Dynamic Mobility Applications (DMA) and Active Transportation and Demand Management (ATDM) Analysis, Modeling, and Simulation (AMS) Testbed Project

DMA Preliminary Results

March 20, 2015
OUTLINE

- DMA Program Overview
- ATDM Program Overview
- DMA-ATDM AMS Testbed Project Overview
- San Mateo Testbed Modeling Effort Overview
- Preliminary Answers for DMA Research Questions
- Project Next Steps and Expected Outcomes
- Contacts
DMA Program Overview
DYNAMIC MOBILITY APPLICATIONS PROGRAM

▪ Vision
  ▫ Expedite development, testing, commercialization, and deployment of innovative mobility application
    ▪ maximize system productivity
    ▪ enhance mobility of individuals within the system

▪ Objectives
  ▫ Create applications using frequently collected and rapidly disseminated multi-source data from connected travelers, vehicles (automobiles, transit, freight) and infrastructure
  ▫ Develop and assess applications showing potential to improve nature, accuracy, precision and/or speed of dynamic decision
  ▫ Demonstrate promising applications predicted to significantly improve capability of transportation system
  ▫ Determine required infrastructure for transformative applications implementation, along with associated costs and benefits

▪ Project Partners
  ▫ Strong internal and external participation
    ▪ ITS JPO, FTA, FHWA R&D, FHWA Office of Operations, FMCSA, NHTSA, FHWA Office of Safety
# DMA Bundles and Applications

**FRATIS:** Freight Advanced Traveler Information Systems

**Apps:** Freight-Specific Dynamic Travel Planning and Performance, Drayage Optimization (DR-OPT)

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**IDTO:** Integrated Dynamic Transit Operations

**Apps:** Connection Protection (T-CONNECT), Dynamic Transit Operations (T-DISP)

- Dynamic Ridesharing (D-RIDE)

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**R.E.S.C.U.M.E.:** Response, Emergency Staging and Communications, Uniform Management, and Evacuation

**Apps:** Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)

- Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
- Emergency Communications and Evacuation (EVAC)

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**MMITSS:** Multimodal Intelligent Traffic Signal System

**Apps:** Intelligent Traffic Signal System (I-SIG), Transit and Freight Signal Priority (TSP and FSP)

- Mobile Accessible Pedestrian Signal System (PED-SIG), Emergency Vehicle Preemption (PREEMPT)

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**INFLO:** Intelligent Network Flow Optimization

**Apps:** Dynamic Speed Harmonization (SPD-HARM), Queue Warning (Q-WARN)

- Cooperative Adaptive Cruise Control (CACC)

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**Enable ATIS:** Enable Advanced Traveler Information Systems

**Apps:** EnableATIS (Advanced Traveler Information System 2.0)
ATDM Program Overview
Active Transportation and Demand Management (ATDM)

- Active Management is the fundamental concept of taking a dynamic approach to a performance based process.

- Dynamically monitor, control, and influence travel, traffic, and facility demand of the entire transportation system and over a traveler's entire trip chain.

- ATDM leverages existing infrastructure to evolve from Static to Active Management.

Trip Chain:
- Destination Choice
- Time of Day Choice
- Mode Choice
- Route Choice
- Lane/Facility Use/Choice
Active Transportation and Demand Management (ATDM) Categories

Active Demand Management
- A suite of strategies intended to reduce or redistribute travel demand to alternate modes or routes.
- Examples: comparative multi-modal travel times, dynamic ride-sharing, pricing and incentive approaches.

Active Traffic Management
- A suite of strategies that actively manage traffic on a facility.
- Examples: variable speed limits, dynamic shoulder use, queue warning, lane control.

Active Parking Management
- A suite of strategies designed to affect the demand, distribution, availability, and management of parking.
- Examples: parking pricing, real-time parking availability and reservation systems.
DMA-ATDM AMS Testbed Project Overview
AMS TESTBED PROJECT OBJECTIVES

- Evaluate the system wide impacts of individual and logical combinations of DMA bundles/ATDM strategies, and identify conflicts and synergies in order to maximize benefits.
  - Evaluate the impacts of the DMA bundles and ATDM strategies when prediction and active management are coupled with data capture and communications technologies
  - Address some of the research questions of the DMA and ATDM programs

**Note:** Detailed overview of the project objectives and status was presented during the AMS Testbed webinar on February 26th, 2015 as part of the DMA program webinar series

KEY ASPECTS OF AN AMS TESTBED

- A virtual computer-based environment, not a physical field deployment

- **Combination of computer models/tools** that can capture impacts of implementing concepts, bundles, and strategies associated with the DMA and ATDM Programs
  - As close to real-world as possible by modeling an actual metropolitan region’s transportation system and transportation demand (e.g., persons, vehicles, transit)
  - Not directly connected to field operational systems or personnel (e.g., traffic management systems, TMC operators, etc.)
  - Developed by building on existing and previous AMS capabilities and modeling efforts

- Multiple AMS tools/components are required to be integrated
  - Prediction Engine
  - Communications Emulator
  - Scenario Generator
  - Systems Manager Emulator
  - Performance Data Capture and Storage
AMS TESTBED PROJECT PHASES AND TIMELINE

- **Phase 1: AMS Testbed Selection**
  - Develop Testbed requirements and selection criteria
  - Conduct preliminary and final selection of AMS Testbed

- **Phase 2: Develop Evaluation Methodology**
  - Develop Testbed specific Analysis Plans
  - Combine Testbed specific plans to develop an overarching Evaluation Plan

- **Phase 3: Modeling, Analysis, and Reporting**
  - Develop and calibrate Testbed models, including data collection
  - Evaluate DMA and ATDM strategies using calibrated Testbeds
  - Report the relevant findings, produce documentation, and make them publicly available
  - Recommend further research for continuation of the DMA / ATDM future projects
AMS TESTBEDS SELECTED

**In this presentation, we will be only summarizing preliminary results from the San Mateo Testbed**
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# Overview of DMA Applications to be Tested Using Different Testbeds

<table>
<thead>
<tr>
<th>Bundle</th>
<th>Application</th>
<th>San Mateo</th>
<th>Phoenix</th>
<th>Pasadena</th>
<th>Chicago</th>
<th>Dallas</th>
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<tbody>
<tr>
<td>Enable</td>
<td>Multimodal Real-Time Traveler Information (ATIS)</td>
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<tr>
<td>ATIS</td>
<td>Smart Park-and-Ride (S-PARK)</td>
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<td>Universal Map Application (T-MAP)</td>
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<td>Real-Time Route-Specific Weather Information (WX-INFO)</td>
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<td>INFLO</td>
<td>Queue Warning (Q-WARN)</td>
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<tr>
<td></td>
<td>Dynamic Speed Harmonization (SPD-HARM)</td>
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<td></td>
<td>Cooperative Adaptive Cruise Control (CACC)</td>
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<td>MMITSS</td>
<td>Intelligent Traffic Signal System (ISIG)</td>
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<td>Transit Signal Priority (TSP)</td>
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<td>Mobile Accessible Pedestrian Signal System (PED-SIG)</td>
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<td></td>
<td>Emergency Vehicle Preemption (PREEMPT)</td>
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<td>Freight Signal Priority (FSP)</td>
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<td>IDTO</td>
<td>Connection Protection (T-CONNECT)</td>
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<td>Dynamic Transit Operations (T-DISP)</td>
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<td>Dynamic Ridesharing (D-RIDE)</td>
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<td>FRATIS</td>
<td>Freight Real-Time Traveler Information with Performance Monitoring (F-ATIS)</td>
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<td>Drayage Optimization (DR-OPT)</td>
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<td>Freight Dynamic Route Guidance (F-DRG)</td>
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<td>R.E.S.C.U.M.E.</td>
<td>Emergency Communications and Evacuation (EVAC)</td>
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<td></td>
<td>Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESPSTG)</td>
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<td></td>
<td>Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)</td>
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The simulation scenarios will be conducted in three stages based on the algorithm acquisition/development timeline.

- Selected logical combinations through a systematic analysis
  - Several combinations will be analyzed, and results will be documented for the individual as well as multiple combinations at an aggregate level

- Results are expected to help address the research questions and provide insights into potential impacts from real-world deployments of a portfolio of DMA applications

<table>
<thead>
<tr>
<th>Scenarios (S)</th>
<th>Stage 1 Scenarios</th>
<th>Stage 2 Scenarios</th>
<th>Stage 3 Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
</tbody>
</table>

| SAFETY ENABLED ATIS (ATIS) | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| INFLO (Q-WARN) | ✓ ✓ ✓ ✓ |
| INFLO (SPD-HARM) | ✓ ✓ ✓ ✓ |
| INFLO (CACC) | ✓ |
| INFLO (ISIG) | ✓ ✓ |
| INFLO (TSP) | ✓ ✓ |
| INFLO (PED-SIG) | ✓ ✓ |
| INFLO (PREEMPT) | ✓ ✓ |
| INFLO (FSP) | ✓ ✓ |
| MMITSS (T-DISP) | ✓ ✓ ✓ ✓ |
| MMITSS (D-RIDE) | ✓ ✓ ✓ ✓ |
| MMITSS (F-ATIS) | ✓ ✓ |
| MMITSS (F-DRG) | ✓ ✓ ✓ |
| IDTO (RESPSTG) | ✓ ✓ |
| IDTO (INC-ZONE) | ✓ ✓ |
| IDTO (RESPSTG) | ✓ ✓ |
| IDTO (INC-ZONE) | ✓ ✓ |

U.S. Department of Transportation
KEY DIFFERENCES BETWEEN IMPACT ASSESSMENTS AND AMS TESTBED MODELING EFFORT

- The DMA Program is currently sponsoring several small-scale prototype demonstrations (PD) of each of the six bundles to test if the bundles can be successfully deployed in the future.

- The DMA Program is also sponsoring separate, multiple efforts (one for each bundle) to conduct an independent Impact Assessments (IA) of the prototype as well as local/regional impacts of the various bundles.
  - The data and findings from the PD and IA are helping U.S. DOT make more informed decisions regarding the technical feasibility and potential impacts of deploying the bundles more widely.

- PD and IA focuses on potential impact of deploying the bundles individually vs. AMS Testbed focuses on determining collective impacts of deploying multiple DMA bundles together in the same region.
CURRENT STATUS

- DMA Applications are being studied using multiple Testbeds
  - San Mateo, Phoenix, Pasadena, Chicago
  - Dallas Testbed is not used for DMA evaluation, primarily used for ATDM evaluation

- Modeling efforts underway for DMA evaluation across different Testbeds
  - SPD-HARM Application acquired and implemented
  - Interim version of MMITSS, INC-ZONE and RESPSTG developed and implemented
  - A common simulation platform that enables data-sharing between different applications developed for modeling application combinations
  - Preliminary framework for some of the DMA applications developed, e.g., D-RIDE and T-DISP applications of the IDTO bundle.
  - USDOT’s Trajectory Convertor Application (TCA) Emulator tool added to enable communication modeling for INFLO and R.E.S.C.U.M.E. bundles

- **Preliminary findings** available from San Mateo Testbed in this presentation
San Mateo Testbed Modeling Effort Overview
8.5 mile long stretch of the US 101 freeway and State Route 82 (El Camino Real) in San Mateo County, California

- The US 101 freeway is an 8 lane freeway, transitioning to 6 mixed flow lanes plus 2 peak period HOV 2+ lanes south of Whipple Avenue
- El Camino Real is a 4 to 6 lane signalized divided arterial with a posted 35 mph speed limit

US 101 carries between 200,000 and 250,000 Average Annual Daily Traffic (AADT). El Camino Real carries between 25,000 and 50,000 AADT

A microsimulation network coded in VISSIM software
SAN MATEO TESTBED (IA VS. AMS TESTBED)

- San Mateo Testbed was used to conduct IA for INFLO bundle and test the potential benefits from implementation of INFLO.

- San Mateo Testbed is used in the AMS Testbed project to test collective impacts of INFLO, R.E.S.C.U.M.E and MMITSS bundles.

- Testbed used for IA includes only US-101 (freeway facility).
  - Only SPD-HARM application was Tested.

- For the AMS Testbed effort, added El Camino Real Arterial Network (17 signalized intersections).
  - Collective impact of SPD-HARM, INC-ZONE, RESP-STG and MMITSS being analyzed and evaluated.

- Additional calibration was conducted (e.g. incident location and severity of incident updated to match real-world observations).

- Further refinement to San Mateo Testbed is underway to identify real-world operational conditions by conducting cluster analysis.
APPLICATIONS TESTED USING THE SAN MATEO TESTBED

1. **SPD-HARM:**
   - Dynamically adjust and coordinate maximum appropriate vehicle speeds in response to downstream congestion, incidents, and weather or road conditions in order to maximize traffic throughput and reduce crashes.

2. **INC-ZONE:**
   - Provide merging and speed guidance to drivers within the vicinity of an incident for enhancing the safety and mobility of the incident section.

3. **RESP-STG:**
   - Provides situational awareness to and coordination among emergency responders—upon dispatch and while en-route— to establish incident scene work zones, both upon initial arrival and staging of assets, and afterward, if circumstances require, additional dispatch and staging (*preliminary results not available at this time*)

4. **MMITSS:**
   - Using high-fidelity data collected from vehicles through V2V and V2I wireless communications as well as pedestrian and non-motorized travelers, this proposed application seeks to control signals and maximize flows in real time.
SIMULATION SCENARIOS FOR SAN MATEO TESTBED

- 3-hour PM peak analysis used (3:30PM to 6:30PM).

- Incident location was a typical freeway section with 1 closed lane for a length of 200 feet.

- Operational Conditions considered for analysis:
  - Dry Weather
  - Rainy weather (lower demand assumed than dry weather day)
  - Short Incident: 30 minutes
  - Long Incident: 60 minutes

- Preliminary modeling conducted for demand patterns expected on an average week day. Analysis underway to identify real-world operational conditions using clustering approach.
PRELIMINARY PERFORMANCE MEASURES USED

- **Average Vehicle Delay**
  - This is the network-wide measure of overall vehicle delay averaged over the number of vehicles and is reported in seconds. Average vehicle delay is a direct mobility measure.

- **Average Vehicle Speed**
  - This is also a network-wide performance measure and is calculated as the average speed of travel of all the vehicles in the network, and is a direct mobility measure.

- **Average Number of Stops**
  - This measure is computed by averaging the number of stops of individual vehicles across the network for the overall simulation period and is a mobility as well as safety measure.

- **Speed Differential**
  - This is the 95th percentile speed differential between consecutive roadway sections (sublinks). It is computed from individual average speeds of 0.5 mile length sublinks, and is a measure of shockwave reduction (safety measure).

- **Average Section Throughput**
  - This measure is used for R.E.S.C.U.M.E. application and determines the number of vehicles that pass through the incident zone in a given hour and is a mobility measure.
Preliminary Answers to DMA Research Questions
## Preliminary Answers for Research Questions

- This presentation addresses preliminary answers for 7 research questions

<table>
<thead>
<tr>
<th>ID</th>
<th>DMA Research Question</th>
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<tbody>
<tr>
<td>1</td>
<td>Are the DMA applications and bundles more beneficial when implemented in isolation or in combination?</td>
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<tr>
<td>2</td>
<td>What DMA applications, bundles, or combinations of bundles complement or conflict with each other?</td>
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<tr>
<td>3</td>
<td>What DMA bundles or combinations of bundles yield the most benefits for specific operational conditions?</td>
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<tr>
<td>4</td>
<td>Under what operational conditions are specific bundles the most beneficial?</td>
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<td>5</td>
<td>Is SAE J2735 BSM Part 1 transmitted via Dedicated Short Range Communications (DSRC) every 10th of a second critical for the effectiveness of the DMA bundles?</td>
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<td>6</td>
<td>What are the impacts of communication latency on benefits?</td>
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<td>7</td>
<td>At what levels of market penetration of connected vehicle technology do the DMA bundles (collectively or independently) become effective?</td>
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</table>
Are the DMA applications and bundles more beneficial when implemented in isolation or in combination?

Preliminary Findings

- The benefit of implementing the applications in isolation or in combination differs from an operational condition to another. For example:
  - Under dry conditions, SPD-HARM and INC-ZONE are more beneficial in reducing average vehicle delays when used in combination, than in isolation.
  - But under rainy conditions (lower demand), INC-ZONE application’s benefits are decreasing when used along with SPD-HARM. Additional analysis is underway.
- Further analysis underway to understand benefits of applications when implemented in different operational conditions. Results are being analyzed for other performance measures such as speed.

Applications tested:
- SPD-HARM
- INC-ZONE
- SPD-HARM + INC-ZONE.

Operational Conditions:
- Dry Weather
- Rain Weather
- Short Incident

Level of CV Penetration:
- 100%

Note: Vehicle Delays are consistently lower in the Rain Conditions compared to the Dry Conditions because the traffic demands modeled were lower in the Rain Conditions.
What DMA Applications, Bundles, or Combinations of Bundles Complement or Conflict with Each Other?

Preliminary Findings

- Some of the DMA applications complement each other while they are implemented together. For example:
  - SPD-HARM and INC-ZONE complement each other under dry conditions.
    - The average delay and number of stops decrease when both applications (SPD-HARM and INC-ZONE) are implemented together.
- Further analysis is underway

- Applications tested:
  - SPD-HARM
  - INC-ZONE
  - SPD-HARM + INC-ZONE.

- Operational Conditions:
  - Dry Weather
  - Short Incident

- Level of CV Penetration:
  - 100%

![Change in Network-wide Performance Measures under Dry Condition.](chart)

+ve value means the value is increasing comparing to the base case (no connected vehicles)
-ve value means the value is decreasing comparing to the base case
What DMA bundles or combinations of bundles yield the most benefits for specific operational conditions?

Preliminary Findings

- Operational condition has an impact on the overall effectiveness of the DMA applications. For example:
  - For Dry weather and Long Incident operational condition, the combination of SPD-HARM and INC-ZONE performs better (less delay) comparing to individual applications.
  - For Rain weather and Long Incident operational condition, the INC-ZONE application separately performs better (less delay) comparing to applications combination.

- Further analysis is underway to understand the effectiveness of combination of bundles under different operational conditions.

- Applications tested:
  - SPD-HARM
  - INC-ZONE
  - SPD-HARM + INC-ZONE.

- Operational Conditions:
  - Dry Weather
  - Rain Weather
  - Short Incident

- Level of CV Penetration:
  - 100%
UNDER WHAT OPERATIONAL CONDITIONS ARE SPECIFIC BUNDLES THE MOST BENEFICIAL?

Preliminary Findings

- The effectiveness of the DMA application varies based on the prevailing operational condition. For example:
  - In terms of 95th percentile speed difference between consecutive roadway sections (sublinks), SPD-HARM performs best for Dry weather and short incident cases as compared to other operational condition.
  - In terms of increase in throughput, INC-ZONE performs best under Dry weather and both incident cases yielded similar results.

- Applications tested:
  - SPD-HARM
  - INC-ZONE
  - SPD-HARM + INC-ZONE.

- Operational Condition:
  - Dry Weather
  - Rain Weather
  - Short Incident
  - Long Incident

- Level of CV Penetration:
  - 50%
Preliminary Findings

- The message frequency is not always critical for the effectiveness of the DMA Application. For example:
  - For INC-ZONE application, messaging at 1/10th of a second is not critical.
  - The impact of 1 and 3 seconds frequency is minimal in terms of average delay, number of stops and average travel speed.
- Further investigation is underway

Applications tested:
- INC-ZONE

Operational Condition:
- Dry Weather
- Short Incident

Level of CV Penetration:
- 100%

Tested Message Frequency:
- 0.1 Second (Base Case)
- 1 Second
- 3 Seconds

+ve value means the value is increasing comparing to the base case
-ve value means the value is decreasing comparing to the base case
WHAT ARE THE IMPACTS OF COMMUNICATION LATENCY ON BENEFITS?

Preliminary Findings

- The effectiveness of the DMA applications reduces by the increase of the latency value.
  - Most of the benefits of the system disappear beyond 1s-latency.
- Further analysis is underway. Advanced communication modeling will be done using TCA (Trajectory Conversion Algorithm) Emulator.

- Applications tested:
  - INC-ZONE
  - SPD-HARM
- Operational Condition:
  - Dry Weather
  - Short Incident
- Level of CV Penetration:
  - 100%
- Tested Message Latency:
  - 0 Second (Base Case)
  - 1, 2 seconds (INC-ZONE)
  - 10, 20 Seconds (SPD-HARM)
Preliminary Findings

- The level of penetration of technology is an essential factor in the DMA application effectiveness. For example:
  - MMITSS reduces 13% total vehicle delay at 100% market penetration comparing to the base case vs, at 25% penetration, vehicle delay decreases by 6%
  - SPD-HARM reduces the speed differential values between consecutives roadway sections (sublinks) as market penetration increases irrespective of the operational conditions (e.g. rain, incident)

Applications tested:
- MMITSS
- SPD-HARM

Operational Condition:
- Dry Weather

Level of CV Penetration:
- 0%, 10%, 25%, 50%, 75%, 100%
Preliminary Findings (Cont’d)

- For INC-ZONE application, higher benefits are yielded by higher market penetration. No major difference was shown between 75 and 100 percent market penetration.

Applications tested:
- INC-ZONE

Operational Condition:
- Dry Weather
- Short Incident

Level of CV Penetration:
- 0% (base case), 10%, 25%, 50%, 75%, 100%
Project Next Steps and Expected Outcomes
PROJECT NEXT STEPS

- Continue Testbed development, calibration, and modeling efforts
- Continue Stakeholder engagement throughout 2015
  - Conferences and webinars
  - Let us know if you are interested in participating
- Reporting Timeline
  - March 2015 – Stage 1 preliminary findings
  - June 2015 - Stage 2 findings/reports
  - October 2015 – Stage 3 findings/reports
  - November 2015 – Final reports
    - Final Report for each Testbed
    - Final Report on Overall DMA Evaluation
    - Final Report on Overall ATDM Evaluation
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