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#### **Title**

Real-world activity of heavy-duty tractors hauling container chassis, flatbed trailer, and tank trailer

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# Real-World Activity of Heavy-Duty Tractors Hauling Container Chassis, Flatbed Trailer, and Tank Trailer

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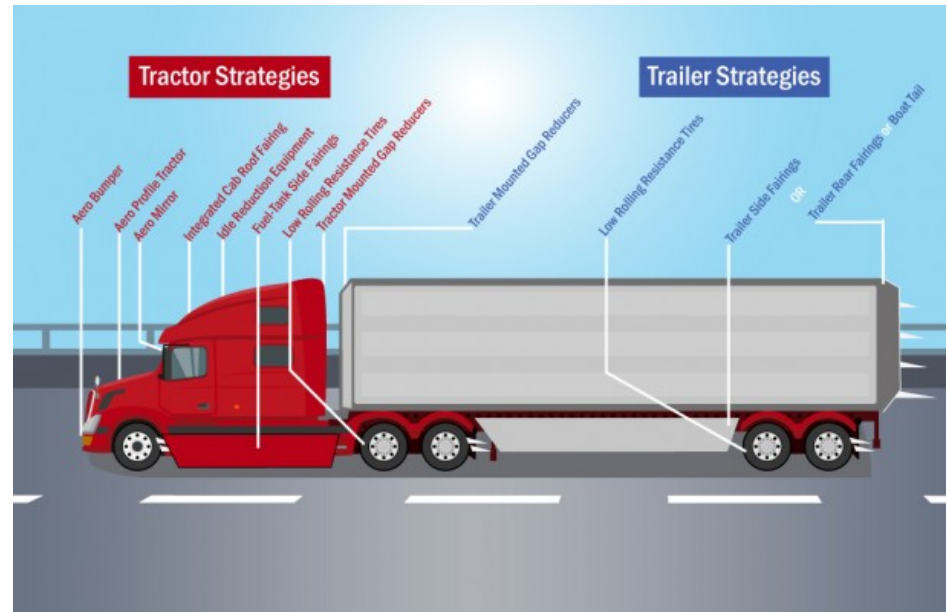
*<sup>b</sup>infoWedge*

*<sup>c</sup>California Air Resources Board*



# Background

- CARB's Tractor-Trailer GHG regulation
  - Requires aerodynamic technologies and low-rolling resistance tires on 53-foot or longer box-type trailers traveling in California.
  - Does not apply to other trailer types.
- CARB is considering to expand the regulation to include other trailer types.
  - Container chassis
  - Flatbed
  - Tanker
  - Curtainside

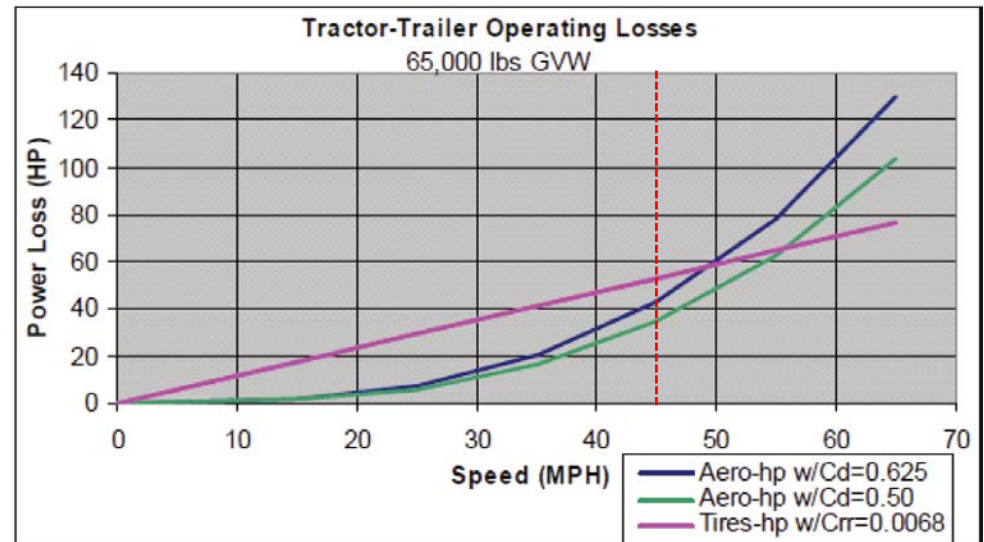


Source: <http://atri-online.org/sustainable-vehicle-practices-2/>



# Study Objectives

- Collect real-world activity data from heavy-duty tractors hauling specific trailer types in California.
  - Container chassis, flatbed, tanker
- Evaluate potential GHG (and fuel saving) benefits from aerodynamic technologies
  - Annual mileage
  - Fraction of vehicle miles traveled (VMT) at speeds greater than 45 mph



Source: National Research Council, 2010



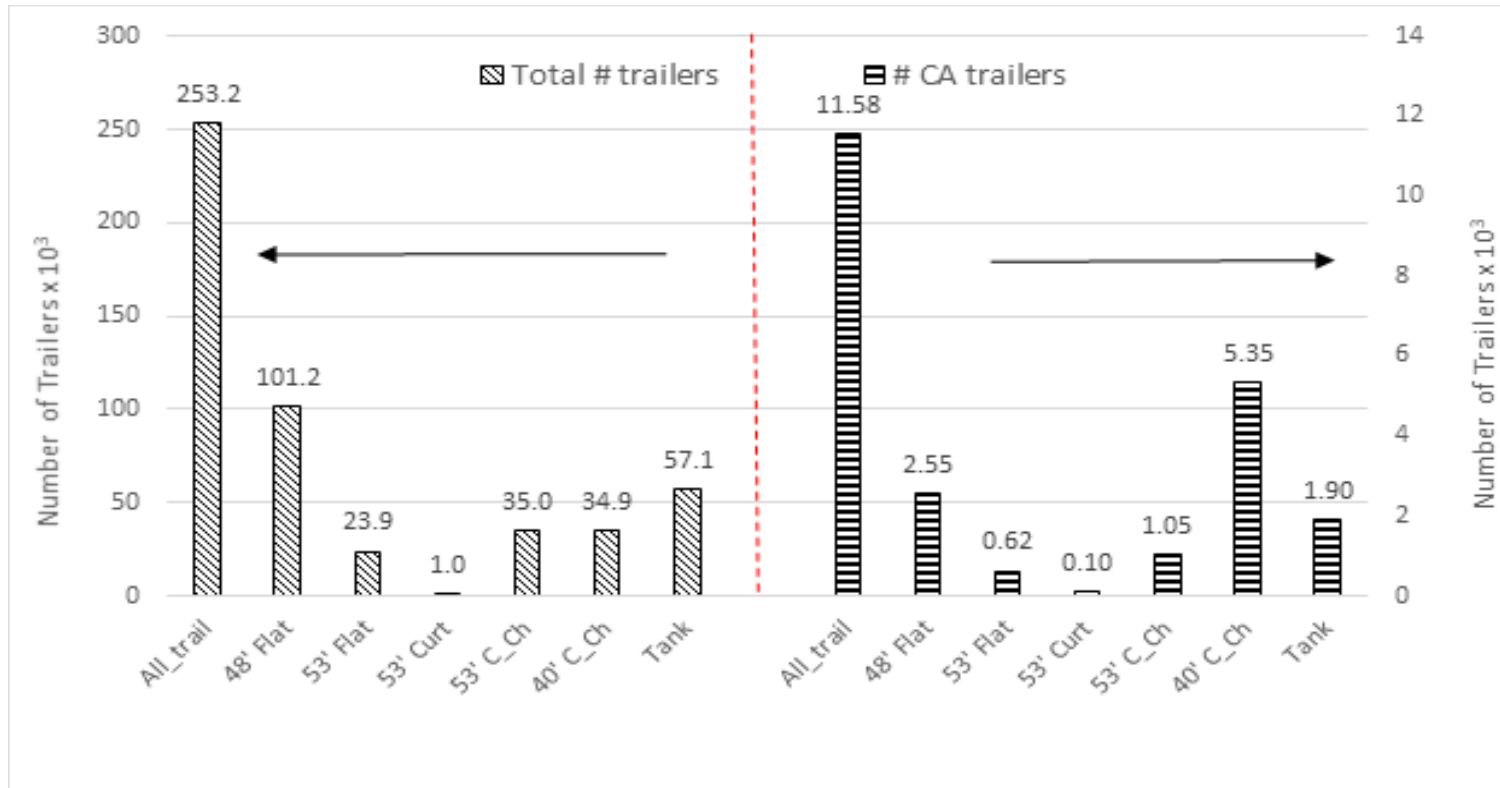
# Scope of Study

- Evaluate a trailer registration database.
  - IHS registration databased 2000-2015
  - Container chassis, flatbed, tanker, and curtainsides
- Fleet survey for fleets with registered trailers of interest.
  - # of different types of trailers, the applications and types of loads these trailers carry, and how these trailers are typically used
- Collect activity data from trucks that haul trailers of interest.



# Trailer Registration Database I

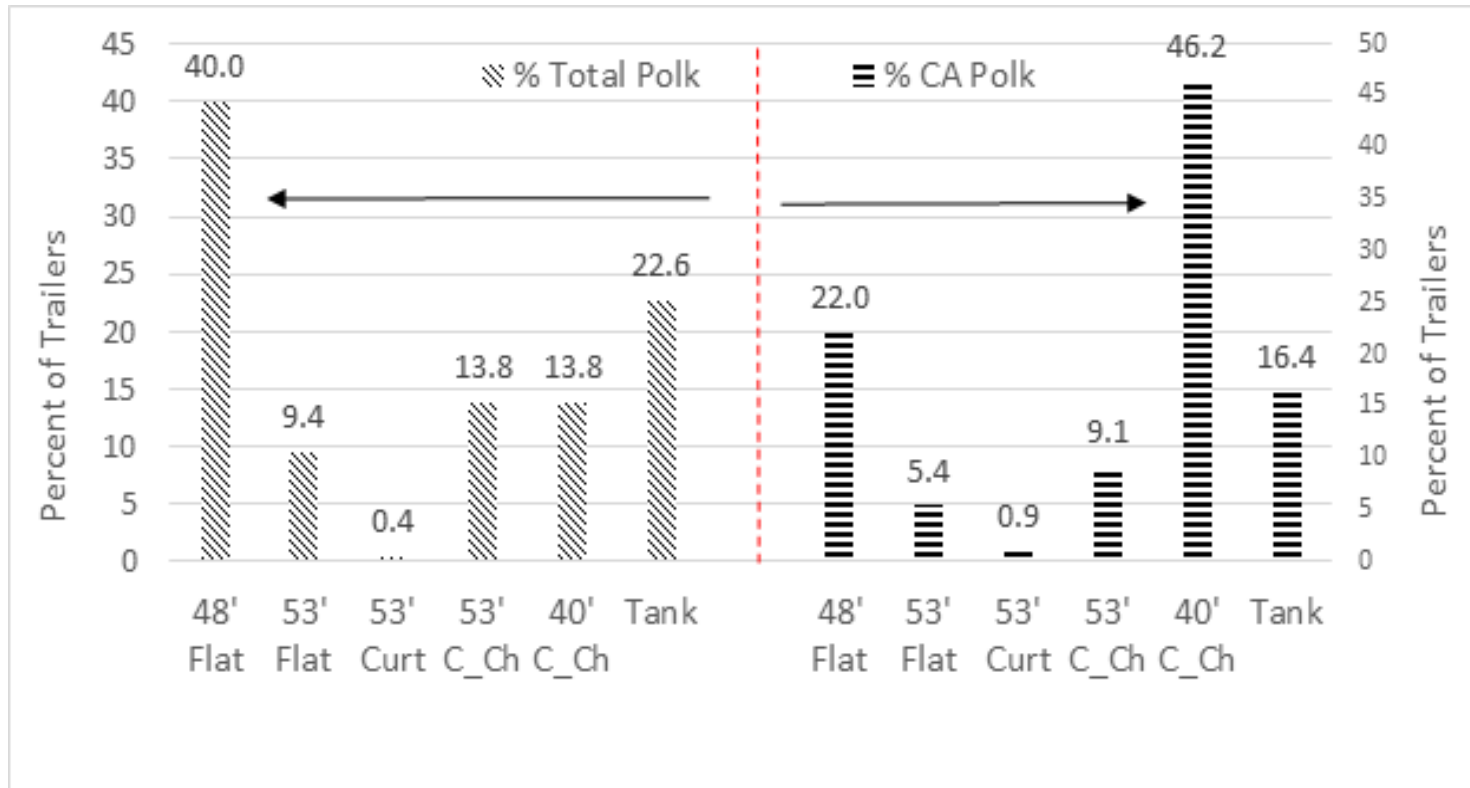
- 253,000 records IHS trailer registration database for 2000-2015 in the U.S.
- 11,575 trailers registered in California.





# Trailer Registration Database II

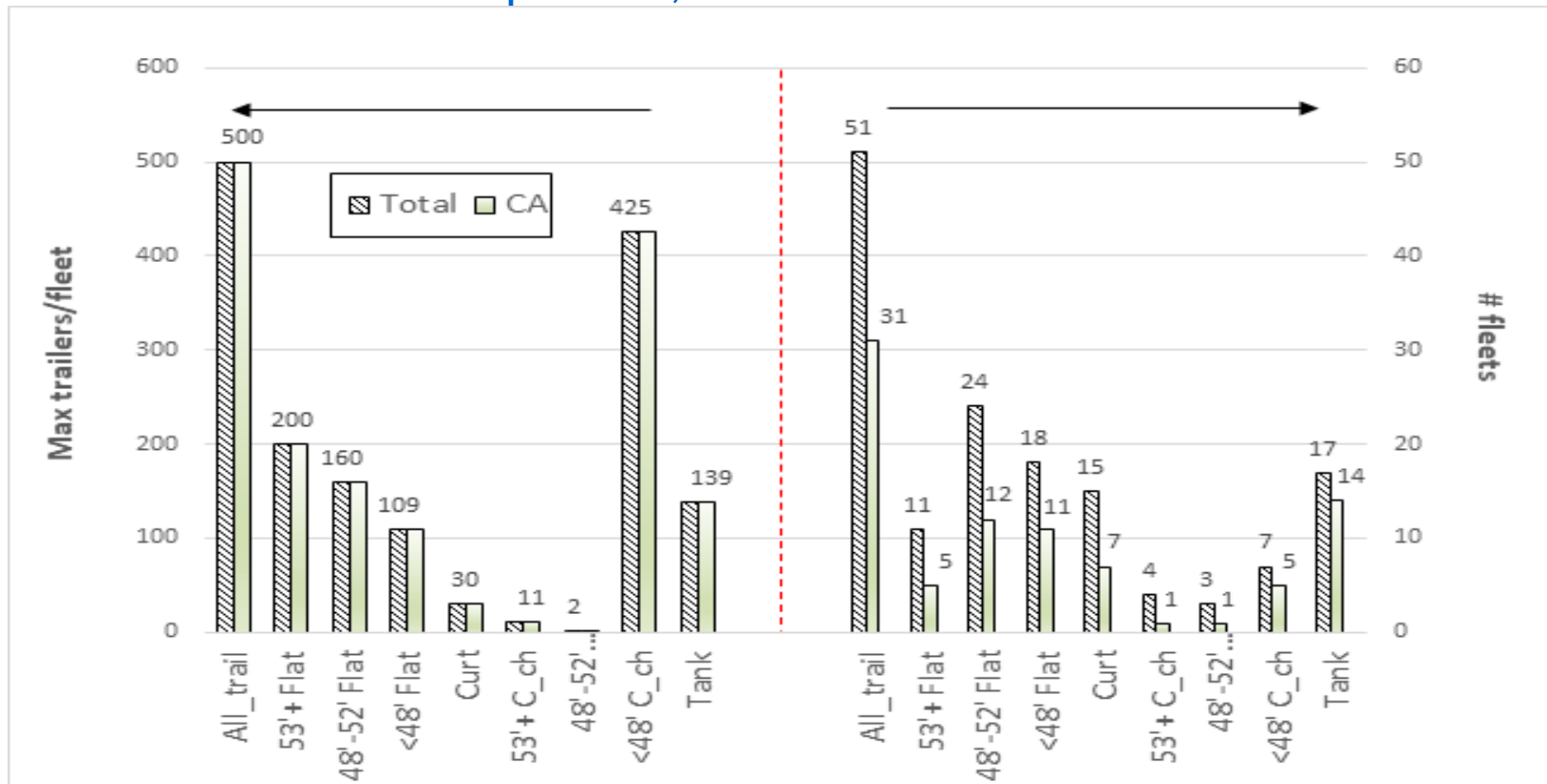
- California had a higher fraction of container chassis.
- Flatbeds and tankers also had appreciable populations.
- Only 103 curtainsides registered in California





# Fleet Survey Results I

- Sent out 6,000 trailer surveys plus phone calls
  - Mostly from the IHS database
  - Received 59 responses, 51 of which owned trailers of interest.

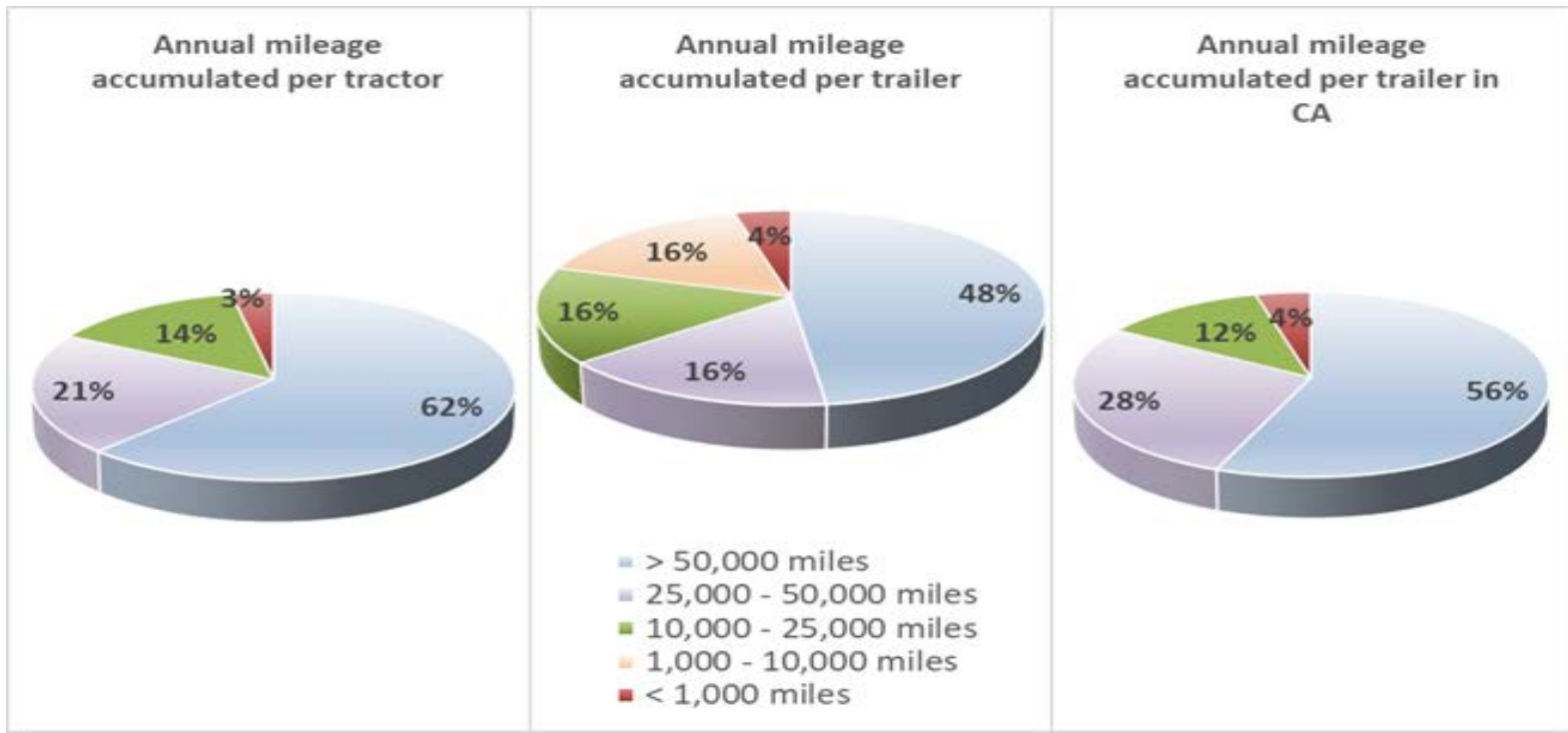






# Fleet Survey Results II

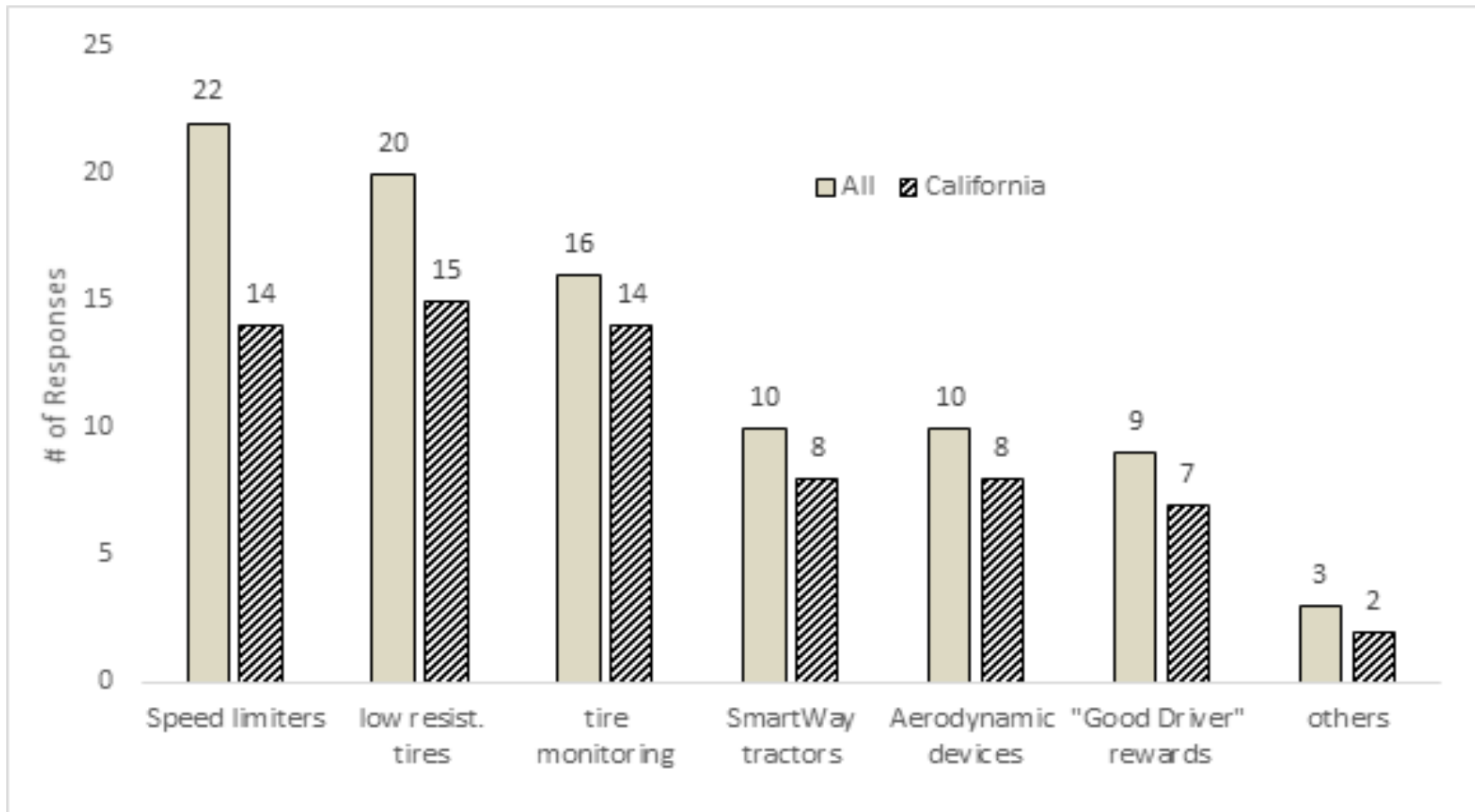
- Majority of fleets used trailers for more than 25,000 miles per year
  - Majority (56%) of CA fleets had ave. trailer mileages >50,000 miles.
  - 84% of trailers in CA had mileages >25,000.





# Fleet Survey Results III

- Many (81%) of California fleets already using fuel saving device or are in fuel savings program





# Activity Data Collection

- Real-world vehicle and engine activity data from 153 tractor-trailers for a minimum of one month each.
  - GPS & ECU data loggers
  - 1 Hz data frequency
  - 170+ engine parameters
- Vehicle and engine information
  - Vehicle make, model, year
  - Engine make, model, year
  - Emission control equipment
  - GVWR
  - Odometer
  - Etc.





# Vehicle Samples

No.	Trailer Type	Primary Revenue Service	Location	Code Name <sup>b</sup>	Number of Vehicles	
					Installed	Completed
1	Container Chassis	Goods Movement	Northern California	CC-NC-1	4	4
2	Container Chassis	Goods Movement	Northern California	CC-NC-2	20	14
3	Container Chassis	Goods Movement	Southern California	CC-SC-1	44	43
4	Container Chassis	Refuse Transfer	Southern California	CC-SC-2	11	11
<i>Container Chassis subtotal</i>					<b>79</b>	<b>72</b>
5 <sup>a</sup>	Flatbed	Agricultural Products	Central Valley	FB-CV-1	65	65
6	Flatbed	Construction Materials	Southern California	FB-SC-1	4	4
<i>Flatbed subtotal</i>					<b>69</b>	<b>69</b>
7	Tanker	Petroleum Fuels	Northern California	TK-NC-1	6	6
8	Tanker	Dairy Products	Central Valley	TK-CV-1	8	6
<i>Tanker subtotal</i>					<b>14</b>	<b>12</b>
<b>Grand Total</b>					<b>162</b>	<b>153</b>

<sup>a</sup>Data for this fleet is from a commercial source.

<sup>b</sup>CC = container chassis; FB = flatbed; TK = tanker

NC = Northern California; SC = Southern California; CV = Central Valley



# Example Vehicles



Container Chassis - NoCal



Flatbed - Central Valley



Tanker - NoCal



Container Chassis - SoCal



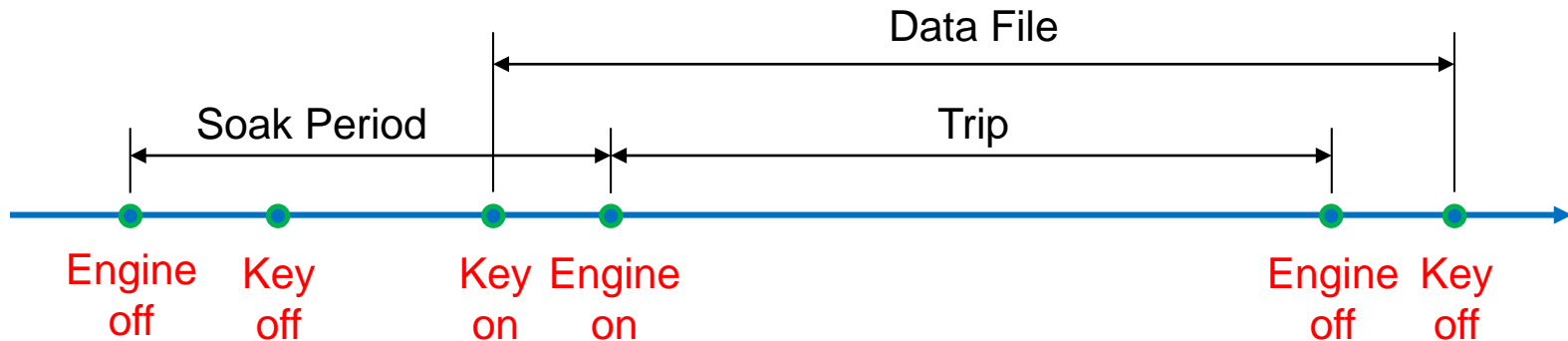
Flatbed - SoCal



Tanker – Central Valley



# Trip Identification



- A data file:
  - Is created when the key is switched on, powering up the logger.
  - Is ended when the key is switched off, powering down the logger.
  - Has no trip if key on is followed by key off.
  - Has multiple trips if engine off is followed by engine on.
- Engine on when  $RPM > 300$
- Idle trip  $\rightarrow$  trip speed  $< 5$  mph and trip distance  $< 5$  miles
  - Idle trips are between 25 and 74% of trips depending on fleet



# Container Chassis

Distribution of VMT by speed and time of day

- 72 vehicles
- 433,946 miles
- 4,487 vehicle-days
- Projected annual mileage per vehicle = 35,000 miles
- Fraction of VMT faster than 45 mph = 65%

Speed Bin	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Sum
Total	1.49	3.10	3.68	3.55	3.41	3.75	4.32	5.22	6.19	7.41	11.07	18.93	22.14	5.54	0.19	0	0	0	100
Hour	Total																		
0	1.99	0.05	0.12	0.14	0.13	0.11	0.12	0.14	0.18	0.20	0.19	0.19	0.22	0.16	0.04	0.00	0	0	0
1	2.32	0.05	0.11	0.12	0.12	0.11	0.12	0.15	0.17	0.21	0.22	0.22	0.26	0.36	0.09	0.00	0	0	0
2	3.38	0.03	0.06	0.07	0.07	0.07	0.09	0.12	0.16	0.21	0.23	0.33	0.69	1.03	0.22	0.00	0	0	0
3	3.39	0.01	0.02	0.02	0.02	0.02	0.03	0.05	0.06	0.09	0.14	0.29	0.89	1.47	0.30	0.01	0	0	0
4	4.75	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.08	0.15	0.30	1.20	2.49	0.34	0.01	0	0	0
5	5.93	0.03	0.06	0.07	0.07	0.08	0.09	0.11	0.14	0.20	0.31	0.67	1.52	2.19	0.39	0.01	0	0	0
6	6.10	0.06	0.12	0.13	0.14	0.16	0.18	0.20	0.25	0.30	0.40	0.74	1.43	1.62	0.35	0.01	0	0	0
7	5.54	0.10	0.21	0.26	0.26	0.25	0.26	0.28	0.33	0.35	0.40	0.63	1.06	0.81	0.32	0.02	0	0	0
8	5.61	0.11	0.25	0.32	0.30	0.27	0.28	0.30	0.36	0.40	0.44	0.60	0.95	0.74	0.27	0.01	0	0	0
9	6.40	0.10	0.22	0.29	0.29	0.26	0.28	0.31	0.37	0.44	0.51	0.78	1.17	1.03	0.33	0.01	0	0	0
10	6.76	0.09	0.20	0.25	0.24	0.23	0.25	0.28	0.35	0.40	0.52	0.83	1.40	1.40	0.31	0.01	0	0	0
11	7.23	0.09	0.18	0.23	0.23	0.22	0.25	0.28	0.35	0.42	0.52	0.82	1.51	1.70	0.41	0.01	0	0	0
12	7.16	0.08	0.15	0.19	0.19	0.18	0.20	0.24	0.30	0.36	0.49	0.82	1.52	1.93	0.49	0.02	0	0	0
13	6.39	0.09	0.19	0.22	0.21	0.19	0.20	0.23	0.29	0.35	0.43	0.75	1.25	1.50	0.48	0.02	0	0	0
14	5.88	0.08	0.18	0.22	0.22	0.21	0.23	0.25	0.30	0.37	0.46	0.72	1.04	1.19	0.42	0.02	0	0	0
15	4.77	0.06	0.15	0.18	0.19	0.18	0.20	0.23	0.28	0.33	0.40	0.60	0.81	0.84	0.30	0.02	0	0	0
16	2.94	0.05	0.11	0.12	0.12	0.12	0.15	0.17	0.21	0.23	0.25	0.34	0.43	0.46	0.18	0.01	0	0	0
17	2.25	0.06	0.11	0.11	0.11	0.12	0.14	0.17	0.19	0.20	0.19	0.22	0.26	0.28	0.10	0.00	0	0	0
18	1.95	0.07	0.12	0.14	0.12	0.11	0.13	0.15	0.17	0.18	0.18	0.16	0.16	0.16	0.08	0.00	0	0	0
19	1.87	0.06	0.12	0.13	0.12	0.10	0.11	0.13	0.15	0.18	0.21	0.20	0.18	0.14	0.03	0.00	0	0	0
20	2.01	0.06	0.11	0.12	0.12	0.10	0.12	0.13	0.16	0.20	0.22	0.23	0.27	0.15	0.03	0.00	0	0	0
21	2.09	0.06	0.10	0.12	0.11	0.10	0.12	0.14	0.17	0.19	0.23	0.25	0.27	0.19	0.04	0.00	0	0	0
22	1.61	0.04	0.08	0.09	0.08	0.08	0.09	0.10	0.13	0.16	0.17	0.19	0.24	0.15	0.03	0.00	0	0	0
23	1.66	0.05	0.11	0.12	0.10	0.08	0.09	0.11	0.13	0.15	0.16	0.19	0.21	0.14	0.02	0.00	0	0	0
Sum	100																		100



# Flatbed Trailer

Distribution of VMT by speed and time of day

- 69 vehicles
- 321,617 miles
- 1,736 vehicle-days
- Projected annual mileage per vehicle = 67,621 miles
- Fraction of VMT faster than 45 mph = 83%

Speed Bin	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Sum	
Total	0.29	0.89	1.05	1.08	1.42	1.85	2.56	3.20	4.31	6.39	10.57	50.15	16.16	0.09	0.01	0.00	0	0	100	
Hour	Total																			
0	3.84	0.01	0.04	0.05	0.05	0.08	0.09	0.12	0.14	0.17	0.25	0.41	1.80	0.63	0.00	0	0	0	0	
1	3.59	0.01	0.04	0.04	0.04	0.06	0.08	0.10	0.14	0.19	0.23	0.36	1.71	0.59	0.00	0	0	0	0	
2	3.48	0.01	0.03	0.04	0.04	0.05	0.07	0.09	0.12	0.16	0.23	0.36	1.72	0.57	0.00	0	0	0	0	
3	3.31	0.01	0.03	0.03	0.03	0.05	0.06	0.08	0.11	0.15	0.23	0.36	1.62	0.54	0.00	0.00	0	0	0	
4	3.10	0.01	0.03	0.03	0.03	0.04	0.05	0.08	0.10	0.13	0.21	0.32	1.50	0.56	0.00	0	0	0	0	
5	3.57	0.01	0.03	0.03	0.03	0.05	0.06	0.08	0.11	0.17	0.26	0.40	1.70	0.64	0.00	0.00	0	0	0	
6	3.09	0.01	0.03	0.03	0.03	0.04	0.05	0.07	0.10	0.15	0.21	0.29	1.50	0.57	0.00	0.00	0	0	0	
7	2.64	0.01	0.02	0.02	0.02	0.03	0.05	0.06	0.08	0.12	0.15	0.25	1.36	0.45	0.00	0.00	0	0	0	
8	2.64	0.01	0.02	0.02	0.02	0.03	0.04	0.05	0.08	0.10	0.14	0.24	1.38	0.51	0.01	0.00	0.00	0	0	
9	2.63	0.01	0.02	0.02	0.02	0.03	0.04	0.06	0.07	0.09	0.13	0.26	1.39	0.48	0.01	0.00	0.00	0	0	
10	3.27	0.01	0.02	0.02	0.02	0.03	0.03	0.05	0.07	0.09	0.15	0.30	1.83	0.63	0.01	0.00	0.00	0	0	
11	3.84	0.01	0.03	0.03	0.03	0.04	0.05	0.07	0.08	0.12	0.18	0.30	2.20	0.71	0.01	0.00	0	0	0	
12	4.78	0.01	0.03	0.04	0.04	0.05	0.06	0.10	0.14	0.20	0.31	0.52	2.57	0.73	0.00	0.00	0	0	0	
13	5.00	0.01	0.04	0.05	0.05	0.07	0.08	0.12	0.15	0.21	0.30	0.51	2.63	0.76	0.00	0	0	0	0	
14	5.38	0.02	0.04	0.05	0.06	0.07	0.09	0.13	0.17	0.24	0.33	0.51	2.78	0.88	0.00	0.00	0	0	0	
15	5.28	0.02	0.06	0.07	0.07	0.08	0.10	0.14	0.17	0.23	0.34	0.54	2.65	0.81	0.00	0.00	0.00	0	0	
16	5.70	0.02	0.05	0.07	0.07	0.09	0.12	0.16	0.18	0.24	0.39	0.62	2.84	0.86	0.00	0.00	0	0	0	
17	5.39	0.02	0.05	0.06	0.06	0.08	0.11	0.16	0.19	0.25	0.39	0.67	2.59	0.76	0.00	0	0	0	0	
18	5.71	0.01	0.05	0.06	0.06	0.08	0.11	0.15	0.19	0.25	0.39	0.66	2.86	0.82	0.00	0.00	0	0	0	
19	5.24	0.01	0.04	0.05	0.06	0.08	0.10	0.14	0.18	0.25	0.36	0.62	2.52	0.81	0.00	0.00	0	0	0	
20	4.79	0.02	0.05	0.06	0.06	0.08	0.10	0.13	0.16	0.22	0.33	0.57	2.33	0.70	0.00	0	0	0	0	
21	4.81	0.02	0.05	0.05	0.06	0.08	0.10	0.15	0.17	0.22	0.33	0.57	2.29	0.71	0.00	0.00	0	0	0	
22	4.59	0.02	0.05	0.05	0.06	0.08	0.10	0.14	0.15	0.19	0.29	0.49	2.21	0.77	0.00	0	0	0	0	
23	4.35	0.02	0.05	0.06	0.06	0.07	0.09	0.12	0.14	0.17	0.27	0.45	2.17	0.68	0.00	0	0	0	0	
Sum	100																			100





# Tanker Trailer

Distribution of VMT by speed and time of day

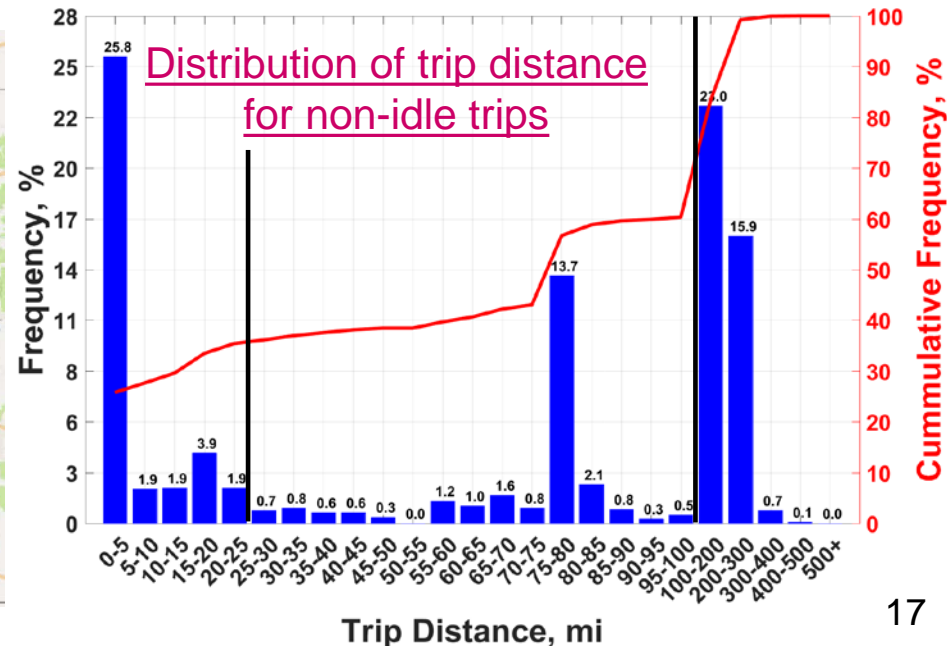
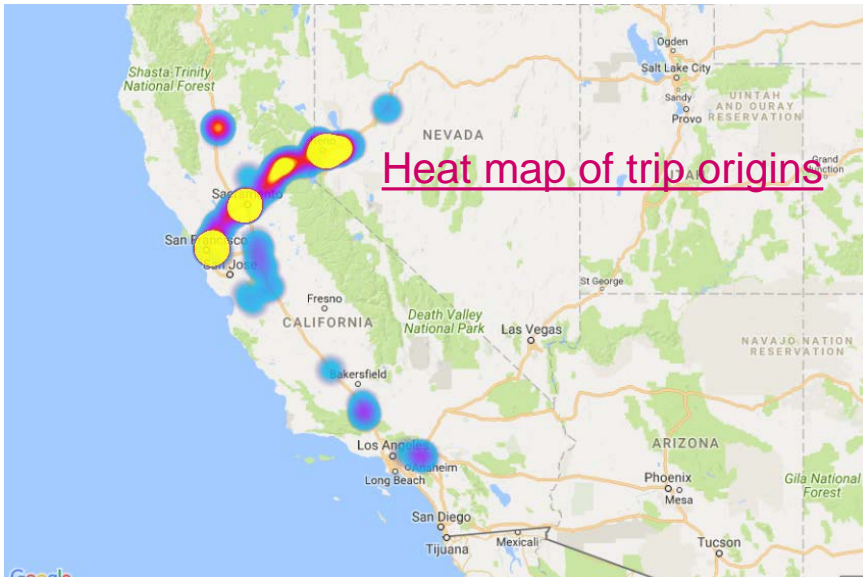
- 12 vehicles
- 48,593 miles
- 647 vehicle-days
- Projected annual mileage per vehicle = 27,413 miles
- Fraction of VMT faster than 45 mph = 93%

Speed Bin	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Sum	
Total	0.24	0.74	0.72	0.56	0.58	0.77	0.86	1.01	1.17	1.37	3.75	28.97	58.97	0.28	0.00	0	0	0	100	
Hour	Total																			
0	1.61	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.03	0.35	1.11	0.01	0.00	0	0	0	0	
1	1.96	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.30	1.51	0.01	0	0	0	0	0	
2	3.22	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.33	2.73	0.00	0	0	0	0	0	
3	3.29	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.06	0.53	2.57	0.01	0	0	0	0	0	
4	3.94	0.00	0.02	0.02	0.01	0.02	0.02	0.02	0.03	0.03	0.08	1.39	2.27	0.01	0	0	0	0	0	
5	4.96	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.17	2.01	2.57	0.01	0.00	0	0	0	0	
6	4.91	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.05	0.06	1.69	2.62	0.01	0.00	0	0	0	0	
7	4.23	0.01	0.05	0.06	0.06	0.04	0.05	0.06	0.06	0.06	0.08	1.44	2.02	0.02	0	0	0	0	0	
8	8.66	0.01	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.05	0.06	2.18	5.86	0.01	0	0	0	0	0	
9	9.40	0.01	0.03	0.03	0.03	0.04	0.06	0.06	0.08	0.11	0.10	3.32	5.86	0.01	0	0	0	0	0	
10	5.10	0.02	0.08	0.06	0.05	0.06	0.08	0.09	0.11	0.13	0.15	1.63	2.34	0.01	0.00	0	0	0	0	
11	8.13	0.01	0.05	0.04	0.04	0.05	0.07	0.09	0.10	0.12	0.13	2.29	4.36	0.04	0	0	0	0	0	
12	9.29	0.01	0.04	0.03	0.03	0.04	0.05	0.06	0.08	0.11	0.15	0.39	2.54	5.75	0.02	0.00	0	0	0	
13	6.13	0.02	0.10	0.10	0.06	0.05	0.07	0.10	0.11	0.13	0.15	0.34	1.60	3.27	0.02	0	0	0	0	
14	4.47	0.02	0.06	0.06	0.05	0.05	0.06	0.07	0.08	0.09	0.10	0.28	1.77	1.75	0.02	0.00	0	0	0	
15	4.71	0.02	0.04	0.03	0.03	0.04	0.05	0.05	0.05	0.06	0.08	0.18	2.03	2.05	0.02	0.00	0	0	0	
16	3.47	0.01	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.15	1.05	1.87	0.01	0.00	0	0	0	
17	1.85	0.01	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.06	0.39	1.12	0.01	0	0	0	0	
18	1.87	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.06	0.43	1.24	0.02	0.00	0	0	0	
19	2.29	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.55	1.57	0.01	0	0	0	0	
20	1.68	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.32	1.23	0.00	0	0	0	0	0	
21	1.34	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.03	0.31	0.90	0.00	0	0	0	0	0	
22	1.91	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.36	1.41	0.01	0	0	0	0	0	
23	1.57	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.03	0.40	1.00	0.00	0	0	0	0	
Sum	100																			



# Container Chassis Fleet CC-NC-2

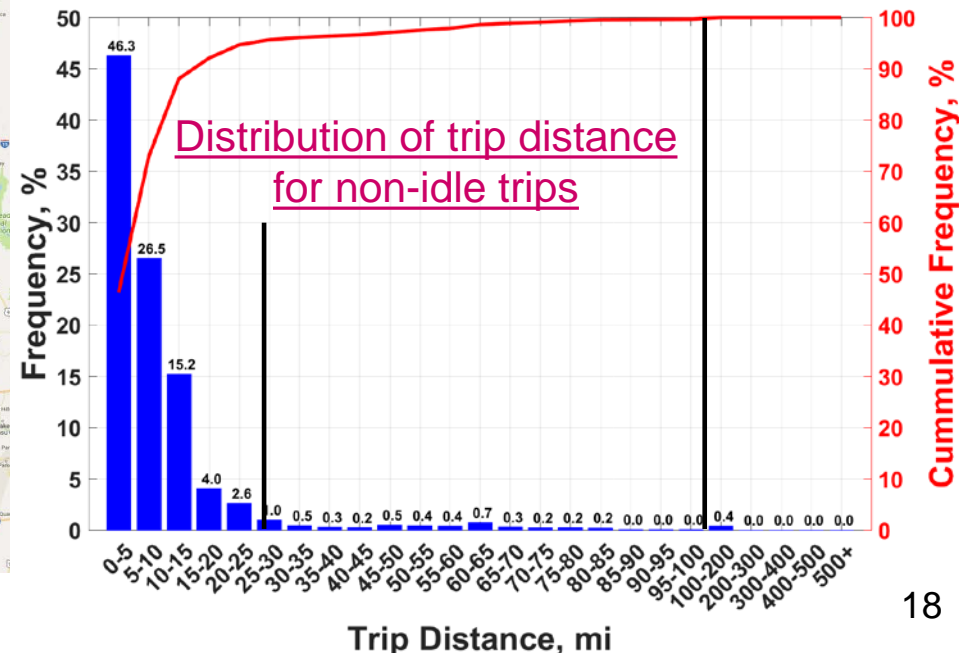
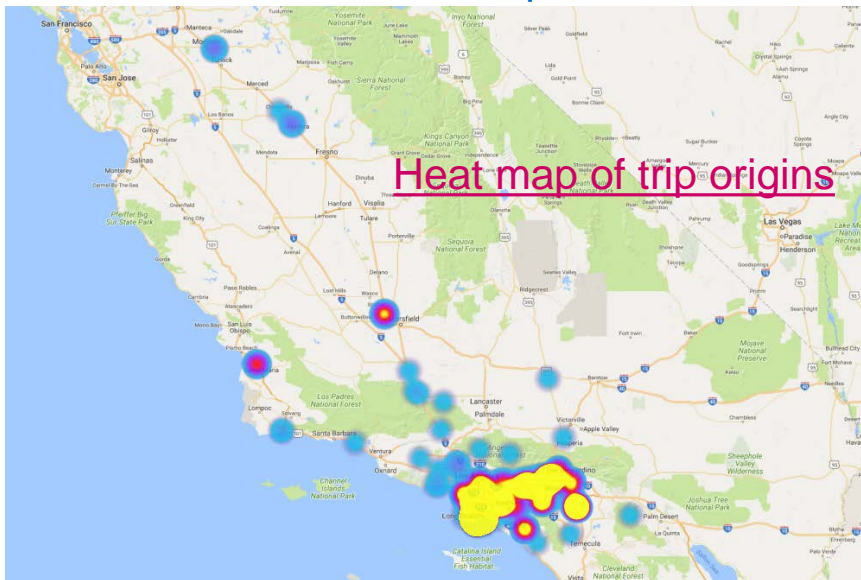
- Primarily long-distance haul
  - Services Port of Oakland, Greater Sacramento region, and locations in Nevada
- 75% of all trips were non-idle trips.
  - 40% of these were shorter than 25 miles.
  - 40% of these were longer than 100 mile
  - 91% of VMT >45 mph





# Container Chassis Fleet CC-SC-1

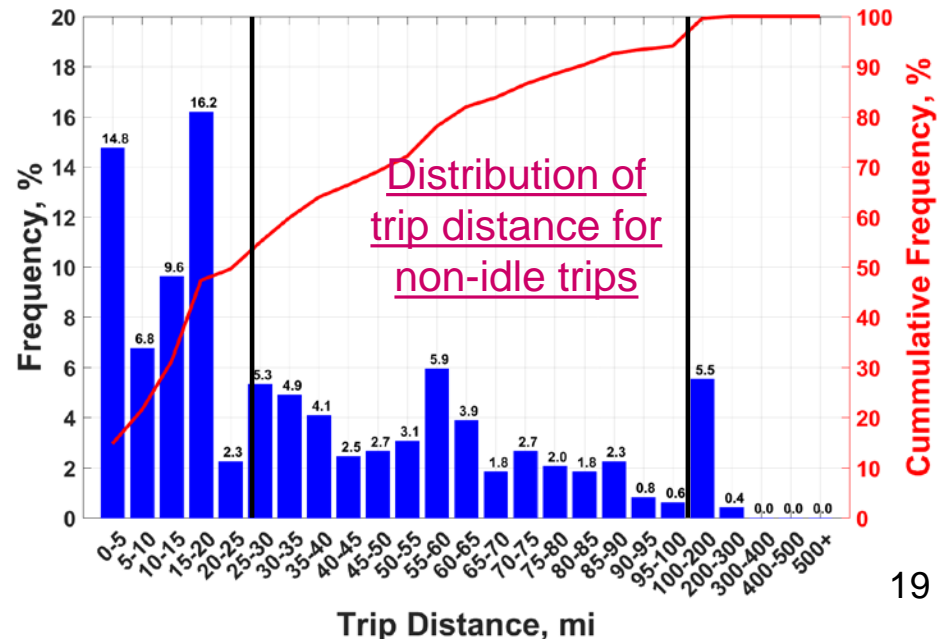
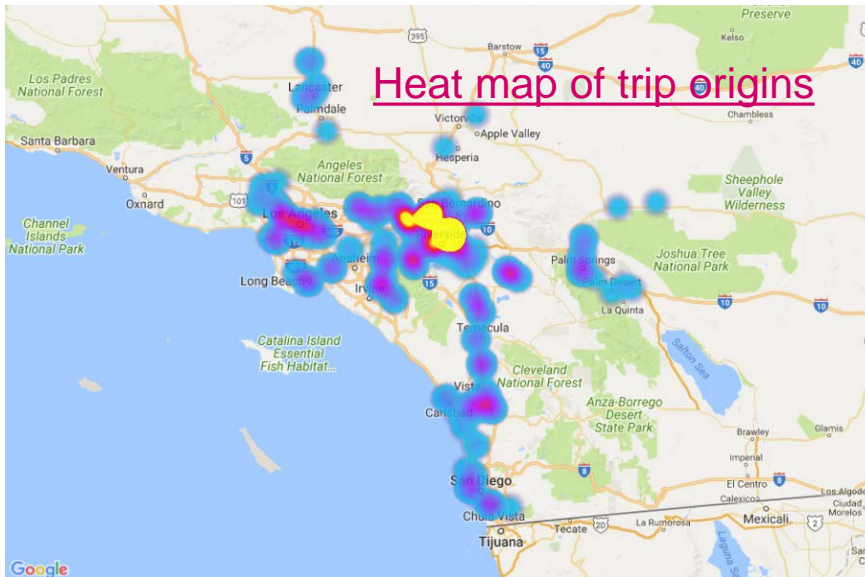
- Primarily drayage operation
  - Services San Pedro port complex, Greater L.A. Metro area, and Inland Empire area
- 52% of all trips were non-idle trips.
  - 88% of these were shorter than 25 miles.
  - 1% of these were longer than 100 miles
  - 42% of VMT > 45 mph.





# Flatbed Trailer Fleet FB-SC-1

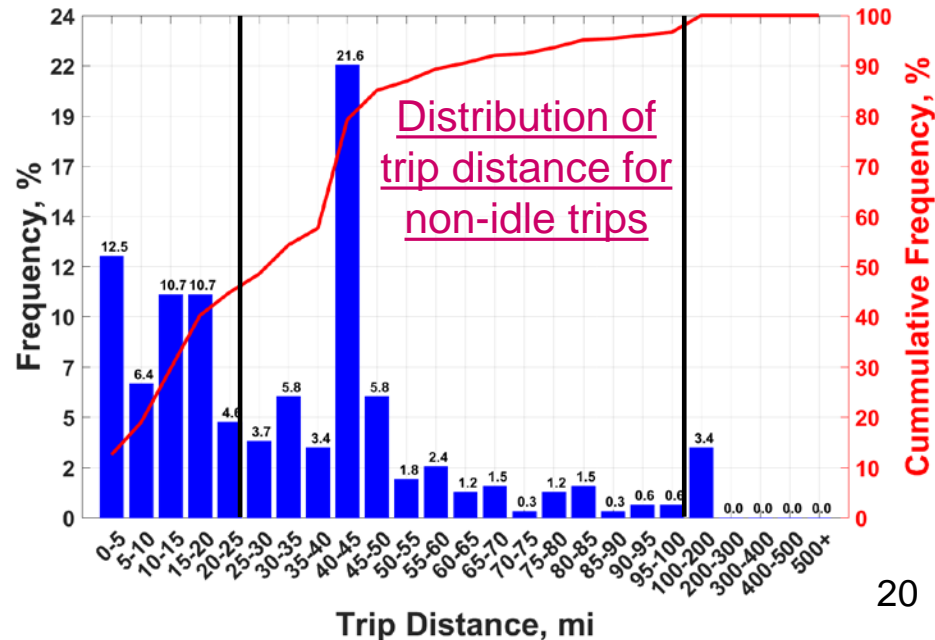
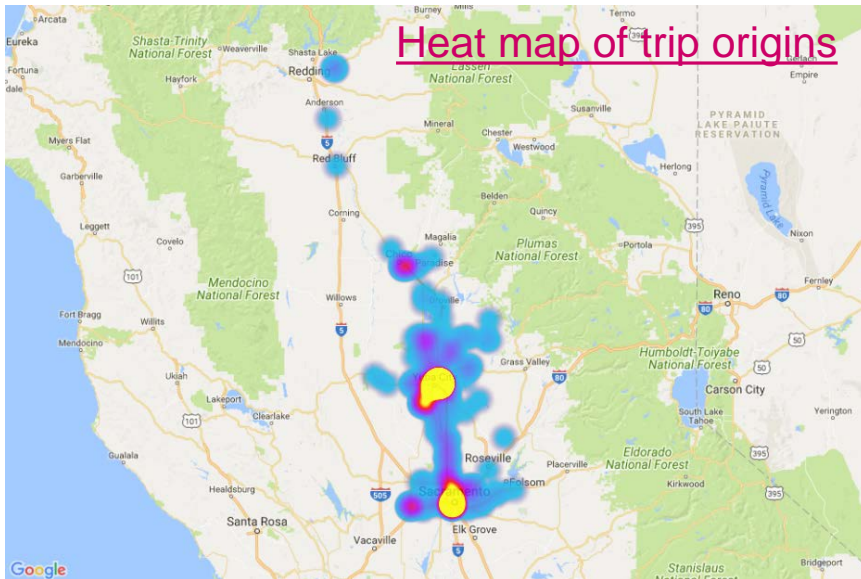
- Primarily short and regional haul
  - Services Inland Empire area, Greater L.A. Metro area, and San Diego County
- 44% of all trips were non-idle trips.
  - 48% of these were shorter than 25 miles.
  - 6% of these were longer than 100 miles.
  - 76% of VMT > 45 mph.





# Tanker Trailer Fleet TK-NC-1

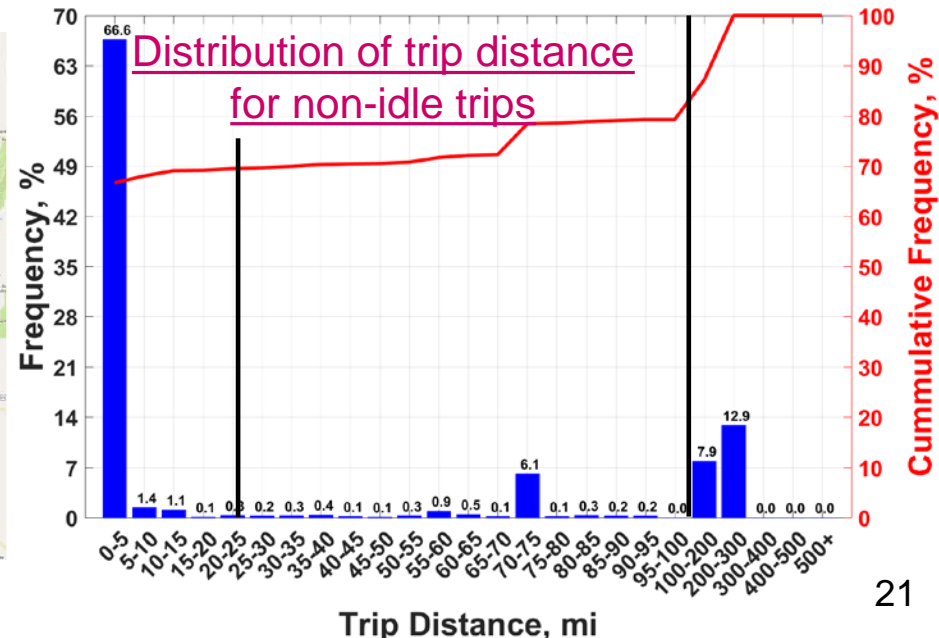
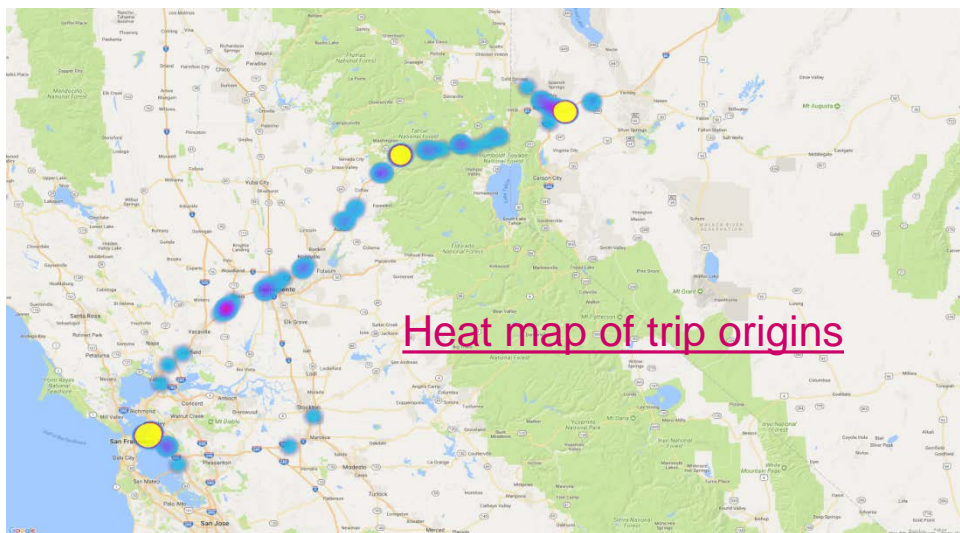
- Primarily short and regional haul
  - Services Greater Sacramento area with some operation further north
- 49% of all trips were non-idle trips.
  - 44% of these were shorter than 25 miles.
  - 4% of these were longer than 100 miles.
  - 77% of VMT > 45 mph.





# Container Chassis Fleet CC-NC-1

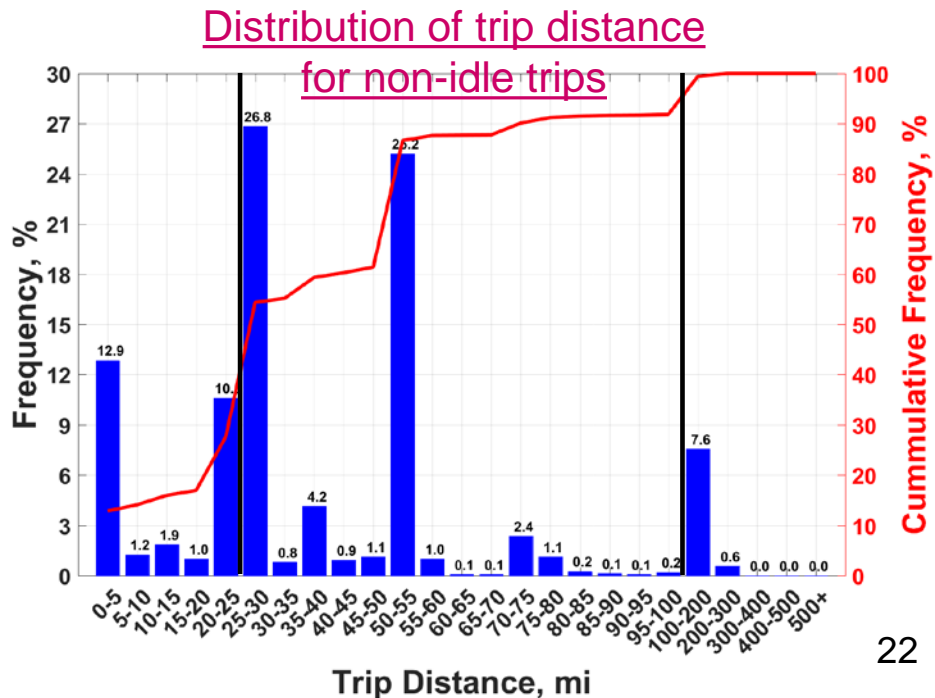
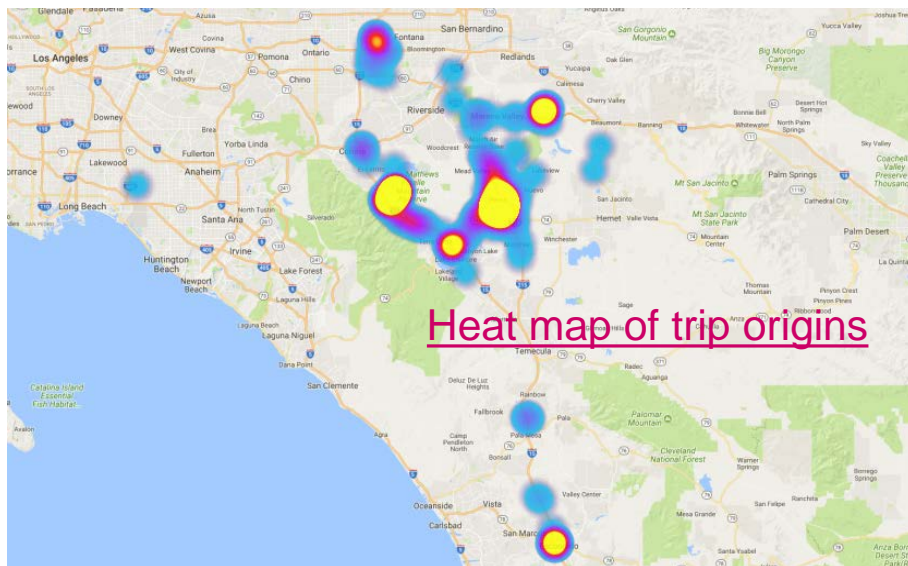
- Short, regional, and long-distance haul
  - Services Port of Oakland, Other Bay Area port locations, Greater Sacramento region, Tahoe, and locations in Nevada
- 34% of all trips were non-idle trips.
  - 67% of these were shorter than 25 miles.
  - 22% of these were longer than 100 mile
  - 90% of VMT >45 mph





# Container Chassis Fleet CC-SC-2

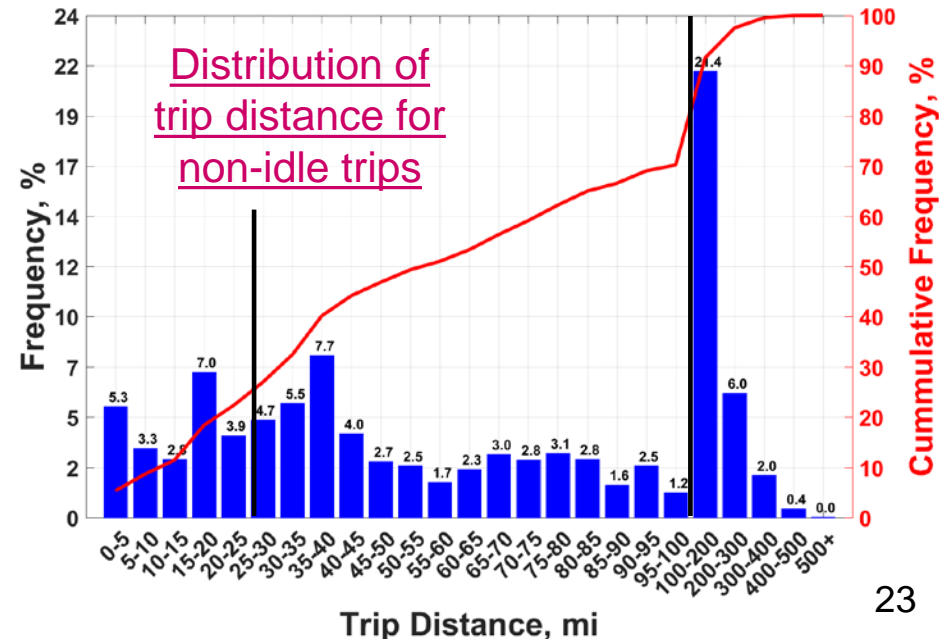
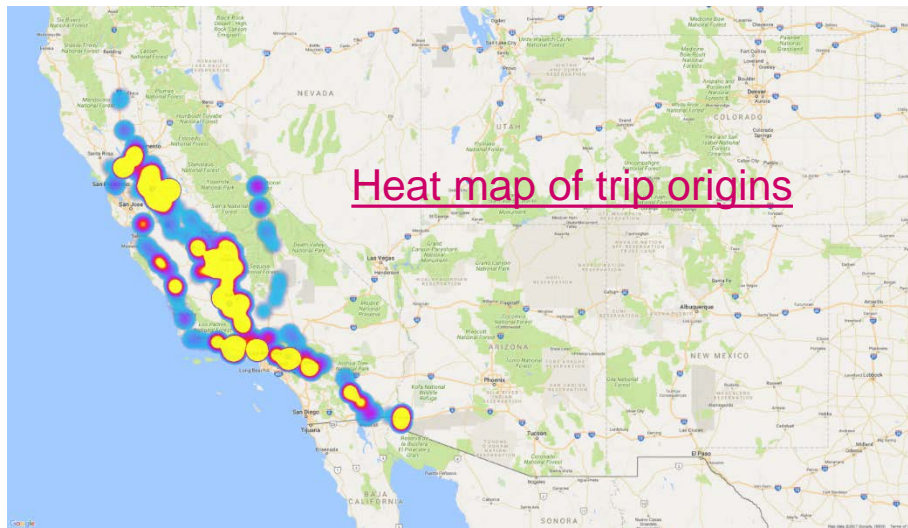
- Primarily local and regional hauling
  - Refuse Hauler in Inland Empire with some San Diego trips
- 48% of all trips were non-idle trips.
  - 27% of these were shorter than 25 miles.
  - 8% of these were longer than 100 mile
  - 67% of VMT >45 mph





# Flatbed Trailer Fleet FB-CV-1

- Short, regional, and long-distance haul
  - Agriculture products hauled throughout the state
- 66% of all trips were non-idle trips.
  - 22% of these were shorter than 25 miles.
  - 30% of these were longer than 100 miles.
  - 84% of VMT > 45 mph.

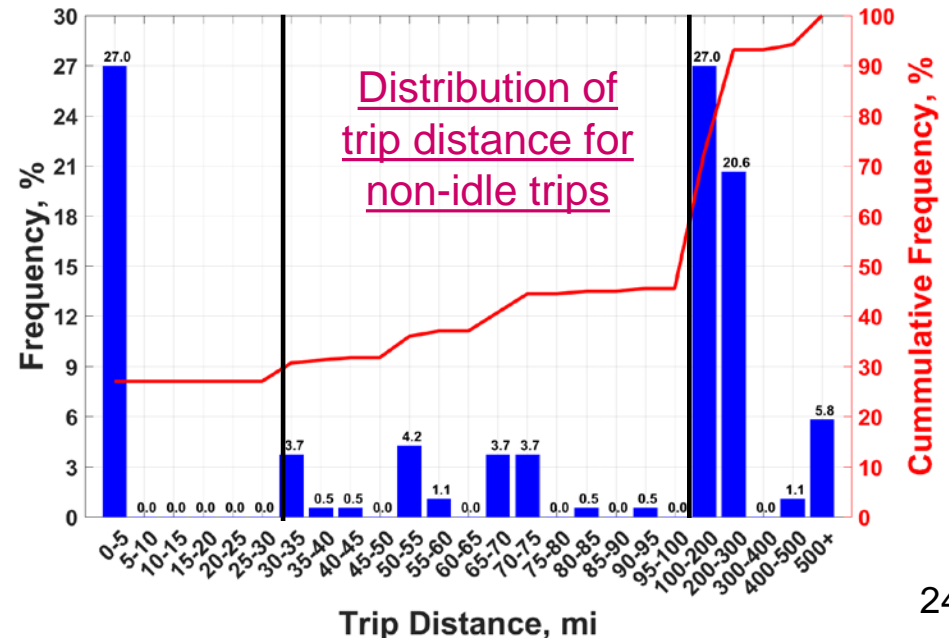
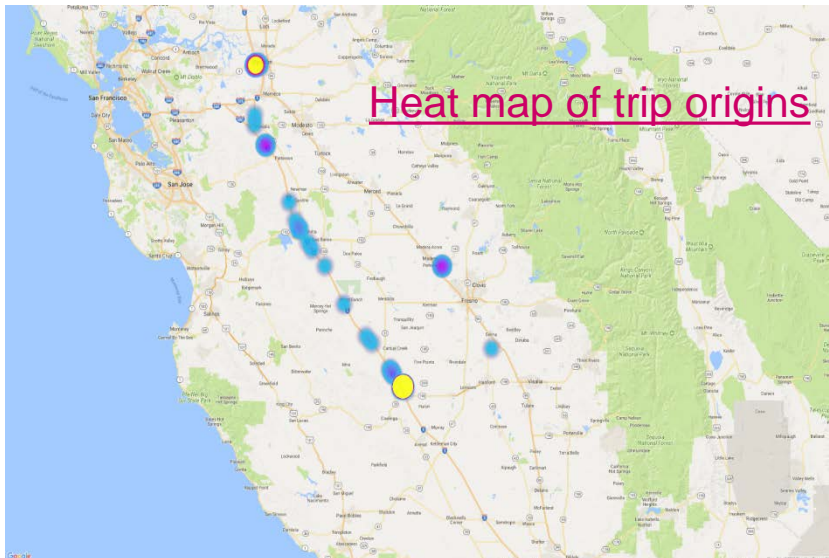






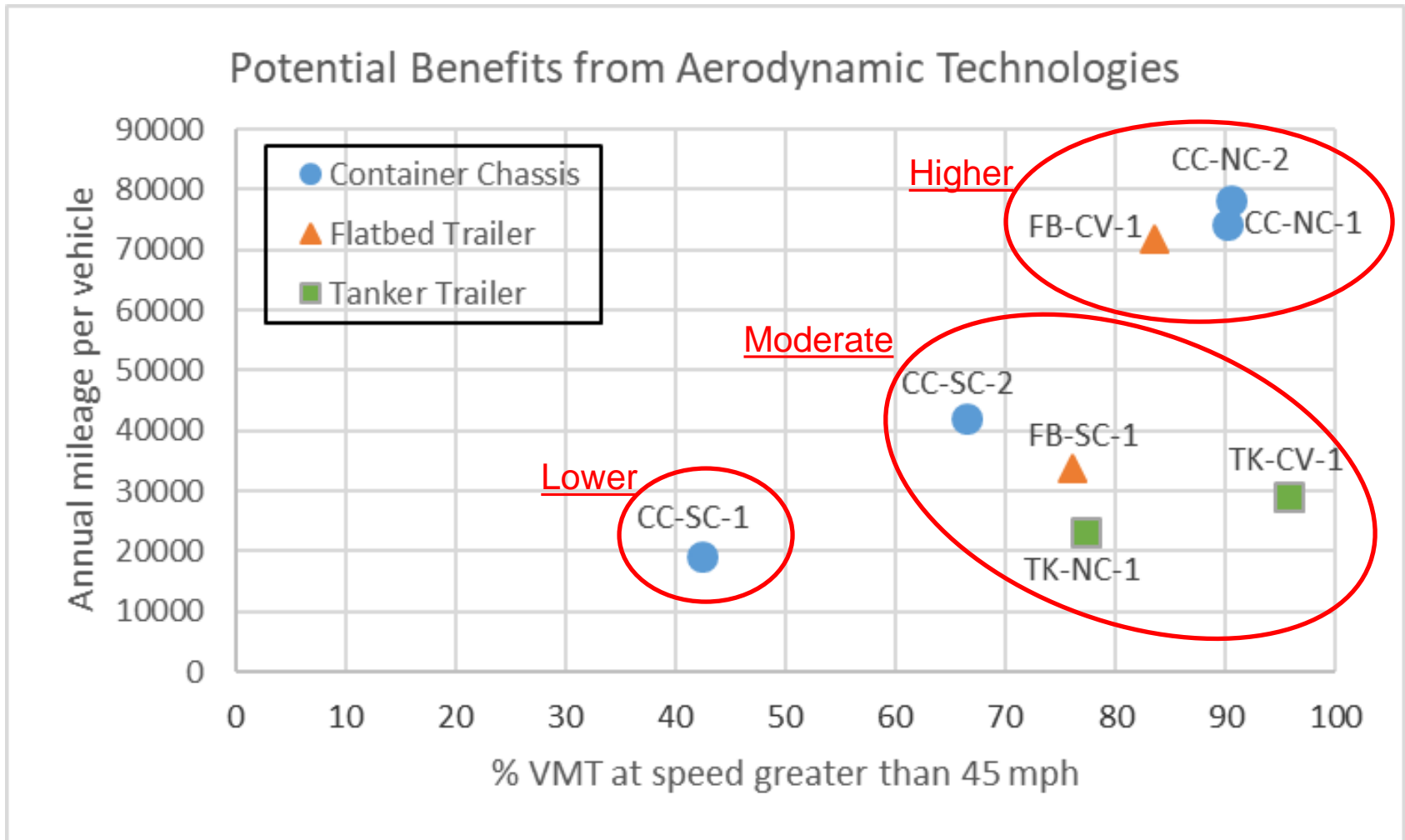
# Tanker Trailer Fleet TK-CV-1

- Short, regional, and long haul
  - Dairy products in the Central Valley
- 26% of all trips were non-idle trips.
  - 27% of these were shorter than 25 miles.
  - 54% of these were longer than 100 miles.
  - 96% of VMT > 45 mph.





# Comparison among Fleets





# Concluding Remarks

- Vehicle activity of 153 tractor-trailers data logged in this study varies.
  - By trailer type and also by fleet within the same trailer type
- For the 8 fleets included in this study:
  - Projected annual mileage per vehicle ranges from 19k to 78k.
  - Fraction of VMT faster than 45 mph ranges from 42% to 96%.
  - Most fleets had  $\geq 66\%$  of VMT  $> 45$  mph
- Results indicate that:
  - On average, most fleets would potentially gain significant benefits from aerodynamic technologies on their trailers.
  - Expansion of the Tractor-Trailer GHG regulation may include exemption for fleets or tractor-trailers with low annual mileage traveling mostly at speeds lower than 45 mph.



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  - Under contract 14-302
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- Participating fleets