



**Berkeley
Transportation
Systems, Inc.**

Integration of WIM Data into an Archived Data User Service

Integration Examples

**North American Travel Monitoring Exposition and Conference
Seattle Sheraton Hotel, Seattle, WA
June 23, 2010**

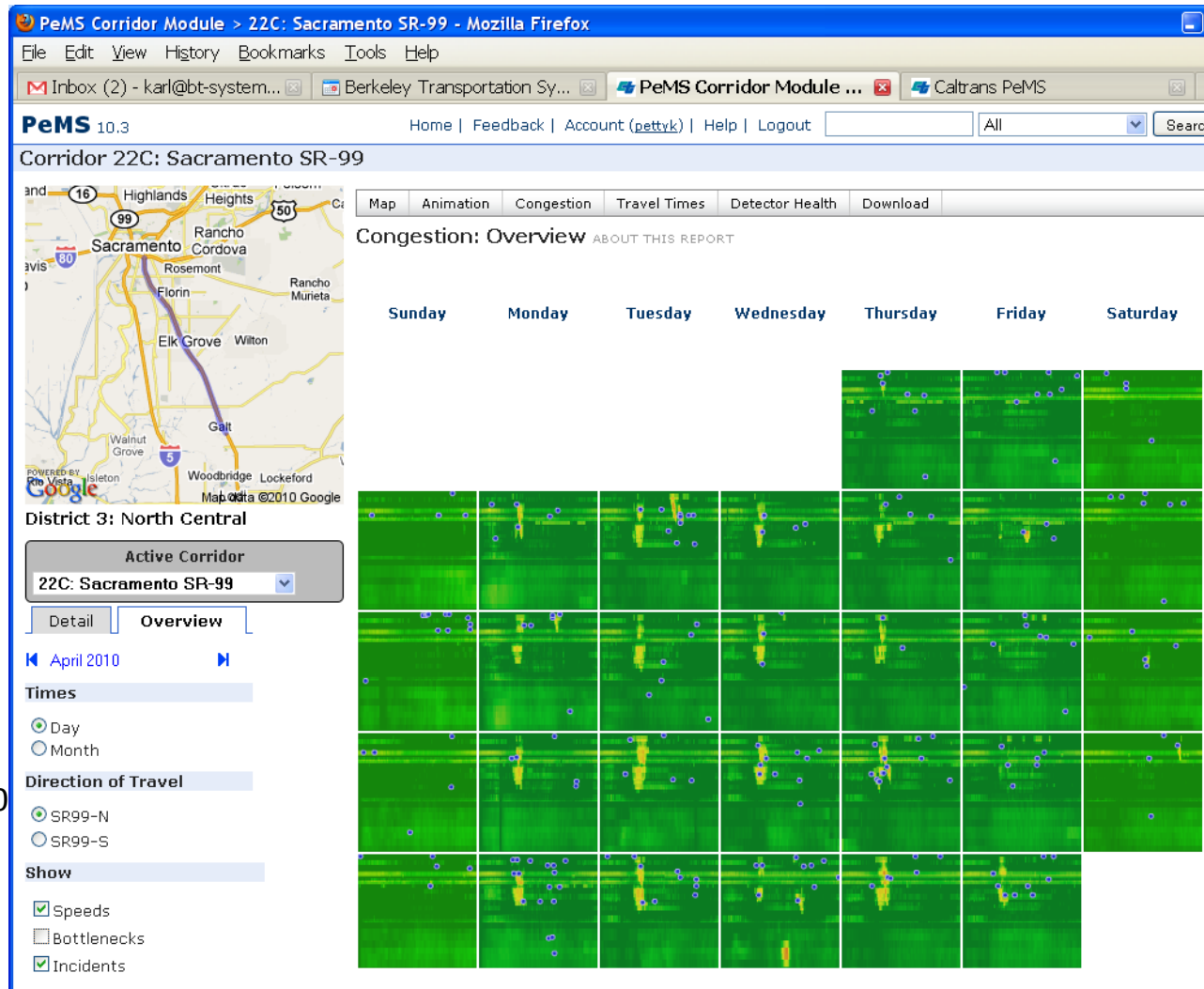
Dr. Karl Petty, David Parsons, Tiffany Barkley, Bill Morris
Berkeley Transportation Systems, Inc.

Overview

- Weight-in-Motion data is a rich, valuable source of traffic information
- Historically the ADMS's have been driven by ITS sensors from freeway operations
- There are a number of uses of this data and incorporation into an ADMS would be beneficial to a DOT
- Talk agenda:
 - California Freeway Performance Measurement System (PeMS)
 - Integrating WIM Data into PeMS
 - Using WIM Data in PeMS
 - WIM Reports and Visualizations
 - Application to MEPDG
 - Next Steps

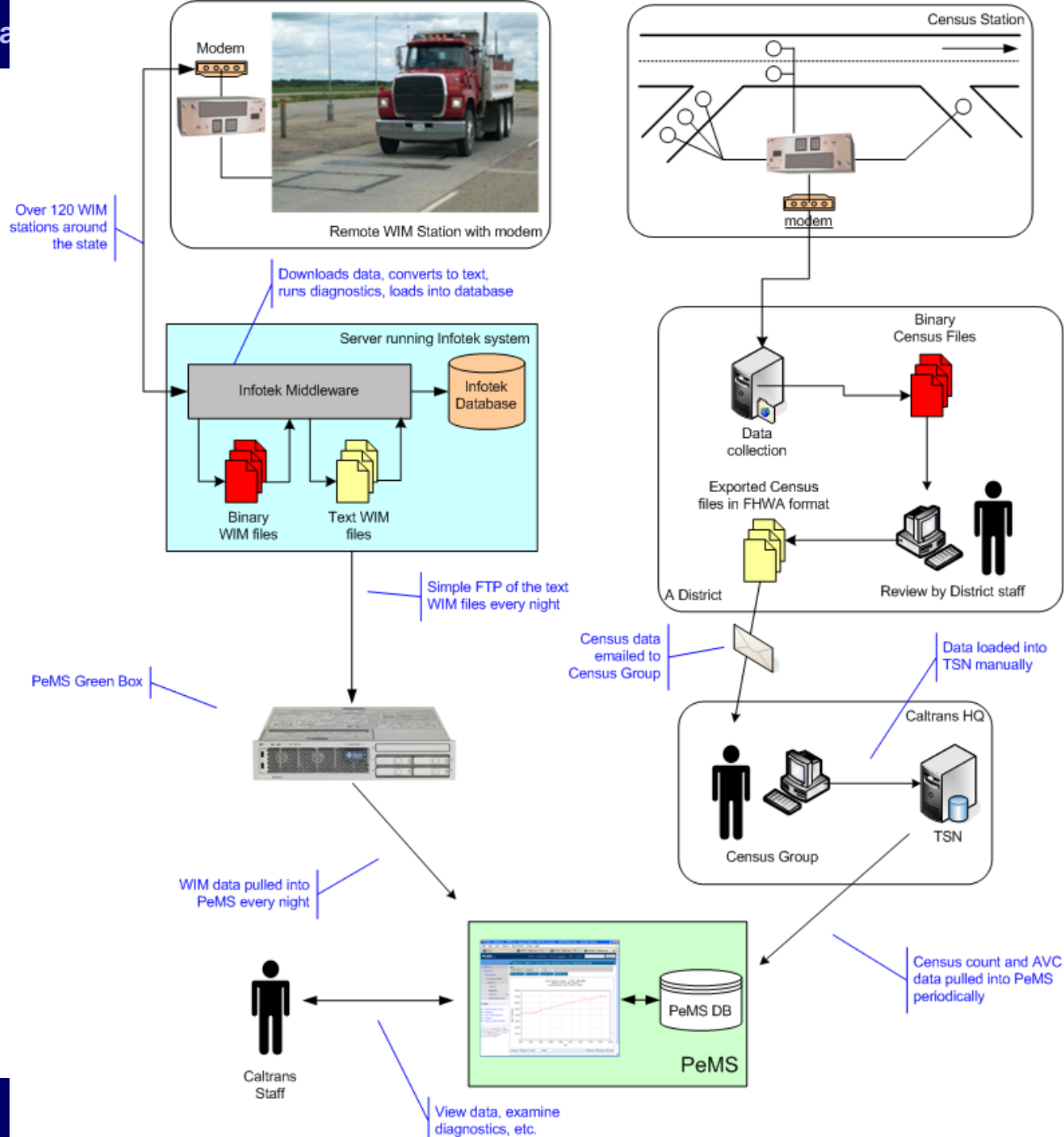
What is PeMS?

- Real-time Archive Data Management System (rt-ADMS)
- PeMS collects many types of detailed, raw data in real-time and in batch mode – primarily freeway operations data
- It processes the data in real-time:
 - Diagnostics
 - Imputation for missing values
 - Aggregations
 - Fusing of different sources
- Computes many performance measures (travel time, delay, etc).
- Large # of tools to plot, chart, etc.
- Stores raw data forever
- Caltrans deployment:
 - Has 32,000 sensors reporting every 30 seconds
 - Over 19,000 census stations
 - Started in 1999, ~12TB of data



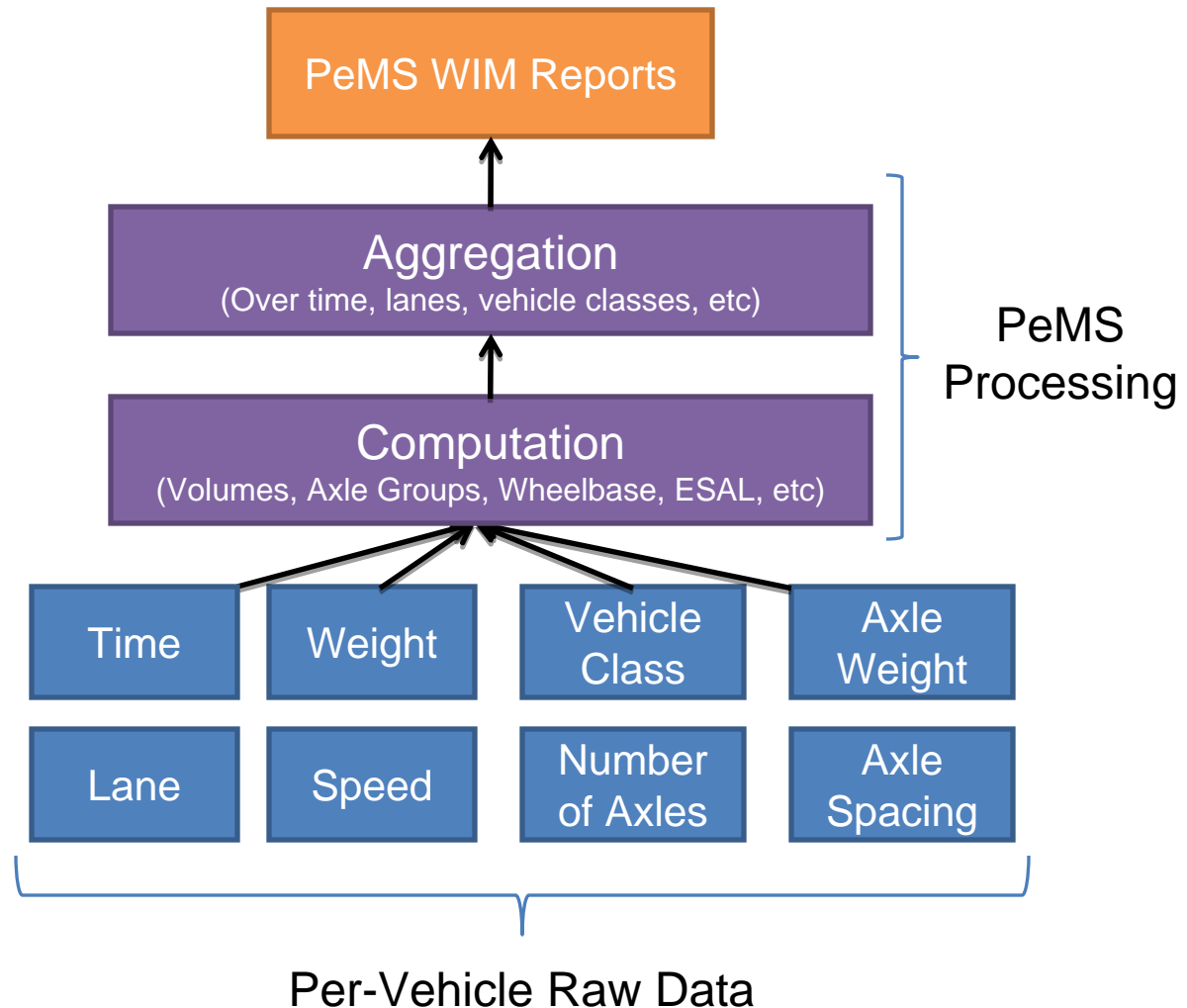
Data Flows

- The WIM data flows through the Infotek system automatically
- WIM data is pulled from all the stations every night
- Receiving data from 184 stations
- Started in Spring of 2008
- PeMS paradigm: store raw data in database forever



Integrating WIM data into PeMS

- Format is compatible with FHWA's Traffic Monitoring Guide (TMG)
- PeMS stores raw records as well as aggregates
- Raw data is processed to compute individual vehicle measures
- These are then aggregated up over time
- Stored at the per-station level
- Various reports on built on top of this



WIM Data in PeMS

- Table shows the number of WIM stations
- Grouped by District
 - 12 Districts in Caltrans
- Total of 184 individual stations
- Users can drill in here to the region that they want
- Or they can jump to the map...

Caltrans PeMS > State of California > Facilities & Devices > Field Elements > Summary - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Inbox (2) - karl@bt-sy... Berkeley Transportatio... PeMS Corridor Module ... Caltrans PeMS > St...

PeMS 10.3 Home | Feedback | Account (pettyk) | Help | Logout All Search

State of California

Overview Facilities & Devices Performance Data Quality Events Tools

Facilities & Devices > Field Elements > Summary ABOUT THIS REPORT

Group By: District Element Type: Truck Weights Hide Empty Rows

Traffic Counters - Truck Weights

District	Census Stations	Substations						Total
		Mainline	HOV	On Ramp	Off Ramp	Fwy-Fwy	Coll/Dist	
01 - Northwest	3	6	0	0	0	0	0	6
02 - Northeast	6	12	0	0	0	0	0	12
03 - North Central	11	22	0	0	0	0	0	22
04 - Bay Area	13	26	0	0	0	0	0	26
05 - Central Coast	4	8	0	0	0	0	0	8
06 - South Central	6	12	0	0	0	0	0	12
07 - LA/Ventura	10	20	0	0	0	0	0	20
08 - San Bernardino/Riverside	15	30	0	0	0	0	0	30
09 - Eastern Sierra	1	2	0	0	0	0	0	2
10 - Central	9	18	0	0	0	0	0	18
11 - San Diego/Imperial	10	20	0	0	0	0	0	20
12 - Orange County	4	8	0	0	0	0	0	8
Totals	92	184	0	0	0	0	0	184

Related Field Elements Reports: Summary • Controllers • Stations • Census Stations • Config Timeseries

State Attributes

Freeway Miles (directional)	30,571
Controllers	5,778
Stations	12,351
Detectors	31,983

Quick Links

Jump to a district:

Access reports related to a district in the state.

Map data ©2010 Europa Technologies, Google, Mapbox

WIM Data in PeMS: Maps

- Users search for WIM stations on a map and jump to truck weight reports
- Inventory Widget shows months and years for which a station has truck weight data
 - Stations don't always report continuously like ITS stations
 - Finding data in time is important

The screenshot displays the Caltrans PeMS web application interface. On the left, a sidebar contains navigation and filter options:

- PeMS 10.3** (Home | Feedback |)
- Real-Time | Performance | **Inventory** | Search | Jump to District...
- ITS Stations**
 - Mainline
 - HOV
 - Ramps
 - Other
- Count Locations**

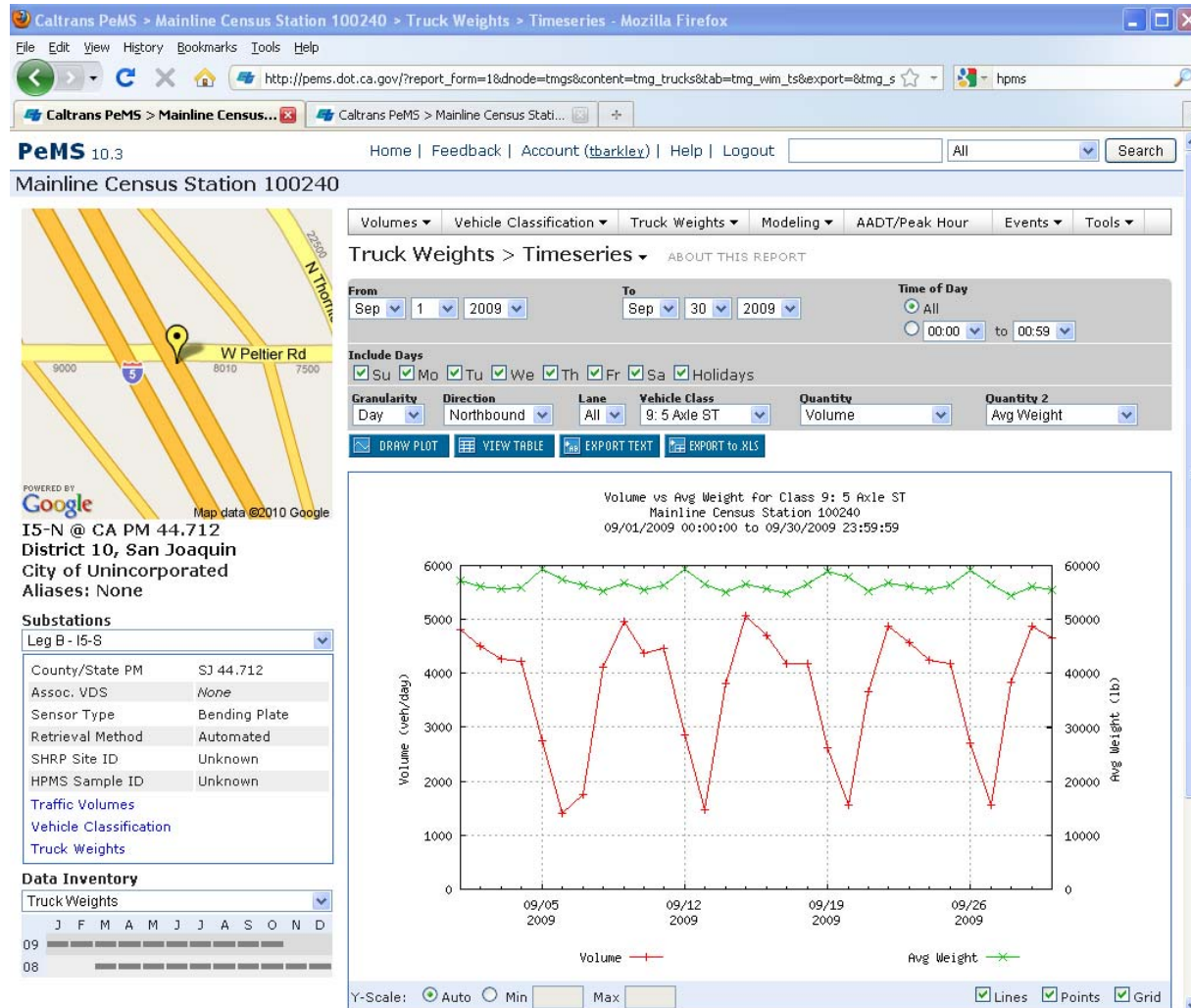
Station Type	Reported Data
<input checked="" type="checkbox"/> Mainline	<input type="checkbox"/> Traffic Volumes
<input type="checkbox"/> Ramps	<input type="checkbox"/> Vehicle Classification
<input type="checkbox"/> Other	<input checked="" type="checkbox"/> Truck Weights
- Other**
 - LDSs
 - 511 ETC Readers (D4)
- Arterials**
 - Intersections
 - Detectors
- Roadway**
 - Corridors
 - Managed Facilities
- Link Status:
 - / Open
 - / Construction
 - / Proposed

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The map on the right shows a location near Lancaster, CA, with a blue arrow pointing to a specific station. A pop-up window for 'Mainline Census Station 128080 - E/O IMPERIAL HIGHWAY; RTE 90' is open, displaying a 'Truck Weights' report for the month of August 2008. The report shows a bar chart with a value of 09.

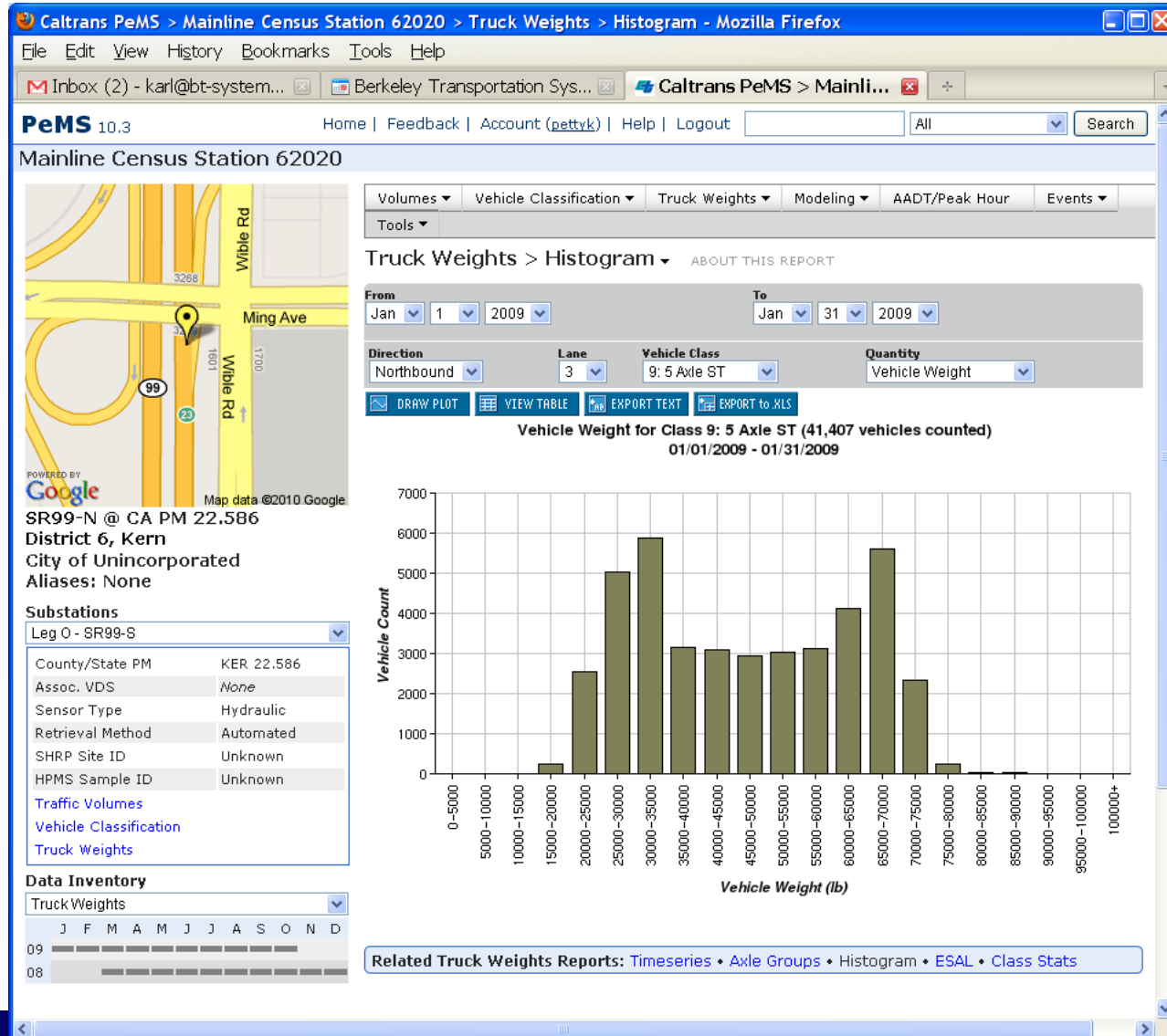
WIM Reports: Timeseries

- Here, we are plotting:
 - Daily Volumes and Average Weight
 - Class 9 (5 Axle ST) only
 - All Lanes
 - I-5 S South of Stockton
- Peak volumes on Tuesdays and peak weights on Saturdays
- Can also plot monthly volumes to view seasonal variations in truck traffic measures
- Plots average: volumes, speeds, weights, lengths, wheelbases over time.



WIM Reports: Histogram

- Plots the distribution of length and width quantities by vehicle class.
- Here, we are plotting the distribution of vehicle weights for Class 9 vehicles in the right-lane (lane 3)
- Can also plot single axle, tandem axle, etc, weights
- Application: Axle Group load distribution required for Load Spectra analysis



WIM Reports: Axle Groups

- Tabular view of axle group information by vehicle class
 - Axle Groups/Vehicle
 - Axle Group Count
 - Weight/Axle Group
 - Average Axle Spacing

- PeMS assigns axle groups from inter-axle spacing information in the raw WIM data

- Here, we are viewing Average Weight per Axle Group in the right-most lane of WB I-210 east of Pasadena

PeMS 10.3 Home | Feedback | Account (tbarkley) | Help | Logout

Mainline Census Station 79050

W Baseline Rd 606
I-210 Fwy
Foothill

I210-E @ CA PM R41.594
District 7, Los Angeles
City of Azusa
Aliases: None

Substations
Leg A - I210-W

County/State PM	LA R41.594
Assoc. VDS	717688
Sensor Type	Hydraulic
Retrieval Method	Automated
SHRP Site ID	Unknown
HPMS Sample ID	Unknown

[Traffic Volumes](#)
[Vehicle Classification](#)
[Truck Weights](#)

From: Feb 1 2009 To: Feb 28 2009
Time of Day: All (00:00 to 00:59)
Include Days: Su, Mo, Tu, We, Th, Fr, Sa, Holidays
Direction: Eastbound Lane: 5 Quantity: Weight/Axle Group

VIEW TABLE EXPORT TEXT EXPORT to XLS

Vehicle Class	Weight/Axle Group				Vehicle Count
	Single	Tandem	Tridem	Quad	
2: Cars	3,219.33	0.00	0.00	0.00	696
3: 2 Axle, 4T SU	3,241.69	2,811.00	2,902.67	0.00	5,783
4: Bus	11,160.80	22,704.15	0.00	0.00	1,726
5: 2 Axle, 6T SU	6,930.88	6,747.85	0.00	0.00	19,246
6: 3 Axle SU	9,658.79	15,814.30	23,810.00	0.00	4,924
7: 4+ Axle SU	13,237.81	28,586.49	37,357.70	0.00	268
8: < 4 Axle ST	8,614.82	12,741.01	0.00	0.00	4,710
9: 5 Axle ST	9,217.13	19,449.74	18,960.00	0.00	58,586
10: 6+ Axle ST	9,809.32	23,445.97	25,297.35	0.00	266
11: < 5 Axle MT	8,067.02	0.00	0.00	0.00	6,434
12: 6 Axle MT	8,098.36	14,646.23	0.00	0.00	1,403
13: 7+ Axle MT	11,032.14	31,650.37	29,069.29	18,592.00	126
14: User-Def	8,467.02	19,103.39	0.00	0.00	1,462
15: Unknown	6,064.73	17,640.26	13,249.51	22,691.26	1,597
All Vehicles	8,001.28	19,145.59	18,502.01	22,281.33	107,227

Quantity: Avg Axle Spacing, **Axle Groups/Vehicle**, Axle Group Count, Weight/Axle Group, Avg Axle Spacing

Related Truck Weights Reports: Timeseries • Axle Groups • Histogram • ESAL • Class Stats

WIM Reports: ESAL

- Based on formulas in the 1993 AASHTO design guide
- Table shows:
 - Flexible and Rigid pavement
 - LEF: Load Equivalency Factors
 - ESAL: cumulative Equivalent Single Axle Load
 - Uses common parameters
- LEF=ratio of the damage per pass of a particular axle group to that of a single axle group with an 18,000 lb load
- ESAL=sum of LEFS over all vehicles in a given time period
- Application: Supports the most common analysis approach of estimating pavement damage with ESALs

Caltrans PeMS > Mainline Census Station 103490 > Truck Weights > ESAL - Mozilla Firefox

http://pems.dot.ca.gov/?report_form=1&node=tmgs&content=tmg_trucks&tab=tmg_wim_esal&export=&t

Caltrans PeMS > Mainline Census Station 103490

PeMS 10.3 Home | Feedback | Account (tbarkley) | Help | Logout

Mainline Census Station 103490

Volumes Vehicle Classification Truck Weights Modeling AADT/Peak Hour Events Tools

Truck Weights > ESAL ABOUT THIS REPORT

From: Nov 1 2008 To: Nov 30 2008 Time of Day: All

Include Days: Su Mo Tu We Th Fr Sa Holidays

Direction: Northbound Lane: 3

VIEW TABLE EXPORT TEXT EXPORT TO XLS

Vehicle Class	Flex LEF		Flex ESAL		Rigid LEF		Rigid ESAL		Count
	pt=3.0 sn=6.0	pt=2.85 sn=4.75	pt=3.0 sn=6.0	pt=2.85 sn=4.75	pt=3.0	pt=2.85	pt=3.0	pt=2.85	
2: Cars	0.00	0.00	4	5	0.00	0.00	4	4	1,460
3: 2 Axle, 4T SU	0.00	0.00	23	29	0.00	0.00	24	24	7,773
4: Bus	0.62	0.64	241	250	0.69	0.69	268	268	391
5: 2 Axle, 6T SU	0.14	0.15	2,389	2,550	0.14	0.14	2,367	2,367	16,516
6: 3 Axle SU	0.21	0.23	812	902	0.29	0.29	1,144	1,144	3,930
7: 4+ Axle SU	1.35	1.42	138	145	1.78	1.78	182	182	102
8: < 4 Axle ST	0.29	0.32	1,608	1,769	0.31	0.31	1,697	1,697	5,539
9: 5 Axle ST	0.63	0.69	45,889	50,249	1.01	1.01	72,949	72,954	72,393
10: 6+ Axle ST	0.39	0.44	110	124	0.71	0.71	199	199	281
11: < 5 Axle MT	0.96	1.02	8,974	9,567	0.92	0.92	8,646	8,644	9,382
12: 6 Axle MT	0.52	0.58	597	670	0.54	0.54	629	628	1,159
13: 7+ Axle MT	1.15	1.13	35	34	2.33	2.35	70	71	30
14: User-Def	0.35	0.38	836	904	0.44	0.44	1,028	1,027	2,356
15: Unknown	0.27	0.28	257	271	0.40	0.40	381	382	954
All Vehicles	0.51	0.55	61,913	67,467	0.73	0.73	89,588	89,590	122,266

Related Truck Weights Reports: Timeseries • Axle Groups • Histogram • ESAL • Class Stats

Substations: Leg 0 - SR99-S

County/State PM: STA 8.693
 Assoc. VDS: None
 Sensor Type: Hydraulic
 Retrieval Method: Automated
 SHRP Site ID: Unknown
 HPMS Sample ID: Unknown
 Traffic Volumes
 Vehicle Classification
 Truck Weights

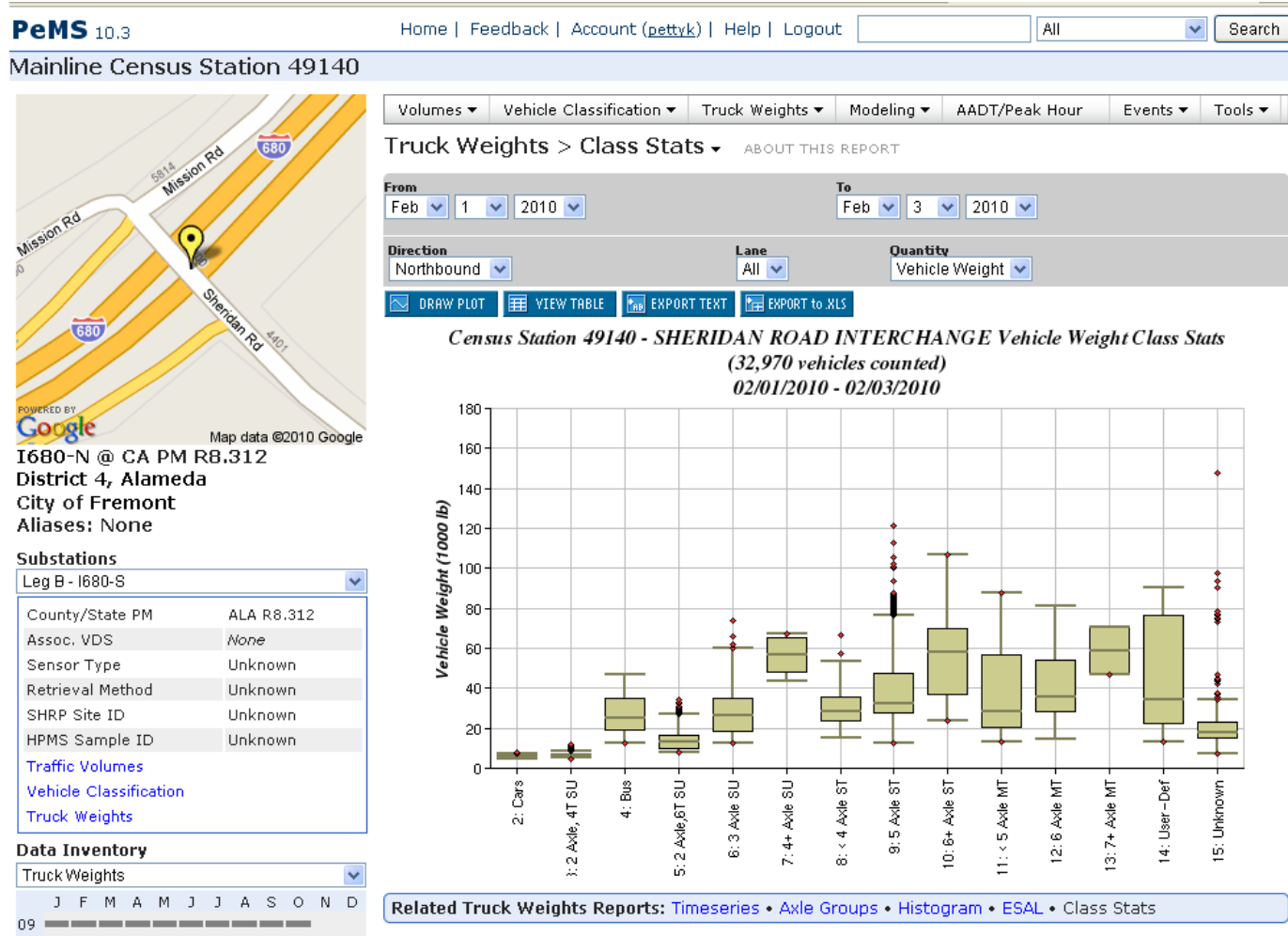
Data Inventory: Truck Weights

J F M A M J J A S O N D

09

WIM Reports: Class Stats

- Class Stats Reports compare the distributions of quantities across all vehicle classes.
- Here, we are plotting vehicle weight distributions by class in Fremont, CA.
- Boxes extend from 25th percentile value to the 75th percentile value
- Whiskers: min and max point within 1.5 * IQR
- Outliers are little dots
- Can plot:
 - Vehicle Length
 - Vehicle Weight
 - Speed
 - Axle Count
 - Total Vehicles



Application: Supply data for MEPDG

- ADMS reports can support MEPDG software data needs
- Mechanistic-Empirical Pavement Design Guide (MEPDG) is the new recommended standard for pavement analysis.
 - Considers load spectra instead of ESALS
 - Reflects improved ability to characterize traffic
- Implication: More intensive data inputs required from designers
- ADMS can assist with this

MEPDG Input	ADMS Support
Average Annual Daily Truck Traffic (AADTT)	Sum of Monthly Timeseries volumes for all truck classes
Annual Truck Distribution Spectra	Sum of Monthly Timeseries volumes within each vehicle class
Monthly Distribution Factors	Monthly Timeseries volumes for all truck classes
Time of Day Distribution Factors	Hourly Timeseries volumes for all truck classes
Axle Load Spectra	Histogram of Weight by Axle Group

Application: WIM data in delay cost calculations

- Lane closure requests require estimation of delay due to late pickup
- Historically spreadsheet driven (a few different formats)

Calculated by: Rhodel DeClaro		Date: Mar 7, 2009				
Dir	County	Route	Prefix	Postmile	Closure Type	Project Operation
EB	SJ	088		14.000	Multi-Lane Closure	Pavement Rehabilitation
Location Description		Chart No.	Count Date	Remarks		
In lone-Martell Cut-off to Begin Passir		1	05/25/06	None		

VOLUME FACTOR TABLE		COST FACTOR TABLE		THROUGHPUT CAPACITY TABLE	
Diversion: 0%		Cost per Truck: \$24/veh-hr		Existing Number of Lanes: 2	
Truck Volume Percent: 6.50%		Cost per Passenger Car: \$9/veh-hr		Number of Lanes Opened: 1	
Passenger Car Percent: 94.5%		Cost for Mixed Traffic: \$10/veh-hr		1-Lane Capacity: 600 veh/hr	
Equivalent Passenger Car per Truck: 15					

Day - Time	Demand (veh/hr)	Adjusted Demand (veh/hr)	Cumulative Demand (veh)	Cumulative Capacity (veh)	Queue Backup (veh)	Queue Length (mile)	Total Delay (veh-hr)	Individual Delay (minutes)
Thu 5:00 AM								
Thu 6:00 AM	982	1009	1009	600	409	0.97	205	41
Thu 7:00 AM	1359	1396	2405	1200	1205	2.85	807	121

DELAY & COST SUMMARY TABLE		
Total Delay:	(205 + 807) veh-hr =	1,012 veh-hr
Total Delay Cost:	(1012 veh-hr) x (\$9.83/veh-hr) =	\$9,940
Delay Cost Per Hour:	(\$9940) / (2 hr) =	\$4,970

DAMAGE = none, does not exceed \$6000/hr requirement

EA : 11- xxxxxx

Direction/RTE/PM: NB/SD-5/R58.76/R60.96

Operation: Multilane Closure

Percent Truck:	2.6%	Cost per Truck:	\$28/Yeh-Hr
Percent Passenger Cars:	97.4%	Cost per Passenger Car:	\$12/Yeh-Hr
Number of Lanes Existing:	3 Lanes	Cost for Mixed Flow Traffic:	\$12/Yeh-Hr
Number of Lanes Open:	1 Lanes	Single-Lane Capacity:	1500 Yeh/Hr
		Open-Lane Capacity:	1500 Yeh/Hr

Time	Demand (Yeh)	Cumulative Demand (Yeh)	Cumulative Capacity (Yeh)	Difference (Yeh)	Area (Yeh-Hr)	Queue Length (mile)	Indiv. Delay (minutes)
4-5 AM							
5-6 AM	3010	3010	1500	1510	755	2.4	60
6-7 AM	5089	8099	3000	5099	3304.5	8.0	204

Max. Individual Delay:	204 minutes
Vehicle Delay Hours:	4,060 veh-hr
Total Cost of Delay:	\$48,447
Delay Cost/10min:	\$4,037

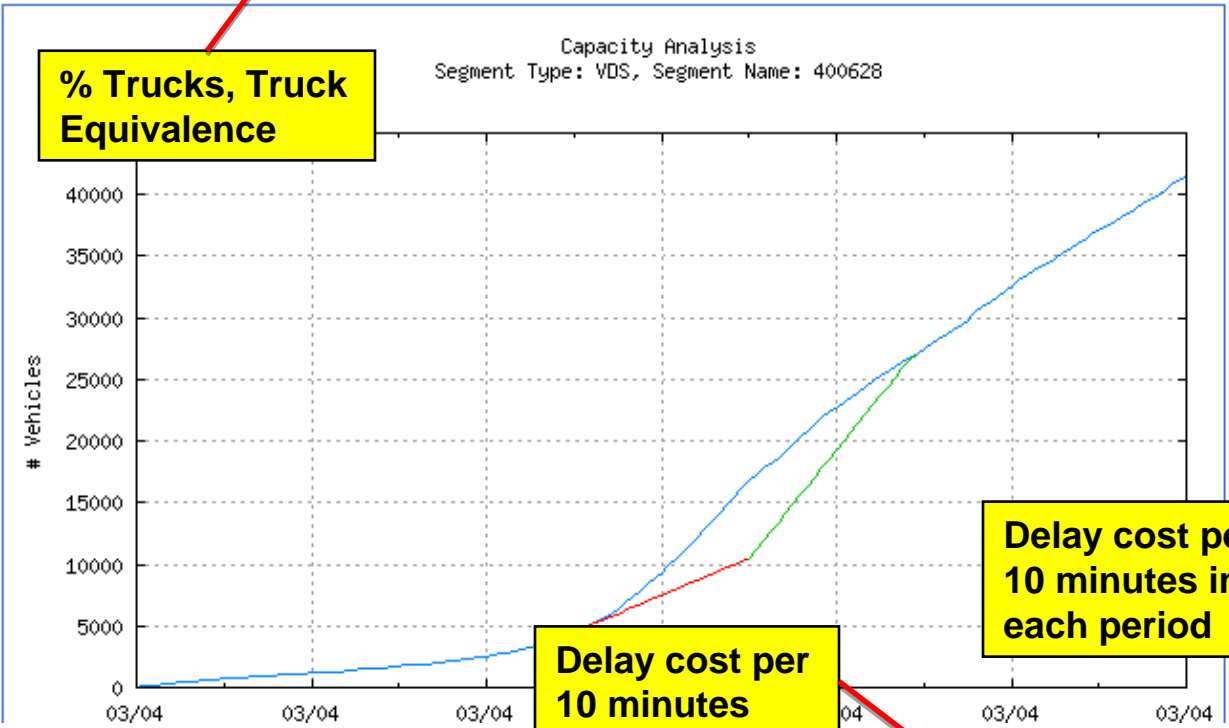
1st Half Hour	2nd Half Hour	2nd Hour
\$2,019	\$3,028	\$4,037

WIM & Delay

- PeMS automates the development of these charts
- Leverages data from an ITS station for input flow
- Typically needed to estimate the truck % (or look it up in a table)
- Can use WIM data from adjacent stations directly

Incident Start Time: Mar 4 2009 0 12 Hours
 Incident Duration: 2 Hours
 # New Lanes: 2 Incident Capacity (per lane): 1500 Discharge Capacity (per lane): 2200
 Diversion %: 0 Truck %: 5 Truck Equivalence: 1.5 x
 Car Cost: 9 \$/(veh*hr) Truck Cost: 24 \$/(veh*hr)

Truck and Car costs



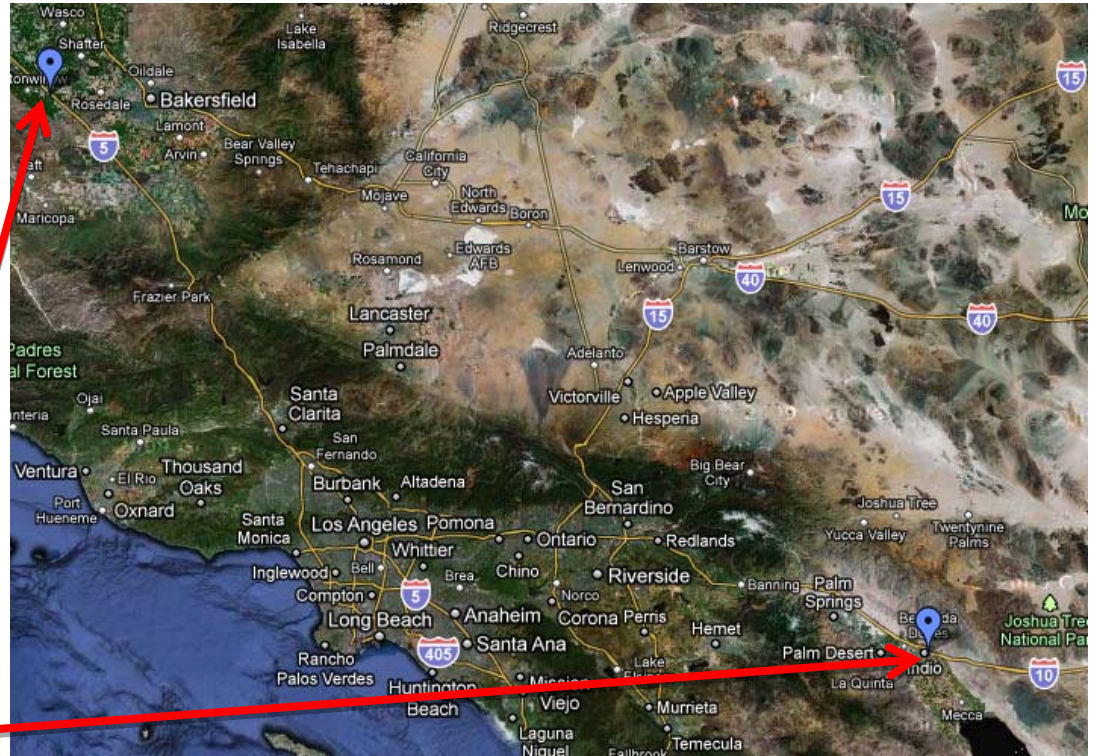
2 Hour Delay, Average Cost, 2 Hour delay cost

Cost Computation

2 hr Delay (Veh*Hr)	Avg. Delay Cost (\$/Veh)	Total Delay Cost (\$)	D (\$/10 min)
4,286.3	9.00	38,576.40	3,214.70
Reopen Delay		Cost per 10 minutes (\$)	
<30 min			1,607.35
30-60 min			2,411.02
>60 min			3,214.70

Application: Regional differences in truck weights

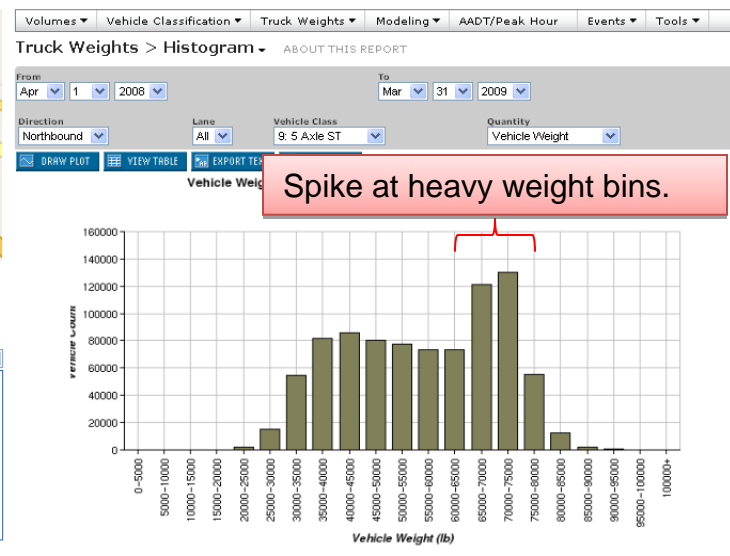
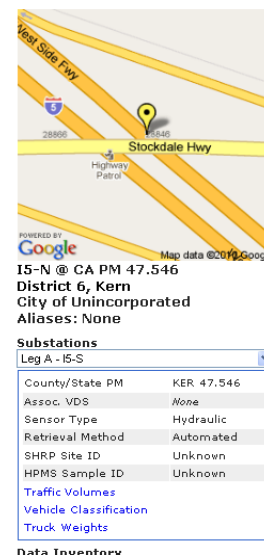
- **Example:** Are trucks heavier leaving Los Angeles to the north or to the east?
- Using PeMS plots of WIM data, we can compare load spectras by vehicle class across the state.
- We can use WIM data from these station on I-5N north of LA and I-10E east of LA to answer this question



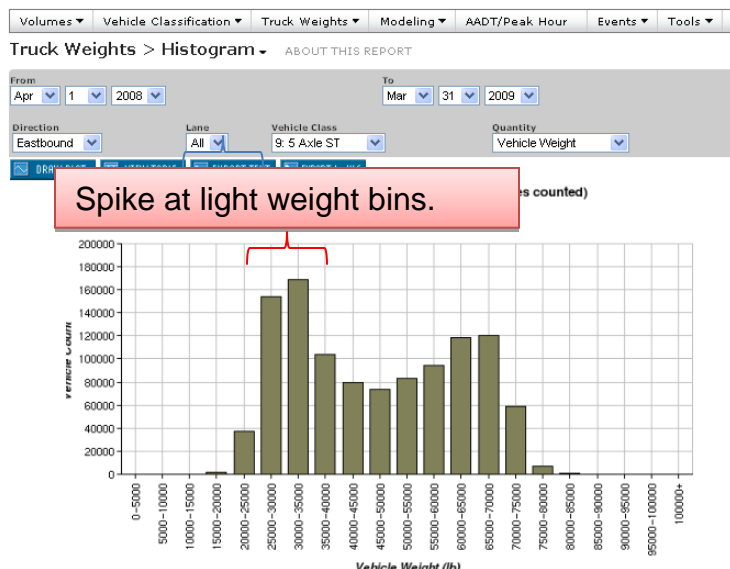
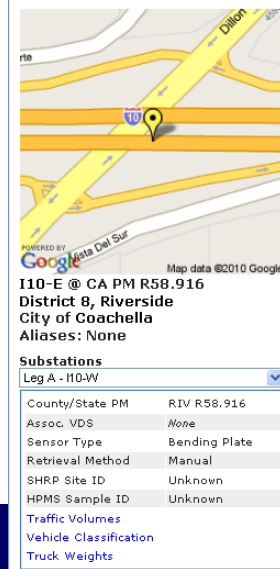
Application: Regional Differences in truck weights

- Plot vehicle weights for Class 9 over an entire year
 - April 2008 – Mar 2009
- Top plot shows I5-North, bottom plot shows I10-East.
- Vehicle weights look higher north of LA.
- Can export to .XLS for further analysis

Mainline Census Station 62010

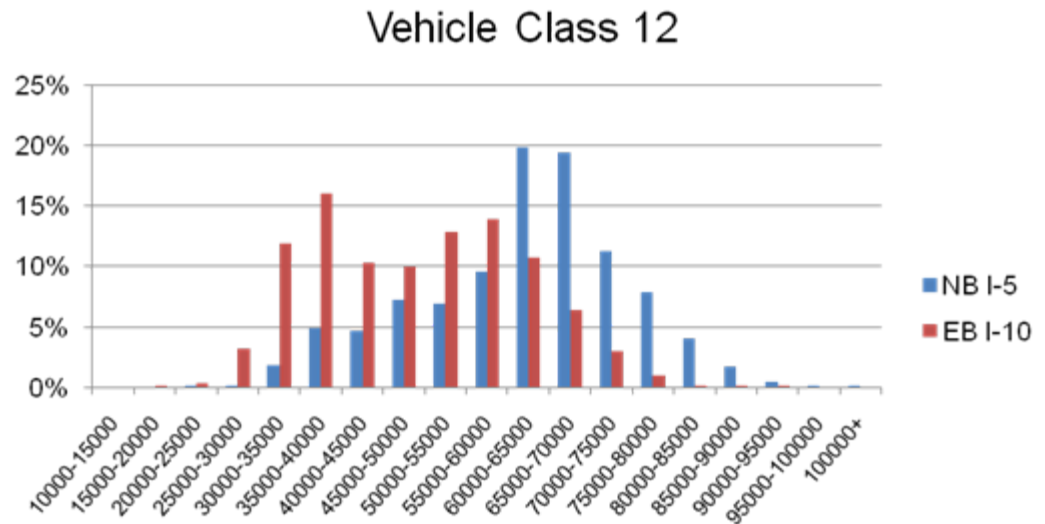
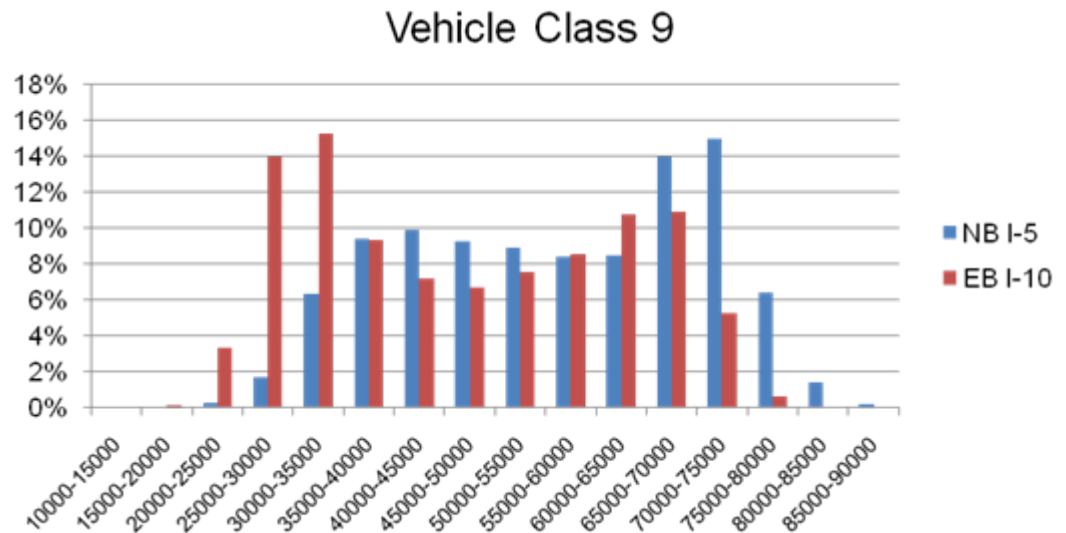


Mainline Census Station 88730



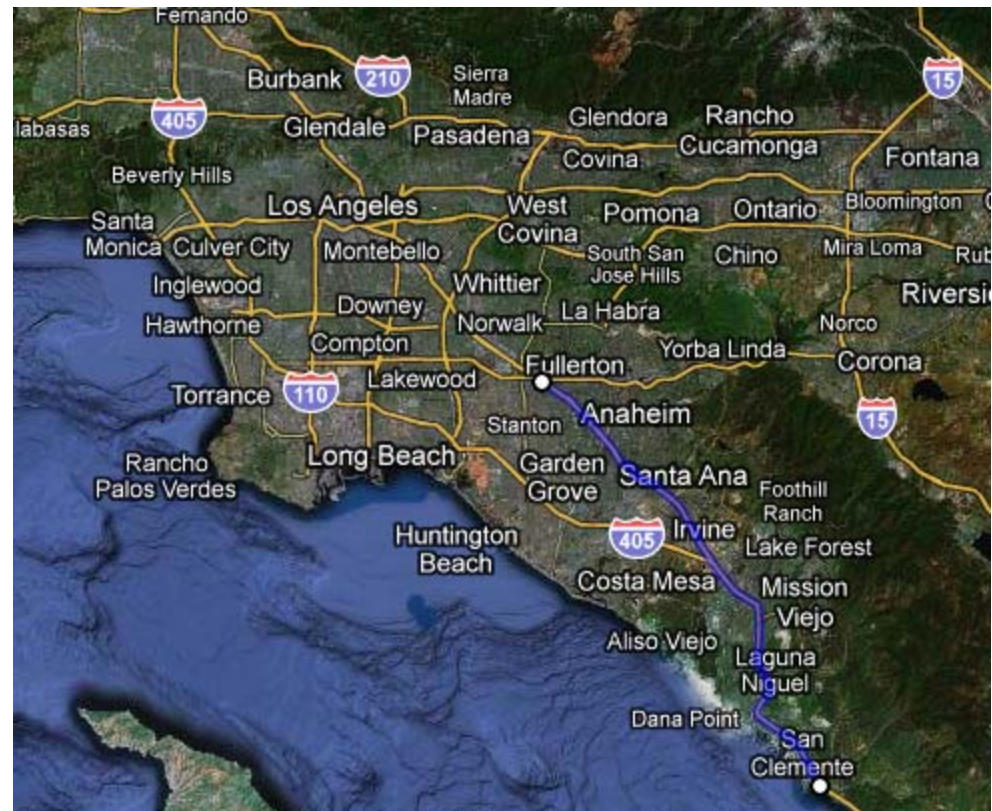
Application: Regional Differences in truck weights

- Plotting weight bins by percentage of total confirms that truck weights are lighter leaving LA to the east than to the north.
- Trend is the same for Vehicle Class 12!
- Conclusion:** Trucks leaving LA to the north are heavier
- Reason?
- We can speculate wildly:
 - Trucks going north on I-5 are leaving LA full?
 - Trucks going on EB I-10 are returning to Mexico empty?



Application: Trucks and Congestion

- Flip previous example around:
 - Instead of looking at the cost for delay due to a closure, look at the cost to trucks that delay is causing
- **Example:** We want to figure out the average weekday delay cost to trucks on I-5 N in Orange County (a major freight corridor).
- Steps:
 1. Use WIM data to find the weekday truck volumes by hour
 2. Use loops to find the weekday delay by hour along the route
 3. Use cost factor to calculate weekday cost of delay to trucks

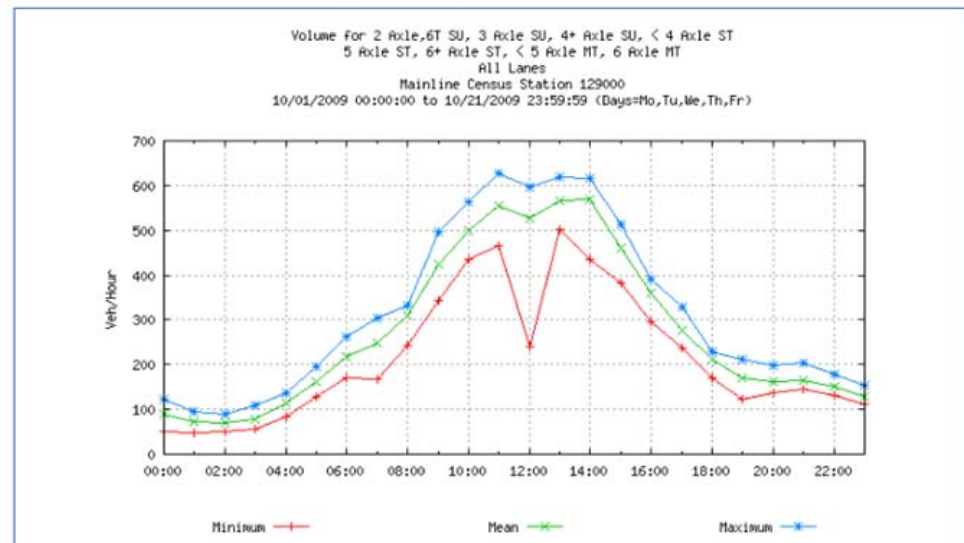
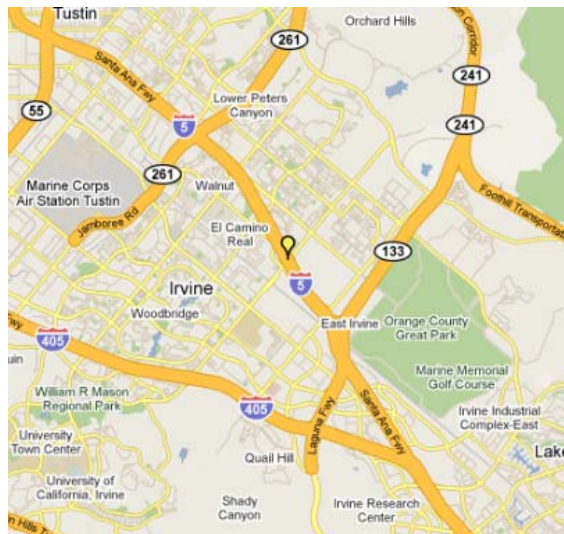


Application: Trucks and Congestion

- Here, we are plotting the average weekday truck volume by hour of the day at a WIM station along the route.
- Peak volumes are between the hours of 9:00 AM and 3:00 PM

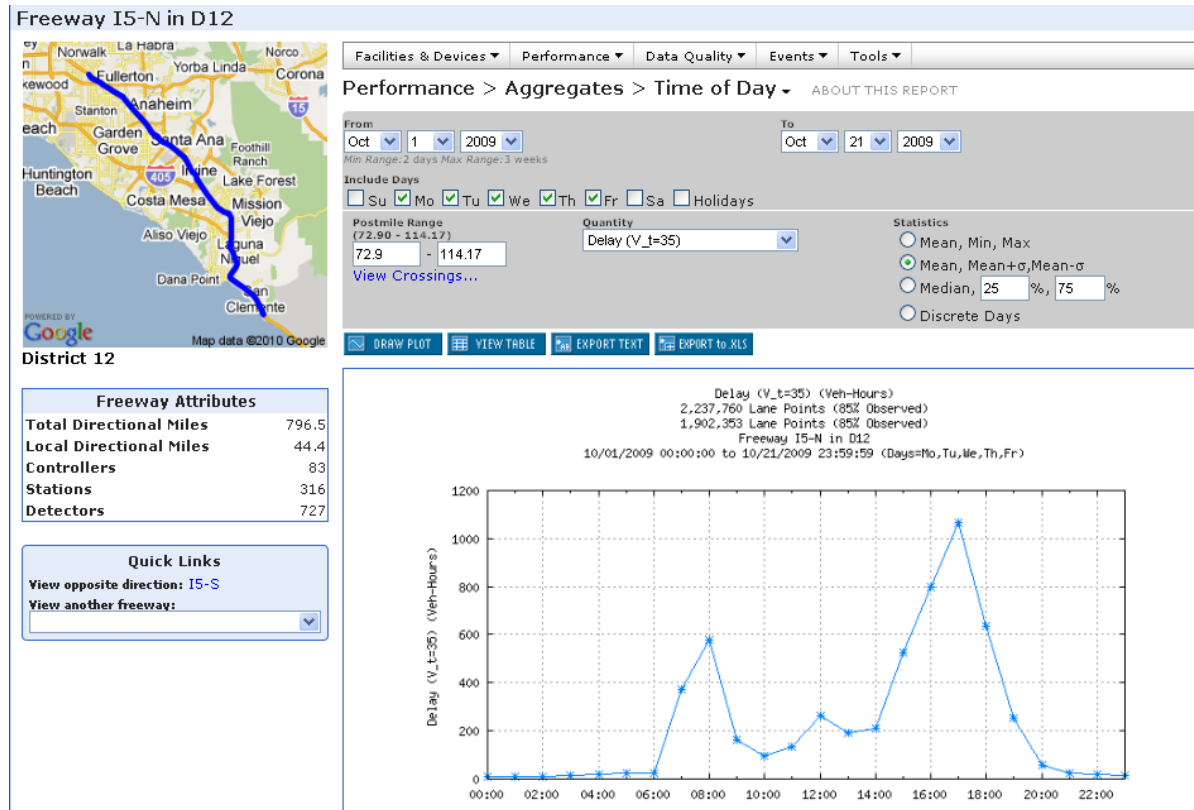
Pulling out just truck classes

From: Oct 1 2009 To: Oct 21 2009
 Min Range: 2 days
 Include Days: Su Mo Tu We Th Fr Sa Holidays
 Direction: Northbound
 View: By Group By Class
 Statistics: Mean, Min, Max Mean, Mean+σ, Mean-σ Median, 25%, 75% Discrete Days
 Motorcycles 3 Axle SU < 5 Axle MT
 Cars 4+ Axle SU 6 Axle MT
 2 Axle, 4T SU < 4 Axle ST 7+ Axle MT
 Bus 5 Axle ST User-Def
 2 Axle, 6T SU 6+ Axle ST Unknown



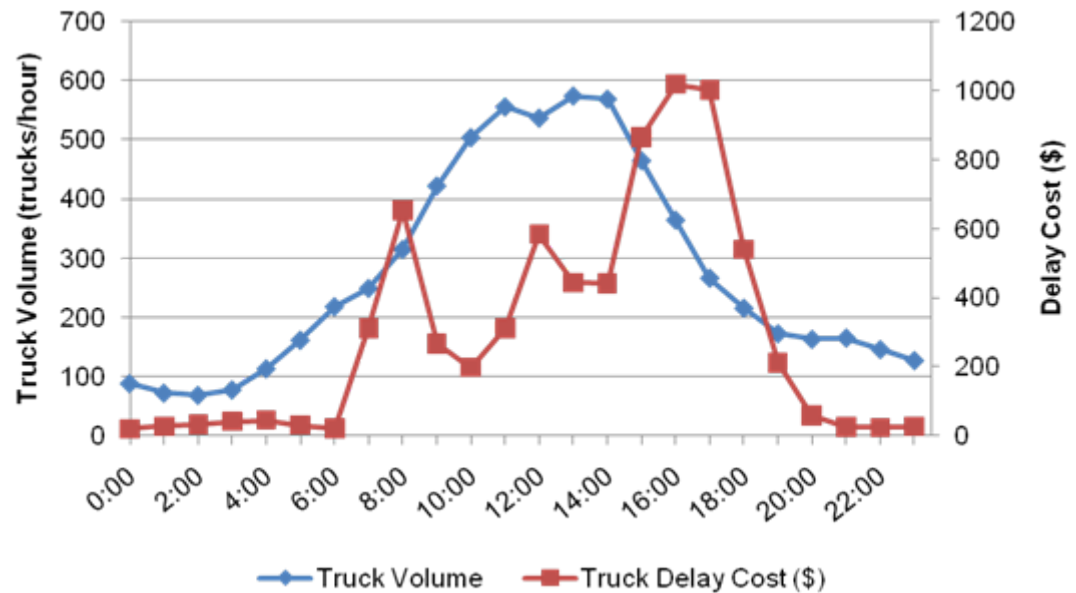
Application: Trucks and Congestion

- Congestion data
- Here, we are plotting the average delay (in veh-hours) along the entire 40 mile route, based on loop detector data (not WIM data)
- Delay peaks at 8:00 AM and between 4:00 PM and 7:00 PM
- From previous slide, we can see that most trucks travel in the off-peak hours.



Application: Trucks and Congestion

- We assume that a truck-hour of delay=\$28.70
- Results: Average weekday truck delay cost=\$7,200 on this corridor (\$144,000 per month!)
- Chart shows that, even though more trucks travel in the midday period, the most cost is incurred during the PM peak.
- Definite argument for demand shifting for trucks
- Can be shared with partners to assist with goods movement strategies



Next Steps

- Adjusting congestion reports by average truck volumes
- Associating truck volumes with incident delays
- Supply information for Pavement Management Programs
- Hourly and Monthly Adjustment Factors by vehicle class
- Error reports that detail violations
- Export files that can be directly imported into MEPDG and other design software (better organization of reports)

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Questions