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

ARB Research Seminar
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Two Systems 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
  - Single-Units
    - Passenger Vehicle
    - Single Unit w/ Trailer
    - Single Unit Truck
  - Multi-Units
    - Multiple Trailers
    - Tractor w/ Semi Trailer

WIM and Signature Model System
- Paired WIM and Signature Data
  - FHWA Class 4
  - FHWA Class 5 - 13
  - FHWA Class 14

Tier 1
- Single-Units
- Multi-Units

Tier 2
- Single Unit w/ Trailer
- Tractor w/ Semi Trailer
- Single Unit Truck
- Multiple Trailers
- Passenger Vehicle

Tier 3
- 8 Classes
- 7 Classes
- 13 Classes
- 19 Classes
- 4 classes
- 10 to 16 classes
- 5 classes

*Trailer Detection
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%

<table>
<thead>
<tr>
<th>Sub-Model</th>
<th>Classes</th>
<th>Accuracy (%)</th>
<th>Volume Error (%)</th>
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<tbody>
<tr>
<td>Passenger Vehicles</td>
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<tr>
<td>Single Unit Trucks</td>
<td>13</td>
<td>72.3</td>
<td>15.4</td>
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<td>Single Unit Trucks w/ Trailer</td>
<td>8</td>
<td>94.2</td>
<td>8.2</td>
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<tr>
<td>Tractors with Semi-Trailer</td>
<td>19</td>
<td>74.3</td>
<td>11.3</td>
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<td>Tractors with Multiple Trailers</td>
<td>7</td>
<td>90.4</td>
<td>7.0</td>
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</tbody>
</table>
Signature Only Model Results (for Semi-Tractor Trailers)

Overall 74.3% Correct Classification Rate across 19 body classes
### 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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<tbody>
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<tr>
<td>FHWA 9 Semi Tractors</td>
<td>16</td>
<td>75.4</td>
<td>12.2</td>
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<td>FHWA 9 Single Trailers</td>
<td>5</td>
<td>96.7</td>
<td>1.7</td>
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<td>FHWA 11 and 12</td>
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</table>
Integrated (WIM + Signature) Model Results

Overall 76% Correct Classification Rate
16 body classes

FHWA Class 9

Correct Classification Rate (CCR)
Hardware Components

Advanced Detector Cards
(Acquire Inductive Signature Data)

Fanless Field Computer
(On Site 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
LIVE DEMO

1. Live Signature Transmission
2. Walk Through TAMS Web Interface
Some 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 impacts by industry

- **Improved Truck VMT Estimates**
  - Through integration with anonymous signature-based truck tracking and/or survey studies
Just Getting Started: *A platform for future research and applications*

- Raw signature data is being continuously archived
- Case in point: Activity inventory of cleaner trucks
  - Recognize trucks by model year to obtain activity trends of clean vs older gross-polluting trucks?
A Work in Progress:  
*Improvements are ongoing...*

- Increase robustness of field deployments
- Improve classification accuracy of trucks
- Implement classification models for state and federal agency reporting requirements
QUESTIONS

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Model Development
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

Data collection setup at Fresno WIM site
Where it all began...

Investigation of Blade Inductive Sensors

- 1\textsuperscript{st} vehicle classification study to focus primarily on distinguishing detailed truck configurations
- Utilized a temporary surface mount sensor
- Model capable of identifying over 100 truck configurations
Background

Pilot study funded by CARB 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 (CSFFM)
- Enhancement of truck classification models
- Expand deployment to over 90 locations along major truck corridors across 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 Representative**
  - 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 Inductive Loop Signature technology (combined with Weigh-In-Motion technology where available)

- **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:

**Combined**
Weigh-In-Motion (WIM) and Inductive 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

Bending Plates

Inductive Loop Sensors

Traveled lane on freeway

Provides 13 axle-based FHWA classifications (14 in California)

Weigh-In-Motion sensors located along a freeway

Over 100 Data WIM sites in California located along Major Truck Corridors

Provide speed, vehicle length and axle spacing measurements
Inductive Signature Technology

Conventional Inductive Loop Detectors (ILDs) produce bivalent outputs
- Generate traffic counts, not truck counts

Advanced ILDs measure inductance changes → ‘Inductive Signature’
- Inductive signatures are indicative of body configuration
Sample FHWA Class 9 (5-Axle Semi-Trailer) signatures by trailer configuration
Inductive Vehicle Signature Applications

Real-time Section Travel Time and Speeds

Single Loop Point Speed Estimation

Section-level Density

Section-level Emissions Estimation
Existing Truck Activity Data Sources

Mobile
- GPS
- Cellphone

Static / Count Data
- Weigh-In-Motion
- Automatic Vehicle Classifier (AVC) System

Surveys
- 2002 National Vehicle Inventory and Use Survey (VIUS)
- 2016 California VIUS
- Regional Intercept Surveys
Research Objective

Develop *and deploy* cutting-edge classification models that

- leverage **existing detector infrastructure**
- to provide truck count data by **detailed configuration**
- using **advanced inductive signature technology**