSL with lower speeds ⇒ reduce VSL to the higher of the 2 outer speed limits

- Toggle Execution Functionality
  - Operator Confirmation of Suggested Fog Response
  - Automatic Execution of Fog Response (System Admin Setting)

- Performance Evaluation capabilities
  - All inputs and response actions suggested and executed by the system, either automatic or manual, are recorded
FWS Response Interface - Main GUI

- Operator can select ‘Accept’ or ‘Reject’
- Row 1 = threshold 2 crossed, Row 2 = threshold 1 crossed
- Third row is displayed because of VSLS smoothing

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Alarm Status</th>
<th>Activating Time</th>
<th>Threshold Visibility Value</th>
<th>Alarm Activation Value</th>
<th>Alarm Time</th>
<th>Suggested Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 12802 - MP164.1</td>
<td>Poor Visibility</td>
<td>2</td>
<td>1000</td>
<td>791</td>
<td>08/11/2006 18:03:32</td>
<td>Site 12802: 42:52</td>
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<tr>
<td>Site 12804 - MP166.0</td>
<td>Decreased Visibility</td>
<td>1</td>
<td>1500</td>
<td>1191</td>
<td>08/11/2006 18:08:40</td>
<td>Site 12804: 33:31</td>
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<tr>
<td>Site 12803 - MP165.0</td>
<td>Normal Visibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Site 12803: 32:30</td>
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</tbody>
</table>
## FWS Response Interface - EB Details

<table>
<thead>
<tr>
<th>Device ID</th>
<th>Device Type</th>
<th>Related Site</th>
<th>Suggested Response Message Text</th>
<th>Executed Response Message Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>7801</td>
<td>DMS</td>
<td></td>
<td>REDUCED VISION AHEAD FOLLOW REDUCED SPEED TRUCKS KEEP RIGHT</td>
<td></td>
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<tr>
<td>7802</td>
<td>DMS</td>
<td>Site 12801 - MP16..</td>
<td>REDUCED VISION AHEAD FOLLOW REDUCED SPEED TRUCKS KEEP RIGHT</td>
<td></td>
</tr>
<tr>
<td>8802</td>
<td>VSL</td>
<td>Site 12801 - MP16..</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8801</td>
<td>VSL</td>
<td>Site 12801 - MP16..</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8804</td>
<td>VSL</td>
<td>Site 12802 - MP16..</td>
<td>40</td>
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</tr>
<tr>
<td>8805</td>
<td>VSL</td>
<td>Site 12802 - MP16..</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>7804</td>
<td>DMS</td>
<td>Site 12803 - MP16..</td>
<td>REDUCED VISION AHEAD FOLLOW REDUCED SPEED TRUCKS KEEP RIGHT</td>
<td></td>
</tr>
<tr>
<td>8807</td>
<td>VSL</td>
<td>Site 12803 - MP16..</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>8803</td>
<td>VSL</td>
<td>Site 12803 - MP16..</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>8810</td>
<td>VSL</td>
<td>Site 12804 - MP16..</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>7806</td>
<td>DMS</td>
<td>Site 12805 - MP16..</td>
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<td></td>
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<tr>
<td>6012</td>
<td>VSL</td>
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<td></td>
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<tr>
<td>8814</td>
<td>VSL</td>
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<tr>
<td>7808</td>
<td>DMS</td>
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<td></td>
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<tr>
<td>8817</td>
<td>VSL</td>
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<tr>
<td>8820</td>
<td>VSL</td>
<td>Site 12808 - MP17..</td>
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<td></td>
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<tr>
<td>8833</td>
<td>VSL</td>
<td>Site 12809 - MP17..</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## FWS Response Interface - WB Details

<table>
<thead>
<tr>
<th>Device ID</th>
<th>Device Type</th>
<th>Related Site</th>
<th>Suggested Response Message Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>70009</td>
<td>DMS</td>
<td>Site 12809 - MP17</td>
<td></td>
</tr>
<tr>
<td>7810</td>
<td>DMS</td>
<td>Site 12809 - MP17</td>
<td>REDUCED VISION AHEAD FOLLOW REDUCED SPEED TRUCKS KEEP RIGHT</td>
</tr>
<tr>
<td>8825</td>
<td>VSL5</td>
<td>Site 12809 - MP17</td>
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</tr>
<tr>
<td>8824</td>
<td>VSL5</td>
<td>Site 12809 - MP17</td>
<td></td>
</tr>
<tr>
<td>8821</td>
<td>VSL5</td>
<td>Site 12808 - MP17</td>
<td></td>
</tr>
<tr>
<td>8822</td>
<td>VSL5</td>
<td>Site 12808 - MP17</td>
<td></td>
</tr>
<tr>
<td>7809</td>
<td>DMS</td>
<td>Site 12807 - MP16</td>
<td>REDUCED VISION AHEAD FOLLOW REDUCED SPEED TRUCKS KEEP RIGHT</td>
</tr>
<tr>
<td>8818</td>
<td>VSL5</td>
<td>Site 12807 - MP16</td>
<td></td>
</tr>
<tr>
<td>8819</td>
<td>VSL5</td>
<td>Site 12807 - MP16</td>
<td></td>
</tr>
<tr>
<td>8815</td>
<td>VSL5</td>
<td>Site 12806 - MP16</td>
<td></td>
</tr>
<tr>
<td>8815</td>
<td>VSL5</td>
<td>Site 12806 - MP16</td>
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</tr>
<tr>
<td>7807</td>
<td>DMS</td>
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<td>REDUCED VISION AHEAD FOLLOW REDUCED SPEED TRUCKS KEEP RIGHT</td>
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<tr>
<td>8813</td>
<td>VSL5</td>
<td>Site 12805 - MP16</td>
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<tr>
<td>8811</td>
<td>VSL5</td>
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<td>50</td>
</tr>
<tr>
<td>7805</td>
<td>DMS</td>
<td>Site 12803 - MP16</td>
<td>REDUCED VISION AHEAD FOLLOW REDUCED SPEED TRUCKS KEEP RIGHT</td>
</tr>
<tr>
<td>8819</td>
<td>VSL5</td>
<td>Site 12803 - MP16</td>
<td></td>
</tr>
</tbody>
</table>

*Accept Suggested Response  Reject Suggested Response*
Software Development Challenges

- DMS and VSLS were the only field devices available for direct testing in lab
- Needed to develop Fog Input Simulator to create
  - Fog events,
  - Incident Events,
  - DMS Device Failures,
  - VSLS Device Failures
  - RWIS Device Failures,
  - Communications Failures
- RTMS and CCTV failures not considered for FWS algorithms => not an input into FWS algorithm
- Biggest issue was integration and interaction of different modules (DMS/VSLS message priority vs Manual Message display priority)
Software Development Challenges

- Theoretical number of possible combinations for 3 different thresholds, each possible device and communications failure > 1.3 Quadrillion
  - How to do meaningful testing?
  - Agreed to several scenarios that will likely occur, test those extensively in both lab and later in field.
  - Observe system continually for several months during the SW Observation Period.
- Simulated different fog scenarios in conjunction with various failure types
- Tested for about 6 wo/man weeks in laboratory
- Additional testing at client site without simulator (fog season)
System Acceptance Testing

- System Acceptance Test onsite revealed punch-list items
  - GUI synchronization problem between existing MIST© modules and new FWS module
  - Synchronization problem of FWS displays between different Operator Workstations
  - VSLS Smoothing not correct under certain conditions
  - Output of RWIS Central System to MIST© was modified and not communicated
- Punch List items were fixed and re-tested in lab
- Re-installation of FWS module at PTC and re-testing
Observations and Conclusions

- FWS module performance appears to be without errors
  - Confirmed by Operators and System Administrator as well as Analysis of performed actions
  - High probability that not all possible deviations have been tested
- Confidence Level of FWS module by PTC is Very High
  - FWS is very flexible allowing System Administrator to modify configuration parameters (Messages, Speed Limits, Priority Levels)
  - FWS module now in Automatic Execution mode
  - PTC considers deployment of additional FWS areas along the Pennsylvania Turnpike
- Entire PTC system viewable on Internet: www.paturnpike.com
Questions?

Thank You

Joerg ‘Nu’ Rosenbohm
Senior ITS Engineer
Telvent Farradyne Inc.
nu.rosenbohm@telvent.abengoa.com
www.Telvent-Farradyne.com