Development and Demonstration of the Truck Activity Monitoring System (TAMS)

Sponsored by:
California Department of Transportation

Presented by:
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SCAG Modeling Task Force Meeting
May 25th, 2016
Truck Configurations

- Logging
- Conventional cab
- Wrecker
- Sleeper cab
- Basic Platform
- Dump
- Reefer Enclosed van
- Utility
- 30ft bus
- Light van
- Beverage
- Service
- Multi stop
- Low loading
- Garbage
- Tank
- Conventional Enclosed van
- Cab over Enclosed van
- Cab over cab
- RV
- Dumpster transport
- Concrete mixer
- 20ft bus
- Crane
Trailer Configurations
Background

- Pilot study funded by California Air Resources Board in 2012
  - Initial development of inductive signature-based truck body classification models
  - Deployed at 16 weigh-in-motion (WIM) and inductive loop detector (ILD) sites in the California San Joaquin Valley

- Current study funded by Caltrans in 2015
  - Improved Validation and Calibration of the California Statewide Freight Forecasting Model (CSFFFM)
  - Enhancement of truck classification models
  - Expand deployment to over 90 locations along major truck corridors in California, encompassing
    - state borders,
    - regional cordons, and
    - metropolitan areas
What is the **Truck Activity Monitoring System (TAMS)**?

* A truck counting system that is...

- **Temporally Continuous**
  - Data collected and transmitted real-time 24/7

- **Spatially Comprehensive**
  - Will be deployed at over 90 major truck corridors across the State of California

- **Sustainable**
  - Leverages existing Inductive Loop and Weigh-In-Motion Detector infrastructure

- **Advanced**
  - Adopts a combination of inductive loop signature and weigh-in-motion technologies

- **High Fidelity**
  - Identifies 40 to 60 truck / trailer body configurations

- **Accessible and Automated**
  - Hosted on an interactive GIS-enabled web-based user interface
Potential Applications

- Estimate proportions of freight and non-freight truck movements
- Statistics relating to empty movements in freight trucks
- Better understanding of truck travel patterns and behavior
- Temporal and spatial travel behavior of trucks by industry
- Estimate proportions of long and short haul trips along major and restricted truck corridors
Detector Technologies Behind TAMS

Two Types of Detector Solutions:

- Combination of Weigh-In-Motion (WIM) and Inductive Loop Signature Technology at existing WIM sites
- Standalone inductive signature technology at existing Inductive Loop Detector sites
Weigh-In-Motion Technology

**Components**

- **Bending Plates**
  - Measure Wheel/Axle Weights

- **Inductive Loop Sensors**
  - Presence detection
  - Speed measurement
  - Transform temporal gap in axle measurements into axle spacing

**Image Descriptions**

- Bending Plates
- Inductive Loop Sensors
- Traveled lane on freeway

**Text Descriptions**

- Provides 13 axle-based classifications (14 in California)
- Over 100 Data WIM sites in California located along Major Truck Corridors
- Weigh-In-Motion sensors located along a freeway
Inductive Signature Technology

- Conventional ILDs produce bivalent outputs
  - Generate traffic counts, not truck counts
- Advanced ILDs measure inductance changes → ‘Inductive Signature’
  - Inductive signatures are indicative of body configuration

**Conventional Measurement**

[0,1] Binary output typically sampled at 30 samples/sec

**Inductive Signature**

High resolution inductive magnitude changes at up to 1000 samples/sec
Inductive Vehicle Signature Applications

Real-time Section Travel Time and Speeds

Single Loop Point Speed Estimation

Section-level Density

Section-level Emissions Estimation

Comparison of “True” and Estimated 30-sec Aggregated Average Speeds during PM Peak of 06/08/2009 on NB I-405 @ Sand Canyon (Model Trained from SB I-5 @ Crescent)
Sample FHWA Class 9 (5-Axle Semi-Trailer) signatures by trailer configuration
Data Collection Sites

- **Land use variation:** four sites with differing land use characteristics
- **Comprehensive data:** still image photos, WIM data, and inductive signatures
- **Temporal variation:** multiple times of day, days of week, and seasons included
- 97 hours of data collected, with 35,000 vehicle records (mostly trucks) processed for model development and testing
Two Types of Body Classification Models Developed:

- **Inductive Signature only Model** (for existing ILD sites)
- **Integrated WIM and Inductive Signature Model** (for existing WIM sites)
Body Classification Architecture: Two Systems of Models

**Signature Only Model System**
- **Signature Data**
  - **Tier 1**
    - **Single-Units**
    - **Multi-Units**
      - **Tier 2**
        - **Passenger Vehicle**
        - **Single Unit w/ Trailer**
        - **Multiple Trailers**
          - **Single Unit Truck**
          - **Tractor w/ Semi Trailer**
    - **Tier 3**
      - **13 Classes**
      - **19 Classes**

**WIM and Signature Model System**
- **Paired WIM and Signature Data**
  - **FHWA Class 4**
  - **FHWA Class 5 - 13**
  - **FHWA Class 14**
    - **Tier 2**
      - **Trailer Detection***
    - **Tier 3**
      - **4 classes**
      - **10 to 16 classes**
      - **5 classes**
Signature Only Model Results

- Body class model results summary
  - 4 categories incorporating 47 truck body classes
  - 34 classes with classification accuracy > 70%
  - 27 classes with volume error < 10%

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<th>Sub-Model</th>
<th>Classes</th>
<th>Accuracy (%)</th>
<th>Volume Error (%)</th>
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<td>Single Unit Trucks</td>
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<td>Single Unit w/ Trailers</td>
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<td>Multiple Semi-Trailers</td>
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<td>90.4</td>
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Signature Only Model Results

Overall 74.3% Correct Classification Rate
19 body classes

Vans with 5 or more axles: 83%
Reefer Vans with 5 or more axles: 75%
Vans with less than 5 axles: 74%
Reefer Vans with less than 5 axles: 46%

53ft Container: 57%
40ft Container: 78%
40ft Container Reefer: 82%
20ft Container: 61%
Platform: 78%
Tank: 71%
Open Top Van: 61%
Auto: 78%
Low Boy Platform: 82%
Drop Frame Van: 61%
Dump: 70%
Logging: 80%
Livestock: 80%
Agriculture: 59%
Beverage: 83%

Correct Classification Rate
Integrated (WIM + Signature) Model Results

- System of 9 sub-models with 63 body classes
- 52 classes with classification accuracy > 70%
- 37 classes with volume error < 10%

<table>
<thead>
<tr>
<th>Model</th>
<th>Classes</th>
<th>Accuracy (%)</th>
<th>Volume Error (%)</th>
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<td>1.7</td>
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<td>FHWA 11 and 12</td>
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Integrated (WIM + Signature) Model Results

Overall 76% Correct Classification Rate
16 body classes
Hardware Components

Advanced Detector Cards
(Acquire Inductive Signature Data)

Fan-less Field Processing Unit
(Data Processing)

Wireless Modem
(Communications to Server)
Types of Site Deployments

- **WIM-Signature Integration**
  - WIM Site on SR-99 between Stockton and Sacramento

- **Inductive Signature Only**
  - Ramp Metering ILD Site on SR-91 in LA
  - Traffic Monitoring Site on CA-4 near Stockton
  - Census AVC Site on I-15 in Escondido
Data Flow Architecture Overview

Weigh-In-Motion Site

- WIM Controller
- Signature Detector Cards
- WIM Processing
- Signature Processing
- Field Unit

Inductive Loop Detector Site

- WIM Controller
- Signature Detector Cards
- WIM Processing
- Signature Processing
- Field Unit

UCI ITS

- REDIS Middleware
  - Channel 1
  - Channel 2
  - Channel 3
  - Channel n

- Database Bridge
  - PostgreSQL Database
1. Live Signature Transmission
2. Walk Through TAMS Web Interface
Collateral Benefits

- **Policy Evaluation**
  - i.e. PierPass: Monitoring truck port activities

- **Enforcement**
  - Monitor truck lane violations
  - Monitor unauthorized travel along restricted routes

- **Impact Assessment of Non-recurrent Events**
  - Determine the impacts of port strikes, freeway closures, etc.

- **Understand Industry Impacts on Traffic, Infrastructure and Emissions**
  - Ability to analyze temporal and seasonal variations of truck activity by industry

- **Anonymous Truck Tracking**
  - Towards improved truck VMT estimates
QUESTIONS

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Case Study I: SR-205 @ Tracy Corridor Analysis

- Located between Port of Oakland and Lathrop rail facility
- Dominated by Enclosed Vans (Typical on most major truck routes)
  - Significant volume extends into the night
- Significant volume of 40-foot Intermodal Containers (~250/day)
  - Peak volume during the day
- Low volume of 53-foot domestic Intermodal Containers (~75/day)
Case Study I: I-5 @ Stockton Corridor Analysis

- Located north of Stockton
- Dominated by Enclosed Vans (3,000 – 4,000 / day)
  - Significant volume extends into the night
- Insignificant volume of 40-foot Intermodal Containers (<100 / day)
  - Peak volume during the day
- Significant volume of domestic 53-foot Intermodal Containers (~ 350/day)