Eastern Research Group, Inc.

Heavy-Duty Vehicle Accrual Rates

Final Report

Prepared for:

California Air Resources Board

Prepared by:

Eastern Research Group, Inc.

June 14, 2019

ERG No. 3982. 01. 001

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June 14, 2019

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1.0 Introduction

The California Air Resources Board (ARB) contracted with ERG to provide recent, California-specific data to better represent annual mileage accrued by heavy-duty vehicles (HDVs) by age, vocation, and weight class in EMFAC. ARB is continually updating and refining emissions inventories to support state air quality planning efforts and compliance with the Clean Air Act. California's Mobile Source SIP Strategy document describes several successful HDV programs already implemented in the state as well as plans for several future measures aimed at reducing oxides of nitrogen (NO_X) and greenhouse gas (GHG) emissions from HDVs (ARB, 2016a). Some highlights of the current suite of control programs are the following:

1. **The 2008 Truck and Bus Regulation** requires privately and federally owned diesel-fueled trucks and buses and privately and publicly owned school buses to fully upgrade to newer, cleaner engines by 2023.
2. **The 2008 Heavy-Duty Tractor-Trailer GHG Regulation** improves fuel efficiency of HDV tractors pulling 53-foot or longer box-type trailers through use of aerodynamic fittings and low rolling resistance tires.
3. **The 2007 Drayage Truck Regulation** accelerates the reduction of NO_X and particulate matter (PM) emissions and reduces the associated community health risks from diesel-fueled engines that move goods into and out of California ports and railyards.
4. **Various Incentive Programs** including the Carl Moyer Program, the Low Carbon Transportation and AQIP, the Loan Incentives Program, and the Proposition 1B Program promote emissions reductions by providing funding to upgrade or replace mobile source engines sooner than required by law.

Further building on these successes, ARB is looking at additional reduction of HDV emissions by potentially implementing the following measures:

1. Low NOx engine standard,
2. Heavy duty inspection/maintenance program,
3. Innovative Clean Transit and Last Mile Delivery,
4. Phase II GHG Standards, and
5. Introduction of zero and near-zero emissions technology.

To evaluate the benefits of these measures, it is critical to characterize the operating HDV fleet as accurately as possible. This work focuses on studying the annual miles accrued by HDVs to potentially update existing assumptions in the EMFAC model. As described in Section 2, the current EMFAC values are largely based on the 2002 federal Vehicle Inventory and Use Survey (VIUS). In 2018, the California Department of Transportation released the results of a California-specific VIUS (hereafter referred to as the Cal-VIUS), which we include in this work. In addition, the fleet management company Geotab (www. geotab.com) provided aggregate summaries of vehicle-miles traveled (VMT) data based on GPS data logging by their HDV customers. The Geotab data were instrumental in this work and demonstrate that telematics can be used to update emissions models and inventories.

Section 3 of the report describes ERG's assessment of data sources for this work. Section 4 outlines the methodology for processing the various data type into profiles of annual miles accrued per year per HDV, by model year, weight class group, and vocation. Section 5 concludes with a summary of the work and recommendations for the future. Sections 6 and 7 contain the acknowledgements and references.

2.0 Background on Current HDV Accruals in EMFAC

The term *accrual rate* refers to the annual miles accumulated per vehicle. Accrual rates vary by age and generally decrease for older vehicles; the accrual rates also vary by vehicle category of gross vehicle weight rating (GVWR) class, interstate vs. in-state operation, trailer vs. single unit body type, and vocation. Accrual rate annual miles are different from *odometer* cumulative miles. The odometer schedules are not necessarily consistent with the accrual rates because vehicles can move between categories as they age (ARB, 2008). A common example of this is that new tractor-trailer trucks may be used for inter-state hauling, and after some aging the truck could be sold and instead used for goods movement at ports.

According to documentation for the 2008 Truck and Bus Regulation, the primary data source behind the current accrual rates in EMFAC is the federal 2002 VIUS (ARB, 2008). The 2002 VIUS data inform the accruals of the heavy-heavy out-of-state and in-state, tractors and single unit trucks, with a few exceptions for specific HDV categories: drayage tractors, agricultural vehicles, utility vehicles, and school buses. Separate ARB surveys were used to build the accrual schedules for ag and utility trucks as well as school buses, while a trip-based model was used to estimate accruals for drayage trucks as part of the 2007 Drayage Truck Regulation. Power Take-Off mileage accruals assumptions in EMFAC were calculated from fuel usage data provided by the California State Board of Equalization, coupled with EMFAC model speed distributions and fuel economy.

As of the 2018 model technical documentation, EMFAC2017 has changed the mappings of T6 heavy (GVWR Class 7) categories to use the T7 (GVWR Class 8) accrual rates instead of the T6 small (GVWR Class 4-6) accrual rates (ARB, 2018). ARB provided ERG with the current set of EMFAC accrual rates for HDVs for this work. Table 2-1 shows the mapping of EMFAC's current 14 unique accrual profiles with 34 vehicle categories, and Table 2-2 shows the miles for each profile. There are two common traits of the accrual rate schedules in Table 2-2. First, the miles for age -1 is usually a calculated value of the fraction 5/12 multiplied by the age 0 miles. Second, the accrual rate schedules tend to be capped at 15 years old.

Table 2-1. EMFAC2017 Accrual Rate Schedule Assignments

Profile Number	Fleet
1	T6 Ag below 10000
	T6 Ag specialty
	T7 Ag below 10000
	T7 Ag specialty
2	T6 Public
	T6 utility
3	T7 Public
	T7 utility
4	T6 Ag 15/20/25
	T7 Ag 15/20/25
5	SBUS
6	T7 SWCV
7	T6 CAIRP small
	T6 instate construction small
	T6 instate small
	T6 OOS small
8	All Other Buses

Profile Number	Fleet
9	PTO
	T6 instate construction heavy
	T7 single
	T7 single construction
	T7 tractor construction
10	Motor Coach
11	T6 instate heavy
	T7 other port
	T7 tractor
12	T7 POAK
13	T7 POLA
14	T6 CAIRP heavy
	T6 OOS heavy
	T7 CAIRP
	T7 CAIRP construction
	T7 NNOOS
	T7 NOOS

Table 2-2. EMFAC2017 Accrual Rate Schedule Values (miles per year)

Age (years old)	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6	Profile 7	Profile 8	Profile 9	Profile 10	Profile 11	Profile 12	Profile 13	Profile 14
-1	1,631	2,968	3,240	5,339	5,945	6,515	10,879	11,207	16,902	22,917	32,045	38,794	42,446	43,847
0	3,915	7,122	7,776	12,813	14,269	15,635	26,110	26,897	40,564	55,000	76,909	38,794	42,446	105,234
1	3,843	7,000	7,776	12,724	14,130	15,635	26,110	26,903	38,807	55,000	76,909	38,794	42,446	105,141
2	3,772	6,879	7,776	12,635	13,990	15,635	26,223	26,661	36,629	55,000	76,003	38,794	42,446	102,228
3	3,703	6,757	7,776	12,547	13,851	15,635	25,740	26,207	34,258	55,000	73,662	38,794	42,446	97,292
4	3,635	6,636	7,776	12,460	13,712	15,635	24,850	25,577	31,877	55,000	70,325	38,794	42,446	91,028
5	3,567	6,514	7,776	12,373	13,572	15,635	23,709	24,800	29,633	55,000	66,367	38,794	42,446	84,030
6	3,502	6,392	7,776	12,287	13,433	15,635	22,444	23,905	27,630	55,000	62,107	38,794	42,446	76,791
7	3,437	6,271	7,776	12,202	13,293	15,635	21,151	22,921	25,931	55,000	57,802	38,794	42,446	69,707
8	3,374	6,149	7,776	12,117	13,154	15,635	19,896	21,870	24,560	55,000	53,651	38,794	42,446	63,069
9	3,312	6,028	7,776	12,033	13,015	15,635	18,712	20,776	23,499	49,500	49,792	38,794	42,446	57,069
10	3,251	5,906	7,776	11,949	12,875	15,635	17,606	19,659	22,691	44,550	46,304	38,794	42,446	51,799
11	3,191	5,784	7,776	11,866	12,736	15,635	16,551	18,537	22,036	40,095	43,206	38,794	42,446	47,251
12	3,132	5,663	7,776	11,783	12,596	15,635	15,490	17,425	21,395	36,086	40,459	38,794	42,446	43,315
13	3,074	5,541	7,776	11,701	12,457	15,635	14,338	16,339	20,590	32,477	37,960	38,794	42,446	39,780
14	3,017	5,420	7,776	11,620	12,318	15,635	12,976	15,287	19,398	29,229	35,552	38,794	42,446	36,336
15	2,962	5,298	7,776	11,539	12,178	15,635	11,257	14,281	17,560	26,306	33,013	38,794	42,446	32,572
16	2,962	5,298	7,776	11,539	12,178	15,635	11,257	14,281	17,560	26,306	33,013	38,794	42,446	32,572
17	2,962	5,298	7,776	11,539	12,178	15,635	11,257	14,281	17,560	26,306	33,013	38,794	42,446	32,572
18	2,962	5,298	7,776	11,539	12,178	15,635	11,257	14,281	17,560	26,306	33,013	38,794	42,446	32,572
19	2,962	5,298	7,776	11,539	12,178	15,635	11,257	14,281	17,560	26,306	33,013	38,794	42,446	32,572
20+	2,962	5,298	7,776	11,539	12,178	15,635	11,257	14,281	17,560	26,306	33,013	38,794	42,446	32,572

3.0 Task 1: Assess Data Sources

Several sources of vehicle mileage were considered for this work. To ensure that EMFAC model results reflect real world operations, several criteria guided the types of data selected. First, the data had to be current within the past five years. Second, the data had to be associated with HDVs with a known (1) age, (2) weight class, and (3) vocation. Third and finally, ARB strongly preferred the data to be California-specific, though other state data is acknowledged to have some use for specific vocations, such as non-school buses. The datasets assessed for this work included telematics (Section 3.1), survey data (Sections 3.2 and 3.3), and data from two out-of-state HDV inspection programs (Section 3.4).

3.1 Geotab Telematics Data

Geotab is a fleet management company headquartered in Ontario, Canada with over 1. 3 million GPS tracking devices in operation on HDVs (https://www.geotab.com/). The devices continuously ping Geotab's customers' vehicle locations to central servers, which record a subset of the data points – only enough to calculate accurate VMT. By using a patented algorithm, Geotab knows when the vehicle makes a maneuver (such as turn) that would affect the distance calculation from the most recent recorded data point. By limiting the data storage to only the necessary information, Geotab can collect more data on a greater number of vehicles than would otherwise be possible, all while being able to calculate total miles traveled during the period of time an HDV is logging data. Geotab can identify which vehicles operate (1) solely in California and (2) sometimes in California. This is particularly useful for updating the EMFAC model which relies on the concept of in-state vehicles vs. out-of-state ones that sometimes travel to California or are registered in the state but travel elsewhere. Geotab also knows the gross vehicle weight rating (GVWR), vehicle model year, body type, and vocation of many but not all its fleet customers. The Geotab data available for this work is California-specific and recent (January 1 to December 31, 2018).

Geotab partnership is required to access the data because they do not provide any individual vehicle's or single fleet's information, not even anonymously. Instead, Geotab will aggregate their vehicle data into summary-level data records before providing it to third parties. Close interaction is required with Geotab staff to communicate specific project needs and data validation steps desired, etc., because Geotab staff perform all the data aggregations and checks. Geotab provided data for this effort for (1) a Main Analysis and two smaller side analyses including (2) an Air Basin level analysis and (3) a School Bus Analysis.

The Main Analysis delivery from Geotab was comprised of two files (identically formatted) having the data field names and descriptions in Table 3-1. The first file, labeled "In-State," contained only vehicles with 99.5% to 100% of their VMT within the geographic boundary of California. The second file, labeled "Out-of-State," contained vehicles that travel to California at least once during 2018 and had less than or equal to 99.5% of their VMT inside the state. The In-State file contained 82,988 trucks aggregated onto 570 data rows, while the Out-of-State file contained 33,651 trucks aggregated onto 320 rows. Each row was categorized by the fields Model Year, Data Year (always 2018) Weight Class, Body, and Vocation. Although Geotab

provided a total sample size of 116,639, only 53,365 trucks could be used for this work (less than half) due to missing model year and weight class.

Table 3-1. Data Fields and Description of the 'Main Analysis' Geotab Delivery Files

Geotab Data Field Name	Description of the Data Values
ModelYear	22 model years (1998 - 2019) or a blank for HDVs with unknown model year.
DataYear	1 value (2018) indicating the data reporting period of Jan. 1 - Dec. 31, 2018.
WeightClass	5 values, defined by GVW A: "T6 Small" [14,001 - 26,000 lbs.], "T6 Heavy" [26,001 - 33,000 lbs.], "T7" [33,001+ lbs.], "Other" [< 14,001 lbs.], or "Unknown"
Body	2 values: "Tractor" [known tractor-trailers] or "Not Tractor" [everything else]
Vocation	9 values (blank, Service, OnDemand, Patroller, QuickStop, DoorToDoor, LongDistance, LocalSchoolTransport, and TourBasedWorkerVehicle)
VMT_CA	Total miles logged inside California (CA) by all HDVs in 'VehicleCount'
VMT_Total	Total miles logged inside or outside CA by all HDVs in 'VehicleCount'
Vehicle_Days_Total	Time period indicating the number of vehicle-days of HDV reporting.
Calendar_Days_Elapsed_Total	Time period indicating the total elapsed days of HDVs reporting data. This period is either the same or longer than the data field 'Vehicle_Days_Total. '
VMT_Day_CA_Avg	Average VMT per HDV per day inside CA, reflecting equal weighting of the HDVs in the data field 'VehicleCount. '
VMT_Day_Total_Avg	Average VMT per HDV per day inside+outside CA, reflecting equal weighting of the HDVs in the data field 'VehicleCount. '
VehicleCount	The number of vehicles.
AverageDaysOperating	Range of values from 35 to 177 days, representing the average number of days per vehicle where data was logged during 2018.
VMT_Day_CA_1P [B]	The 1st, 5th, 20th, 50th, 80th, 95th or 99th percentile [B] for the data field 'VMT_Day_CA_Avg'.
VMT_Day_CA_5P	
VMT_Day_CA_20P	
VMT_Day_CA_50P	
VMT_Day_CA_80P	
VMT_Day_CA_95P	
VMT_Day_CA_99P	
VMT_Day_CA_StdDev [C]	The standard deviation [C] for the data field 'VMT_Day_CA_Avg. '
VMT_Day_Total_1P	The 1st, 5th, 20th, 50th, 80th, 95th or 99th percentile for the data field 'VMT_Day_Total_Avg'.
VMT_Day_Total_5P	
VMT_Day_Total_20P	
VMT_Day_Total_50P	
VMT_Day_Total_80P	
VMT_Day_Total_95P	
VMT_Day_Total_99P	
VMT_Day_Total_StdDev	The standard deviation for the data field 'VMT_Day_Total_Avg. '

[A] GVW is the Gross Vehicle Weight in pounds (lbs.)
[B] Percentile is a metric indicating the value below which a certain percentage of observations in the group falls.
[C] Standard deviation is a metric indicating the amount of variation or dispersion of the observations within a group.

The data fields for the Air Basin Analysis are shown in Table 3-2. The data fields are nearly the same as the Main Analysis except for the addition of Basin_Name and VMT_Basin. The purpose

of this deliverable was to investigate any differences by region of California; however, ERG found that the accrual profiles were similar by basin.

Table 3-2. Data Fields and Description of the 'Air Basin Analysis' Geotab Delivery

Geotab Data Field Name	Description of the Data Values
ModelYear	22 model years (1998 - 2019) or a blank for HDVs with unknown model year.
DataYear	1 value (2018) indicating the data reporting period of Jan. 1 - Dec. 31, 2018.
WeightClass	5 values, defined by GVW A: "T6 Small" [14,001 - 26,000 lbs.], "T6 Heavy" [26,001 - 33,000 lbs.], "T7" [33,001+ lbs.], "Other" [< 14,001 lbs.], or "Unknown"
Body	2 values: "Tractor" [known tractor-trailers] or "Not Tractor" [everything else]
Vocation	9 values (blank, Service, OnDemand, Patroller, QuickStop, DoorToDoor, LongDistance, LocalSchoolTransport, and TourBasedWorkerVehicle)
Basin_Name	10 values indicating name of the Air Basin (MOJAVE DESERT, MOUNTAIN COUNTIES, NORTH CENTRAL COAST, SACRAMENTO VALLEY, SALTON SEA, SAN DIEGO COUNTY, SAN FRANCISCO BAY AREA, SAN JOAQUIN VALLEY, SOUTH CENTRAL COAST, SOUTH COAST)
VMT_Basin	Total miles logged inside the Air Basin by all HDVs in 'VehicleCount'
VMT_CA	Total miles logged inside California (CA) by all HDVs in 'VehicleCount'
VMT_Total	Total miles logged inside or outside CA by all HDVs in 'VehicleCount'
Vehicle_Days_Total	Time period indicating the number of vehicle-days of HDV reporting.
Calendar_Days_Elapsed_Total	Time period indicating the total elapsed days of HDVs reporting data. This period is either the same or longer than the data field 'Vehicle_Days_Total. '
VMT_Day_CA_Avg	Average VMT inside California per HDV per day, reflecting equal weighting of the HDVs in the data field 'VehicleCount. '
VMT_Day_Total_Avg	Average VMT total per HDV per day, reflecting equal weighting of the HDVs in the data field 'VehicleCount. '
VehicleCount	The number of vehicles.
AverageDaysOperating	Range of values from 36 to 204 days, representing the average number of days per vehicle where data was logged during 2018.
VMT_Day_CA_1P [B]	The 1st, 5th, 20th, 50th, 80th, 95th or 99th percentile[B] for the data field 'VMT_Day_CA_Avg'.
VMT_Day_CA_5P	
VMT_Day_CA_20P	
VMT_Day_CA_50P	
VMT_Day_CA_80P	
VMT_Day_CA_95P	
VMT_Day_CA_99P	
VMT_Day_CA_StdDev [C]	The standard deviation[C] for the data field 'VMT_Day_CA_Avg. '
VMT_Day_Total_1P	The 1st, 5th, 20th, 50th, 80th, 95th or 99th percentile for the data field 'VMT_Day_Total_Avg'.
VMT_Day_Total_5P	
VMT_Day_Total_20P	
VMT_Day_Total_50P	
VMT_Day_Total_80P	
VMT_Day_Total_95P	
VMT_Day_Total_99P	
VMT_Day_Total_StdDev	The standard deviation for the data field 'VMT_Day_Total_Avg. '

[A] GVW is the Gross Vehicle Weight in pounds (lbs.)

[B] Percentile is a metric indicating the value below which a certain percentage of observations in the group falls.
[C] Standard deviation is a metric indicating the amount of variation or dispersion of the observations within a group.

Geotab's third and final delivery for this work was a school bus operation summary of their fleet customers with the vocation "Local School Transport. " Geotab aggregated their school bus VMT data for each week of 2018 by weekday and weekend multi-day portion of the week. ERG noticed that was not a strong seasonal trend in VMT by month, likely due to California's track system of rotating school years. With exception of holiday weeks of New Years and Christmas, the weekend day school bus VMT was close to a mean fraction of 0. 12 of the weekday VMT (range from approximately 0. 05 to 0. 20 by non-holiday weeks).

Table 3-3. Data Fields and Description of the 'School Bus Analysis' Geotab Delivery

Geotab Data Field Name	Description of the Data Values
Week_Num	53 values (0 - 52) corresponding to the week number of 2018. Weeks 0 and 52 are partial weeks of Jan 1-6 and Dec 30-31, respectively.
Week_Start	53 values corresponding to the start date of the week in MM/DD/YYYY format (1/1/2018 – 12/30/2018).
Week_End	53 values corresponding to the end date of the week in MM/DD/YYYY format (1/6/2018 – 12/31/2018).
VMT_Total	VMT from all School Buses for the week.
Weekday_Start	Date of the first weekday in the week, MM/DD/YYYY.
Weekday_End	Date of the last weekday in the week, MM/DD/YYYY.
VMT_Weekday	VMT from all School Buses during weekdays.
Weekend_Start	Date of the first weekend day in the week, MM/DD/YYYY.
Weekend_End	Date of the last weekend day in the week, MM/DD/YYYY.
VMT_Weekend	VMT from all School Buses during weekend days.
VehicleCount	Number of School Buses in the sample.

Geotab's knowledge of the vocation of its fleet customers was important to be able to match vehicle data to EMFAC categories this work. Geotab has a standardized list of 15 different vocations listed in Table 3-4. The original 15 categories caused a large amount of data to drop out of the Air Basin analysis due to privacy concerns about individual fleets being isolated on some rows. To remedy the small samples, ERG asked Geotab to aggregate their 15 vocations into 8 similar groups, which worked to reduce noise in the Air Basin Analysis. For consistency, Geotab used the same 8 vocation groups throughout the two Main Analysis files as well.

Table 3-4. Geotab Vocation Names, Descriptions, and Examples

Aggregated 8 Vocations	Original 15 Vocations	Description	Examples
Service	All Hours Tour With Long Stop	Operates at all hours going point-to-point and spends a long time at these locations.	Energy company
	Daytime Tour With Long Stop	Operates during the business day going point-to-point and spends a long time at these locations.	Cable / phone / internet installers, Food and Beverage Delivery
	Nighttime Tour With Long Stop	Operates during the night and/or overnight going point-to-point and spends a long time at these locations.	
	Hub Spoke Long Stop	Operates back and forth from a central hub and makes long stops prior to returning to the hub. This is usually over a wider geographic area.	On-site service and repair
	Local At All Hours	Operates at all hours of the day within a local area (usually within a 3-mile radius).	Yard management, Mining
Door To Door	Door To Door	Visits many locations in several small geographic areas that usually cover a wider area. This could be planned routes in similar geographic areas.	Couriers
Quick Stop	Hub Spoke Quick Stop	Operates back and forth from a central hub and makes quick stops prior to returning to the hub. This is usually over a wider geographic area.	Pizza Delivery, Parts Delivery
	Local Quick Stop	Makes many quick stops in a local area (usually within a 3-mile radius). The trips might be in a star or tour-based topology, but locations are very local.	Courier, Delivery
Local School Transport	Local School Transport	Operates in the morning and mid-afternoon within a local area (usually within a 3-mile radius).	School buses
Long Distance	Long Distance All Hours	Operates over long distances at all hours of the day.	Long haul
	Long Distance Daytime	Operates over long distances usually only during night hours.	Long haul
	Long Distance Overnite	Operates over long distances usually only during business hours.	Long haul
null	null	Unknown Vocation	
Patroller	Patroller	Drives a significant amount throughout the course of the day where the distance between origin and destination is not a straight shot. There is in general more driving than idling for this vocation.	Taxi, Police, Uber
Tour Based Worker Vehicle	Tour Based Worker Vehicle	Drives a significant amount throughout the course of the day where the distance between origin and destination is not a straight shot. There is in general more idling than driving for this vocation.	Utility Vehicles, Garbage Trucks

3.2 California Vehicle Inventory and Use Survey

The national Vehicle Inventory and Use Survey (VIUS) program used to support a broad range of vehicle analyses including for planning and policy. Ever since it was discontinued in 2002, the data are becoming increasingly outdated due to new trends in the trucking industry. The California Department of Transportation (Caltrans) directed the Cal-VIUS effort to replace the California portion of the national VIUS by collecting new information about the trucking fleet operating in the state. The information from the survey includes physical characteristics (such as age, GVWR, operating fuel type, body style, trailer type, etc.) and operational data (such as total mileage estimated in the past 12 months).

Caltrans' contractor sent surveys to many fleet owners and received responses for nearly 14,800 individual vehicles for an overall response rate of 5%. Caltrans provided the results electronically in the file "CAVIUS_2018_SurveyData. xlsx" in December 2018 for this work. The Excel file contained 78 data fields across the columns and 14,789 rows – one for each VIN. Table 3-5 lists the 14 data fields used in this study.

Table 3-5. Cal-VIUS Survey Data Fields and Descriptions, Subset for this Work

Cal-VIUS Data Field	Description of the Data Values
Region	6 values (CA SURROUNDING, CENTRAL COAST/CENTRAL VALLEY, LA/INLAND EMPIRE/SD, OTHER REGION, REST OF STATE, SACRAMENTO/BAY AREA).
Survey Year	3 values (2016, 2017, or 2018)
Dataset	2 values (DMV or IRP)
Model Year	41 values (1974, 1977, and 1980-2018)
State	51 values of state or Canadian province (e.g., California, Alberta, Arizona, etc.)
GVW [A]	6 values: 1. Class 3 (10,001 - 14,000 lbs.) 2. Class 4 (14,001 - 16,000 lbs.) 3. Class 5 (16,001 - 19,500 lbs.) 4. Class 6 (19,501 - 26,000 lbs.) 5. Class 7 (26,001 - 33,000 lbs.) 6. Class 8 (> 33,000 lbs.)
Vehicle Type	2 values (Straight, Tractor)
Home Base Type	8 values: 1. Company office/headquarters 2. Distribution center 3. Manufacturing plant 4. Other 5. Private residence (home, farm, etc.) 6. Terminal/port/railyard 7. Transload facility 8. Blank
Annual VMT	values range from 1 to 220,000 miles. Best estimate of total miles during the last 12 months.
Inside CA	Percent of truck mileage during the last 12 months inside the state of CA.

Cal-VIUS Data Field	Description of the Data Values
Service Truck	2 values (Yes, No). Answer to the survey question: Is the truck a service truck (e.g., plumber or electrician) that does not haul any goods or cargo?
Commodity 1	16 values (e.g., Agriculture products, Crude petroleum, Logs, Waste material)
Trailer Type 1	10 values (e.g., Auto, Bulk, Container Chassis, Dry Van)
Weight	Survey Expansion Factor, values range from 8 to 1,288.

[A] GVW is the Gross Vehicle Weight in pounds (lbs.)

The "Region" field was useful in distinguishing the drayage trucks more likely to operate at the ports that are distinguished in EMFAC: Port of Oakland, Port of Los Angeles, and the rest of the state.

The "Survey Year" and "Model Year" fields together provide the age (years old) of the truck at the time of survey response.

The "Dataset," "State," and "Inside CA" fields together inform whether trucks align with the in-state vs. out-of-state (OOS) vehicle types in EMFAC described in Table 3-6.

Table 3-6. Assignment of Cal-VIUS Data to EMFAC Operation In/Out of State Vehicle Types

Dataset	Inside CA	State	Vehicle Type	Description	Number of VINs	Number of Weighted Vehicles
DMV	100	California	In-State	Operates only inside California	10,725	385,620
	<100	California	CAIRP	CA-registered vehicles that sometimes travel out of state	2,174	86,811
IRP		British Columbia (BC), Washington (WA), Oregon (OR), Idaho (ID), Nevada (NV), and Arizona (AZ)	NOOS	Neighboring State vehicles that travel to CA	314	51,711
		All **except** BC, WA, OR, ID, NV, and AZ.	NNOOS	Non-Neighboring State vehicles that travel to CA	1,576	235,555
Total					**14,789**	**759,698**

The "GVW" field allows categorization of the surveyed trucks into EMFAC weight categories of T6 small (Class 4-6), T6 heavy (Class 7), and T7 (Class 8) trucks. The "Vehicle Type" field in Table 3-5 indicates whether the truck was is a straight truck or tractor-trailer.

Two of the seven "Home Base Type" values were of interest in this work. The first, "Distribution center" was useful as a surrogate for delivery trucks, a possible new vocation type in the next

version of EMFAC. The second, “Terminal/port/railyard” identified drayage trucks that move goods at ports.

The “Annual VMT” is the data field providing the annual mileage accrual estimated for the vehicle.

The “Service Truck” field had two values: “Yes” for trucks that do not haul any cargo (e.g., a plumber or electrician) or “No” for trucks that haul goods or cargo. We used the “Service Truck” filtered for *Yes* as a surrogate to associate Cal-VIUS trucks with the EMFAC vocations Utility and Public.

The data fields “Commodity1” and “TrailerType1” were a set in a series of five (Commodity1 through Commodity5) to allow responses for trucks that haul different commodity types throughout the year. Tractor-trailer trucks can exchange trailers at any time as well. For example, a tractor truck can have a container-chassis trailer during summer months and switch to a box type trailer to move parcels in the fall. The suffix number from 1 to 5 indicates highest percentage of the time (1) to least (5). This flexibility of how tractor-trailers operate in the real world makes it difficult to match Cal-VIUS truck vocations based on commodity/trailer with the static EMFAC vocations. We look at Commodity1 and TrailerType1 as a simplification to understand how the truck is mostly used during the year.

Lastly, but importantly, the final data field “Weight” represents how the sampled vehicle types’ represent the universe of actual trucks operating in California. For example, a single VIN can have a “Weight” value anywhere from 8 to 1,288. The count of VINs is 14,789 while their weighted sum (from the “Weight” field) is 759,698 trucks, comparable to the 700,000 trucks the ARB reports has a GVWR of over 10,000 lbs. (CADOT, 2018). During subsequent analysis of Cal-VIUS described in Section 4.1, any aggregating or averaging of reported mileage over VINs is done using the weighted average using the values in the “Weight” field. Unweighted Cal-VIUS counts were used to weight any Cal-VIUS accrual rates prior to combining with Geotab accrual rates in this study (e.g., Figure 4-10).

3.3 School Bus Fleet Survey

The ARB conducted the 2016 School Bus Fleet Survey to understand the annual mileage of buses in California school districts to guide emissions-reduction investments by ARB and the Air Districts. Because mileage, bus weight, and model year are all provided, the results are useful to compare to existing school bus mileage in EMFAC. ARB provided the survey results electronically to ERG in September 2017 in the file “School Bus Survey Raw Data. xlsx.”

The survey results included records for 352 unique VINs, a small number compared to California’s total population which may range between 25,400 school buses (ARB, 2016b) to 26,500 school buses (ARB, 2016c). Table 3-7 shows each of the data fields included for each VIN, covering nine different school districts, four fuel types, 34 model years (body) or 32 model years (engine), the gross vehicle weight, reported annual mileage (in 2016) and cumulative mileage (odometer).

Table 3-7. School Bus Fleet Survey Data Fields and Descriptions

Survey Data Field Name	Description of the Data Values
VIN	vehicle identification number (VIN); 352 unique values of 17-digit VINs
Fleet Name	9 values (e.g., BALLICO-CRESSY SCHOOL DISTRICT, Chula Vista Elementary School District)
Fuel Type	4 values (CNG, Gasoline, Diesel, Propane)
Bus Model Year	34 values (1980, 1985-2017)
GVWR	gross vehicle weight, values range from 9,999 to 36,320 lbs., or blank
Engine Model Year	32 values (1980, 1986-1994, 1996-2016, 2019) or blank
Annual Mileage	values range from 256 to 32,327 miles, or blank
Cumulative Mileage	values range from 1,754 to 488,880 miles, or blank

3.4 State Inspection Program Odometer

State HDV inspection programs are a source of mileage data because the trucks appear at regular intervals to have their emission control systems evaluated and odometer readings recorded at specific test dates. Because the HDVs re-appear for testing regularly (on a 2-year cycle in some states), odometer readings from the same vehicle could be subtracted from two known points to calculate mileage accrued over the time period. The GVW class and model year are available from the VIN, and some limited vocation and operation information can be inferred from the body style and presence in IRP datasets or license plate type.

ERG obtained two states' diesel inspection and maintenance (I/M) program data from air agency contacts in Colorado and New Jersey. Unfortunately, we were not able to gather California HDV inspection data because the records were paper based rather than electronic, and they were not available for use.

The Colorado inspection dataset spanned the program years 2009 to 2017 and contained 600,000 records, although only 425,000 of those matched to the Colorado registration database – required to identify the GVW, model year, and vehicle type. After adding GVW to the Colorado inspection dataset, approximately three quarters of the data were excluded because the vehicles weighed less than 14,000 lbs. ERG then merged the data with Colorado's International Registration Plan (IRP) database to identify the vehicles in the inspection dataset with more likely long-haul operations. IRP-registered vehicles are those that plan to drive out of state, so IRP participation is a reasonable surrogate for long-distance operation as opposed to only local delivery trips. We then used the registration data's body type, GVW, and IRP participation to divide the Colorado inspection dataset vehicle types into the following seven categories: (1) School Bus, (2) Non-School Bus Short-haul, (3) Non-School Bus Long-haul, (4) T6 Short-haul, (5) T6 Long-haul, (6) T7 Short-haul, and (7) T7 Long-haul. Table 3-8 describes the categorization methodology. These categories were also assigned to the New Jersey I/M program data and to EMFAC vehicles for later comparison. The table below shows that there were about 97,000 classifiable records. Within those records, there were about 25,000 unique

VINs with multiple test dates during the 9 years of program data. On average, this is approximately 4 inspection dates (and therefore 4 odometer readings) per vehicle during the 9-year period.

Table 3-8. Summary of the HDV Test Records in Colorado's Inspection Program Database

Vehicle Type	Description	VIN-Test Frequency
Unclassifiable	Missing GVW or GVW is below 14,000 lbs.	327,732
BUS	These are vehicles with a registration vehicle type of "BUS" that are not school buses.	2,222
SBUS	These are vehicles with a registration vehicle type of "BUS" and a passenger type of "J".	2,008
T6 Short-haul	These are vehicles with a GVW of 14,001 – 33,000 lbs that were not in the IRP data.	60,452
T6 Long-haul	These are vehicles with a GVW of 14,001 – 33,000 lbs that were in the IRP data.	204
T7 Short-haul	These are vehicles with a GVW over 33,000 lbs that were not in the IRP data.	31,643
T7 Long-haul	These are vehicles with a GVW over 33,000 lbs that were in the IRP data.	993

The New Jersey data covered a shorter period – years 2013 to 2017 – and it contained a little over 260,000 records, though 60,000 of them weighed less than 14,000 lbs. The dataset did not require merging with state registration or IRP databases because the I/M data independently contained enough information to categorize the vehicle types for direct comparison to Colorado and EMFAC (discussed later in Section 4.3).
Table 3-9 shows the frequency of I/M records in the New Jersey dataset by the vehicle categories. In the New Jersey data, approximately 200,000 test records included 37,000 unique VINs, so vehicles appeared 5 times for an odometer reading during the 5-year period on average. We categorized the New Jersey program trucks as Long-haul where the bus or tuck had an "apportioned" license plate type.

Table 3-9. Summary of the HDV Test Records in New Jersey's Inspection Program Database

Vehicle Type	Description	VIN-Test Frequency
Unclassifiable	Missing GVW or GVW is below 14,000 lbs.	60,794
BUS	These are vehicles where the NJA_INSP_TYPE begins with a "CB".	39,160
SBUS	These are vehicles where the NJA_INSP_TYPE begins with an "S".	144,272
T6 Short-haul	These are vehicles with a GVW of 14,001 – 33,000 lbs. where the NJA_PLATE_TYPE is not "AP".	8,118
T6 Long-haul	These are vehicles with a GVW of 14,001 – 33,000 lbs. where the NJA_PLATE_TYPE is "AP".	1,273

Vehicle Type	Description	VIN-Test Frequency
T7 Short-haul	These are vehicles with a GVW over 33,000 lbs. where the NJA_PLATE_TYPE is not “AP.	3,695
T7 Long-haul	These are vehicles with a GVW over 33,000 lbs. where the NJA_PLATE_TYPE is “AP”.	5,804

4.0 Task 2: Analyze Data and Evaluate Current HDV Assumptions

In this task, ERG analyzed and processed the available data, performed calculations to transform the it into annual mileage accrual profiles, and comparing them to the current assumptions in EMFAC. The analyses and transformations are documented and discussed in this section. To the extent possible, EMFAC accrual profiles were compared to the new data categorized by the Sub-Level 3 groups shown in Table 4-1. In addition to the table below, school bus mileage accrual data are available from two sources, Geotab and the 2016 School Bus Fleet Survey.

Table 4-1. Scope of Work and Additional HDV Categories with Sample Sizes

Weight Class	Sub-Level 1	Sub-Level 2	Sub-Level 3	Geotab N	Cal-VIUS N	Cal-VIUS Weighted N
Class 7 to 8	Inter-state	Tractor	All Long-haul Trucks	3,791	3,083	294,905
	Intra-state	Tractor	Port Trucks	-	169	10,722
			Utility Trucks	1,214	55	3,001
			Public Trucks			
		Single	Delivery Truck	*See combined T6 Delivery*		
			Construction	*N/A*		
			Solid Waste Refuse Trucks	103	100	6,778
			Utility Trucks	2,280	171	10,272
			Public Trucks			
Class 4 to 6	Intra-state	Single	Class 7 Delivery and Class 4-6 Last Mile Delivery Trucks	1,452	275	3,001
			Airport Shuttle Buses	*N/A*		
Additional Categories						
Class 4 to 6	Intra-state	Single	Public/Utility Trucks	3,955	1,058	33,963
Class 4 to 6	Inter-state	Single	T6 small Out-Of-State	9,439	504	29,995
Class 7	Intra-state	Single/ Tractor	T6 heavy in-state other [A]	2,247	468	27,721
Class 8	Intra-state	Tractor	T7 tractor in-state other [A]	4,265	1,286	78,781
Class 8	Intra-state	Single	T7 single in-state other [A]	4,852	427	25,339
Any weight class	Intra-state	Single	School Buses [B]	295	-	-
Class 4 to 6	Intra-state	Single	T7 small in-state other [A]	8,924	4,121	110,890
Totals				**42,817**	**11,717**	**635,369**

[A] "Other" means these vehicles are not included already by the other categories Public/Utility, Delivery, etc.

[B] The ARB School Bus Fleet Survey also provides N=352 school buses for this category.

4.1 Geotab and Cal-VIUS Analyses

Geotab

The Geotab Main Analysis deliverables (In-State and Out-Of-State) contained summaries of vehicle groups where individual rows represented anywhere from 3 to 3,405 vehicles. To leave data calculation options open for ARB, we requested that Geotab provide VMT two different ways: (1) as a total VMT for all vehicles-days logged reported in the row, and (2) as a Daily VMT that was the average (mean) of all vehicles on the row. Geotab provided the VMT metrics (total logged and Daily VMT) for both California-only and Total travel. The list below summarizes these four key mileage data fields.

Data Field Name	Description
1. VMT_CA	VMT logged inside California for multiple vehicle-days logged
2. VMT_Total	VMT logged inside + outside CA for multiple vehicle-days logged
3. VMT_Day_CA_Avg	Daily VMT inside CA, averaged over multiple vehicles
4. VMT_Day_Total_Avg	Daily VMT inside + outside CA, averaged over multiple vehicles

The VMT logged totals (items 1 and 2 above) allow for the possibility of computing a VMT-weighted average for the accrual rate, whereas the Daily VMT metric (items 3 and 4) allow for the possibility of computing an accrual rate where each vehicle has equal weighting. The two averaging methods are described in more detail in Section 4.1.2. To better understand the raw data behind the daily VMT metrics, Geotab also provided ERG with statistics including the 1st, 5th, 20th, 50th, 80th, 95th, and 99th percentiles and standard deviation.

Below is an example of a real Geotab-based accrual profile for T6 Delivery Trucks. The black solid line series in Figure 4-1 is the average miles per day overlaid onto individual values of "VMT_Day_Total_Avg" from the Geotab In-State file delivery shown in blue *x* marks; both these values of Daily VMT correspond to the primary Y-axis. The secondary Y-axis shows the number of vehicles N behind the average at each age. For example, at age 0 the average VMT per day is 100 miles and the sample size N is 107 vehicles. There were 4 individual data points in the Geotab dataset at age=0 T6 delivery trucks, though one is difficult to see in the figure. The four data points from Geotab were:188. 5 miles (N=7), 105. 7 miles (N=57), 87. 3 miles (N=6), and 76. 4 miles (N=37).

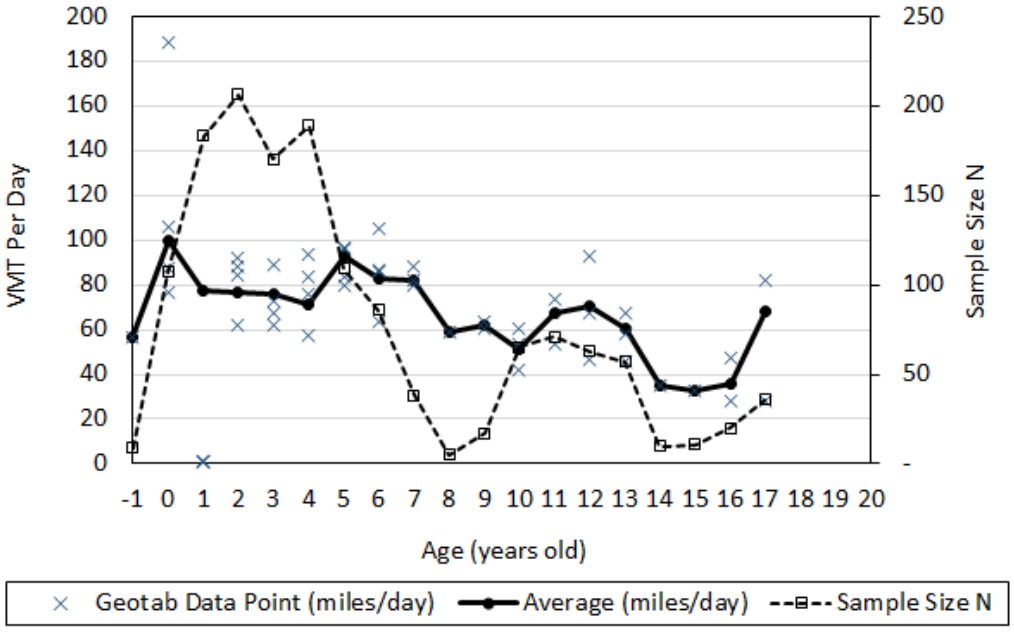

Figure 4-1. Sample Average VMT-Per-Day Accrual Profile

Figure 4-2 shows the spread of the data behind each Geotab value of VMT_Day_Total_Avg for these four data points at age 0 in Figure 4-1. The percentiles give an idea of the distribution of individual vehicles. The mean (VMT_Day_Total_Avg) is close to the 50th percentile in each Geotab data point. The first set of 7 vehicles range in daily VMT from 65 to 342 miles per vehicle per day.

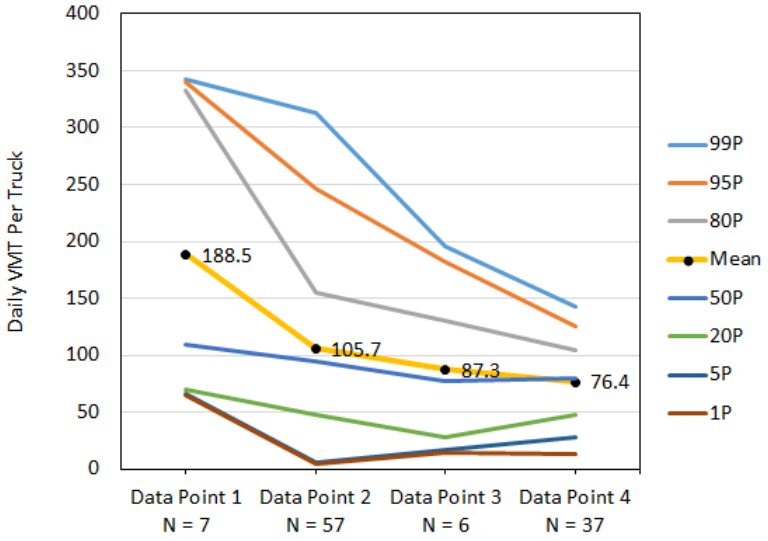

Figure 4-2. Distribution of VMT-Per-Day for Age 2 in Sample Accrual Profile

4.1.1 Scaling to Annual

Regardless of the VMT metric (vehicle-logged total or daily average), the Geotab VMT required transformation to an annual value. The current assumption in EMFAC is that HDVs operate 312 days per year for trucks and 327 for buses (personal communication with ARB by telephone, March 2019). So, one option would have been to apply that assumption to scale the new Geotab data to annual. However, the method selected for this study directly uses the Geotab data fields (1) Vehicle_Days_Total and (2) Calendar_Days_Elapsed_Total to understand the number of days operating per year, according to Equation 1. The Vehicle_Days_Total is the sum of days that the vehicles logged miles. For example, a single data row representing 3 vehicles could have a Vehicle_Days_Total value of 165 if the individual vehicles logged for 40, 60, and 65 days each; we would be able to understand the 165 number as 55 days per vehicle logged during 2018 on average (165/3=55) because we do not have any individual vehicle data from Geotab. Figure 4-3 shows the distribution of Vehicle_Days_Total per truck for all 116,639 trucks in the Main Analysis (In-State and Out-of-State together). Note that the smallest bin of days logged per vehicle is above 35 days. At the request of ARB, we asked Geotab to exclude data from individual vehicles logging for less than one month.

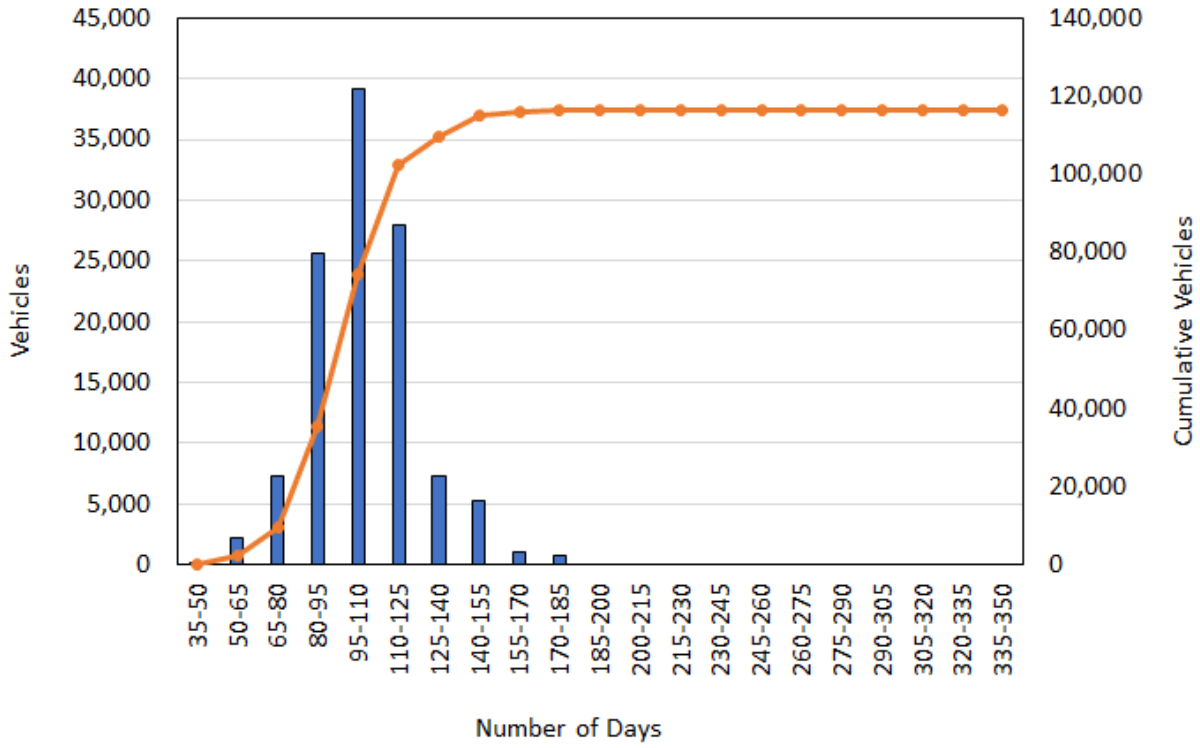

Figure 4-3. Distribution of Geotab Truck-Days Logged in Year 2018

Figure 4-4 shows the distribution of total calendar days elapsed for the 116,639 trucks. The distinction between the two is that Figure 4-3 shows the number of days vehicles drive in Geotab's sample, while calendar days elapsed is their total reporting period around logging periods including non-operation periods (e.g., weekends).

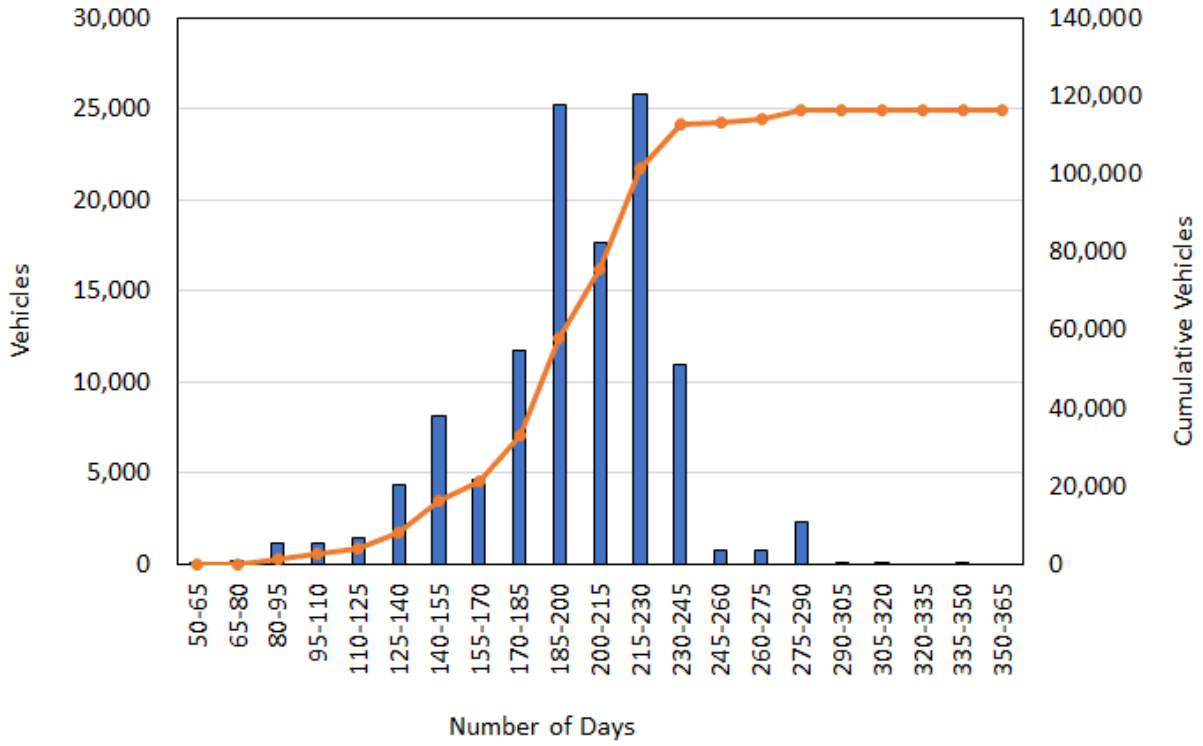

Figure 4-4. Distribution of Geotab Truck-Days Elapsed around Logging in Year 2018

Equation 1 below shows a data-driven way to calculate a scaling factor to annualize day VMT. The assumption behind this equation is that the operation pattern while vehicles are Geotab customers (Calendar_Days_Elapsed_Total) would be true for an entire year.

$$Scalar = \frac{Vehicle\_Days\_Total}{Calendar\_Days\_Elapsed\_Total} * 365 \qquad \text{Eqn. 1}$$

Where:

Scalar is the number of days per year a vehicle operates for each data row. See Figure 4-5 for the final scalar values used in this work.

Vehicle_Days_Total is a Geotab data field containing the number of vehicles multiplied by their days logging VMT, for each data row.

Calendar_Days_Elapsed is the Geotab data field containing the number of vehicles multiplied by their total time period of reporting data to Geotab.

365 is the number of days in a non-leap year.

The average scalar calculated by Equation 1 range is just shy of 200 days per year. This is significantly fewer days than the 312 days assumed in EMFAC. Figure 4-5 shows the distribution of annual scalars in the Geotab data from Equation 1.

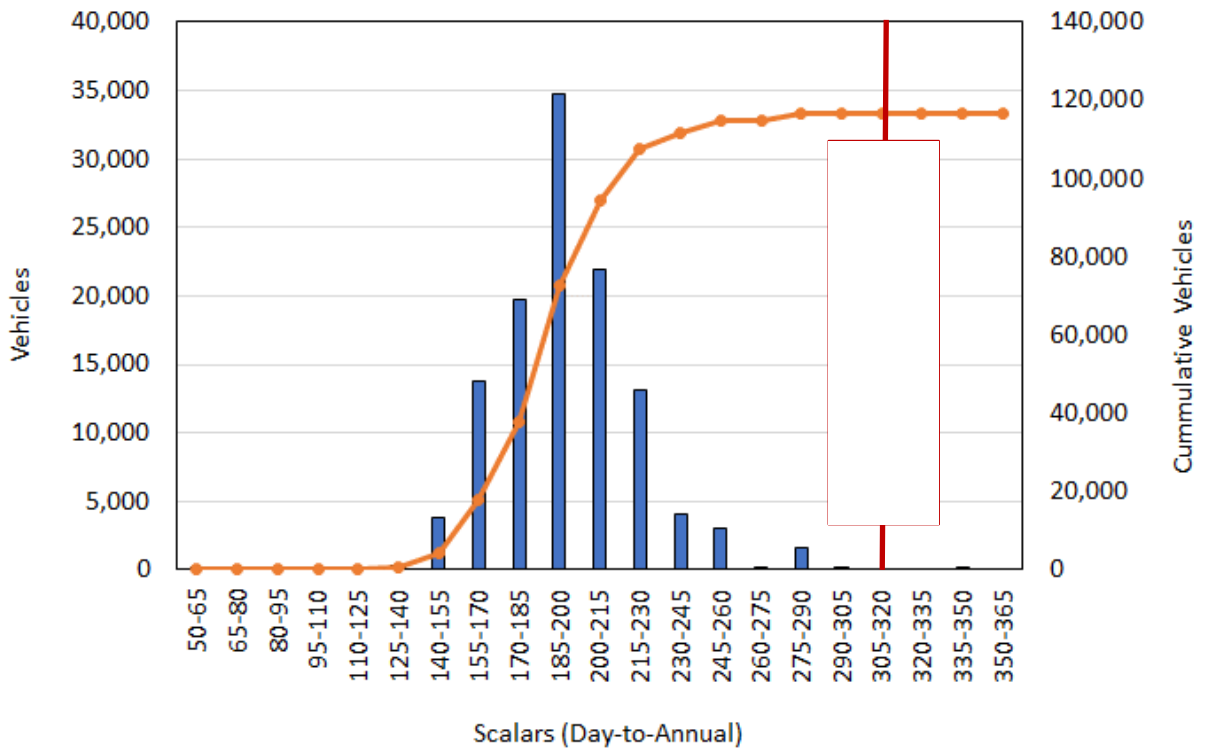

Figure 4-5. Distribution of Geotab-based Equation 1 Scaling Factors

4.1.2 Averaging Method

As previously mentioned, Geotab provided VMT data two ways: total logged (data field 'VMT_Total') and daily (data field 'VMT_Day_Total_Avg'). The former VMT metric (total logged) allows for creating VMT-weighted average miles by age by using Equation 2. To combine over multiple rows, the VMT_Total can simply be summed, then divided by the sum of total days logged.

$$Day\ VMT_{Weighted} = \frac{\sum_r VMT\_Total}{\sum_r Vehicle\_Days\_Total} \qquad \text{Eqn 2.}$$

Where: ***Day VMT$_{Weighted}$*** is the VMT-weighted average miles per day.
VMT_Total is a Geotab data field containing the total number of miles traveled by all vehicles on a row ***r***.
Vehicle_Days_Total is a Geotab data field containing the number of vehicles multiplied by their days logging VMT, for each data row ***r***.

The alternative to VMT-weighting is to allow each vehicle to have equal importance in the average. Equation 3 shows how to combine equal weighted daily VMT into more aggregate

groups. Figure 4-6 shows the difference between the Eqn 2 and 3 approach for an example accrual profile, Class 7 and 8 trucks that operate in-state.

$$Day\ VMT_{Equal} = \frac{\sum_r (VMT\_Day\_Total\_Avg \times VehicleCount)}{\sum_r VehicleCount} \quad \text{Eqn 3.}$$

Where: ***Day VMT$_{Equal}$*** is the mean daily miles over all vehicles in any group.
VMT_Day_Total_Avg is a Geotab data field containing the daily VMT per truck averaged over all vehicles on a row ***r***.
VehicleCount is a Geotab data field containing the number of vehicles reporting data on row ***r***.

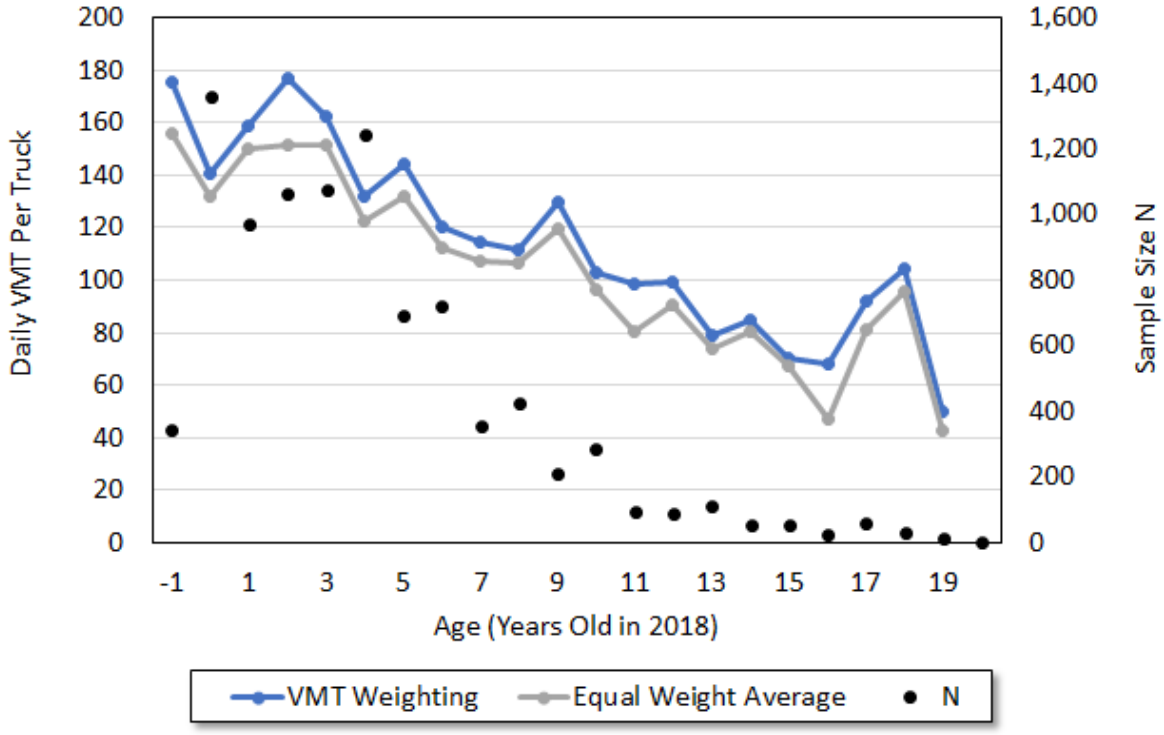

Figure 4-6. Averaging Method Effect on Daily VMT Per Truck for Sample Accrual Profile

The recommended approach for processing Geotab data for EMFAC is to use equal weighting (Eqn. 3) with the Geotab-data-based scaling approach (Eqn. 1). Putting these together results in Equation 4 below. All the Geotab results presented in the rest of this report rely on equal weighting and data-driven scaling to annual.

$$Annual\ VMT = \frac{\sum_r (VMT\_Day\_Total\_Avg \times VehicleCount)}{\sum_r VehicleCount} \times Scalar$$ Eqn 4.

Where: ***Annual VMT*** is the average annual miles accrued.
VMT_Day_Total_Avg is a Geotab data field containing the daily VMT per truck averaged over all vehicles on a row ***r***.
VehicleCount is a Geotab data field containing the number of vehicles reporting data on row ***r***.
Scalar converts day VMT to annual; see Eqn 1.

Cal-VIUS

Calculations with the Cal-VIUS data proceeded differently than Geotab data in two main ways. First, the Cal-VIUS mileage does not require scaling to annual despite some of the surveyed vehicles reporting that they only operated part of the year. Second, the averaging of individual vehicles' mileage into larger categories (for example, Class 4 through 6 trucks rolling up to "T6 small") required the use of population-based weighting factors, documented previously in Table 3-5, to reflect the sample vehicles' proportion in the California fleet. In contrast, our recommended approach for Geotab averaging was to proceed using an unweighted average where each vehicle has equal importance.

Cal-VIUS Reporting of Direct Annual Miles

The VMT reported for each vehicle reflects a complete 12-month history of activity, due to the wording of the survey question. The survey responses trickled in over a three-year period from 2016 to 2018, according to the data field "Survey Year" (refer to Table 3-5). Regardless of when fleet owners responded to the survey (e.g., April 2017), they reported their vehicles' mileage estimates for the past 12-months (e.g., May 1, 2016 to April 30, 2017). In contrast, the Geotab data did not necessarily capture a full year of activity for each truck, but rather was a snapshot of the distance driven during 2018.

The Cal-VIUS activity accounts for one year of VMT including periods of non-operation for many reasons. For example, some vehicles were taken out of service for repair, or not used for several months because of planned seasonal operation, etc. The survey asked whether vehicles were in operation in January through December, requesting a "Yes" or "No" response by month. Figure 4-7 summarizes the number of months in the year that the 14,789 VINs were in operation. Nearly 80% of the survey VINs were driving during all 12 months, while the other 20% operated between 1 and 11 months with a distribution slightly skewed toward fewer months.

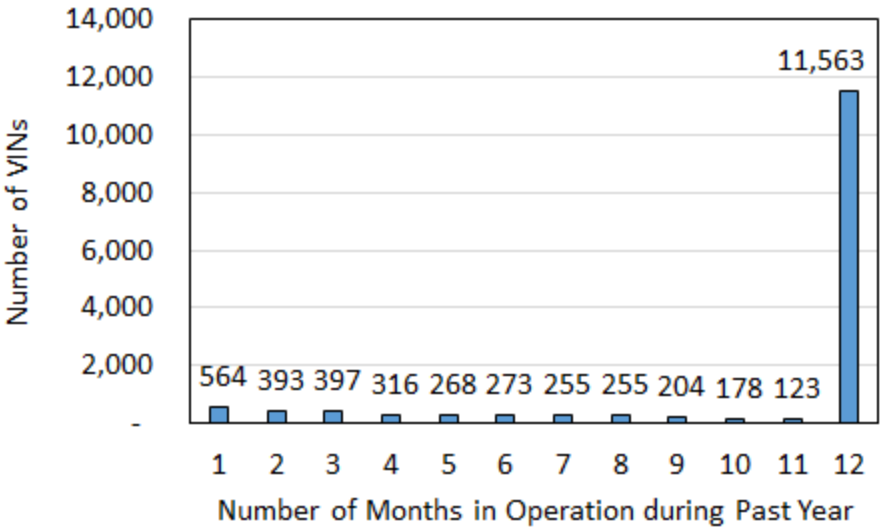

Figure 4-7. Cal-VIUS Truck Operation in the Past 12 Months

We considered scaling the miles from vehicles with partial-year operation to a full year using number of months. However, we ultimately judged that it was not appropriate to scale up the partial-year VMT because during any given year, trucks will be out of operation for periods of time and that the average reported from this sample should be representative.

Population Weighting in the Cal-VIUS

The calculation of annual mileage accrual for Cal-VIUS vehicle groups was a weighted average according to Equation 5.

$$Annual\ Mileage\ Accrual_{A,V} = \frac{\sum_A (AnnualVMT_i \times Weight_i)}{\sum_A Weight_i} \quad \text{Eqn 5.}$$

Where: ***Annual Mileage Accrual$_{A,V}$*** is the number of miles accrued during one year for each vehicle group ***V*** comprised of individual vehicles ***i*** that are age ***A*** years old.
A is the age of the vehicle (years old), calculated by subtracting the Model Year from the Survey Year data field.
V is the vehicle group made up of individual vehicles ***i*** that share similar characteristics.
AnnualVMT is the data field containing estimated 12-month VMT for individual vehicles ***I***.
Weight is the Cal-VIUS data field containing the population-based weighting factor.

Figure 4-8 shows an example weighted-average accrual profile from Cal-VIUS data overlaid onto the 3,110 individual VINs that are Class 7 and 8, Tractor, Interstate trucks. The sample size by age ranges from a low of 20 vehicles at age "-1" year old (meaning a 2019 model year in 2018 survey year) to a high sample size N of 376 vehicles at age 1 year old. The sample size of vehicles that are 11 or more years old is only 34 to 73 vehicles, so most of the vehicles are younger. The Cal-VIUS model year range extends to40 years old, but the sample size of the oldest vehicles was so small that we decided to group 20+ year old trucks into the age category of 20.

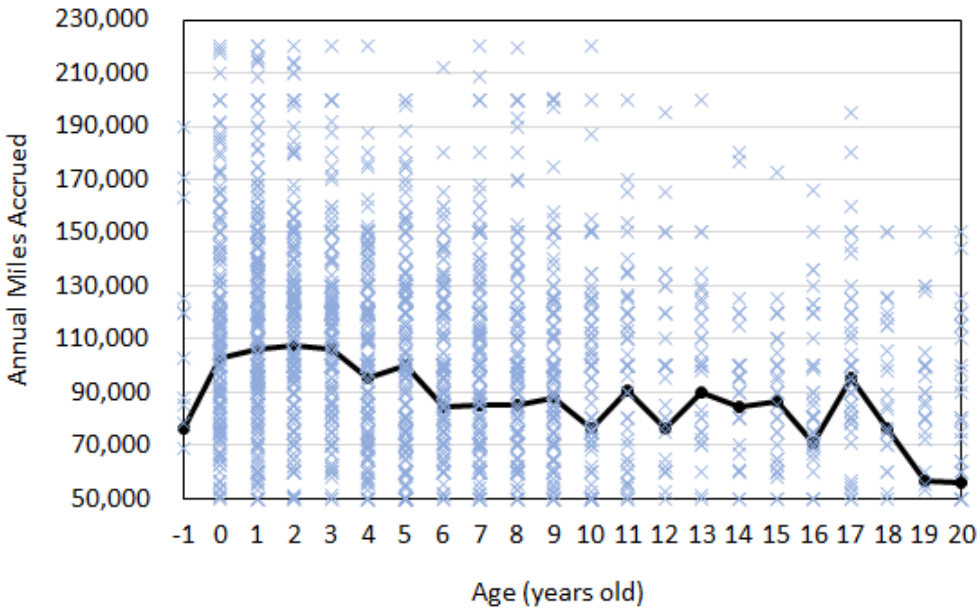

Figure 4-8. Sample subset of individual HDVs and weighted-average annual accrual profile

Comparisons of Cal-VIUS and Geotab with Current EMFAC profiles

The next eleven sub-sections figures compare potential new annual accrual profiles developed from Cal-VIUS and Geotab data to the current EMFAC profile on the same plot wherever possible. The figures cover every Sub-Level 3 category (refer to Table 4-1) except two vocations: Construction (e.g., cement truck) and Airport Shuttle Buses. There wasn't enough description available in either dataset to classify those two Sub-Level 3 category vocations.

4.1.3 Results for Long-Haul Trucks

The first Sub-Level 3 category, "All Long-Haul Trucks," includes all Class 7 and 8 trucks that have interstate travel and a tractor-trailer body type. In addition, the Geotab vocation was filtered to include only the aggregated vocation "Long Distance" from Table 3-4. The Cal-VIUS trucks were identified through the data field "Service Truck" data field value equal to "No," which limits the truck types to commodity-hauling, as opposed to those that perform a service at a destination.

Currently, there is one profile in EMFAC that applies to several out-of-state HDV types in the list below. Throughout the results, the EMFAC accrual schedule being evaluated appears as a black "dash" line series. Potential replacement profiles are shown in different colors but in a similar "dash" style to indicate a smoothed profile from a trendline to differentiate them from raw data or sample size.

- T7 NOOS (Neighboring Out-Of-State)
- T7 NNOOS (Non-Neighboring Out-Of-State)
- T7 CAIRP (California-based International Registration Plan)
- T7 CAIRP construction
- T6 OOS heavy
- T6 CAIRP heavy

Figure 4-9 shows the current EMFAC accrual profile and the mean annual miles accrued for Geotab (blue) and Cal-VIUS (orange) by age, respectively. The two datasets align closely for the younger vehicles age 0 to 7. While Geotab and Cal-VIUS diverge at older vehicle ages, both suggest that the current EMFAC mileage is too low for the older vehicles.

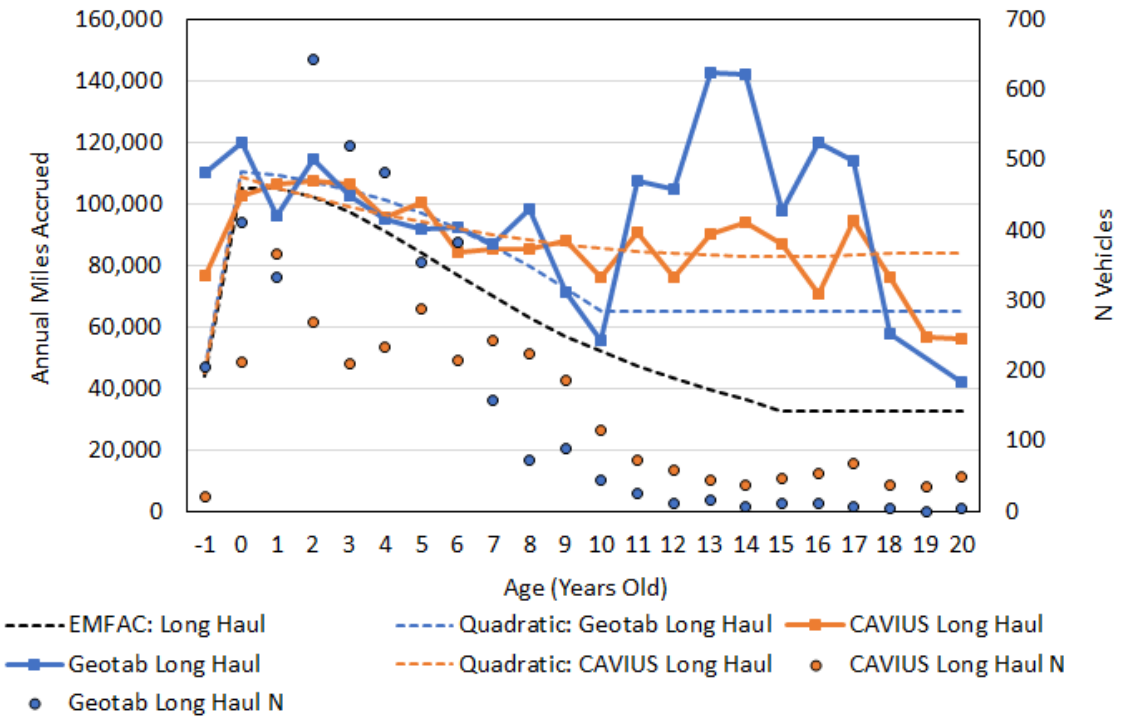

Figure 4-9. Class 7-8, Interstate, Tractor, "All Long-Haul Trucks"

The sample sizes of Geotab and Cal-VIUS were N = 3,791 and 3,083 trucks, respectively, displayed above on the secondary vertical axis. Although the overall sample size is similar, the Geotab distribution of N vehicles by age is skewed toward the newer vehicles compared to Cal-VIUS. Because of the difference in vehicle counts by age, the Figure 4-10 combined average accruals by age and trendline (purple) is closer to Cal-VIUS for older long-haul trucks.

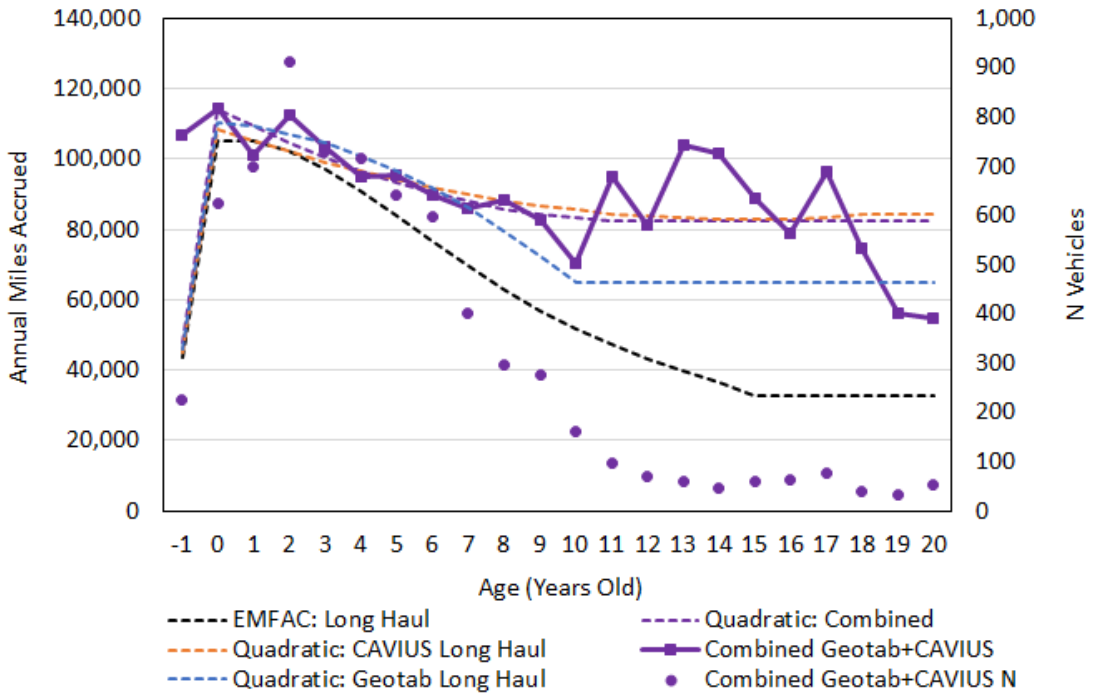

Figure 4-10. Class 7-8, Interstate, Tractor, "All Long-Haul Trucks" Combined Dataset

In the two figures above, all trendlines are quadratic (second order polynomial) fit over age 0 to the age at which 97% of the cumulative number of vehicles is reached. The accrual at age -1 (i.e., the 2019 model year in calendar year 2018) was set to the fraction 5/12 multiplied by the calculated trendline value at age 0. After age 10 (Geotab) and age 18 (Cal-VIUS), the accrual profiles are capped and do not vary with increasing age over the last 3% of the datasets' sample size. For consistency in producing trendlines for other categories, the 97% vehicle count threshold was applied to all vehicle types in this work.

While the Geotab dataset does not include any information on the state of registration of vehicle groups, the Cal-VIUS identifies the state of each VIN in the survey and whether the data source was DMV or IRP. Using the combinations of the state and data source explained previously in Table 3-6, we divided the Cal-VIUS long-haul truck categories into three categories: those registered in California and part of the IRP (CAIRP), IRP-registered trucks from neighboring out of state (NOOS; includes British Columbia, Washington, Oregon, Idaho, Nevada, and Arizona), and IRP-registered trucks from non-neighboring out of state (NNOOS). Figure 4-11 shows that CAIRP (brown) consistently falls below the Cal-VIUS data (orange) and NNOOS (red) lies above. Figure 4-12 shows the quadratic trendlines corresponding to these data. Because the NOOS data (green) has high variability in mean accrual, relatively low sample size N, and a nonsensical trendline (Figure 4-12),we recommend using the Figure 4-10 average combined profile (purple) for NOOS long haul trucks. Our recommendations for the long-haul category are the three new profiles shown in Figure 4-13 and
Table 4-2.
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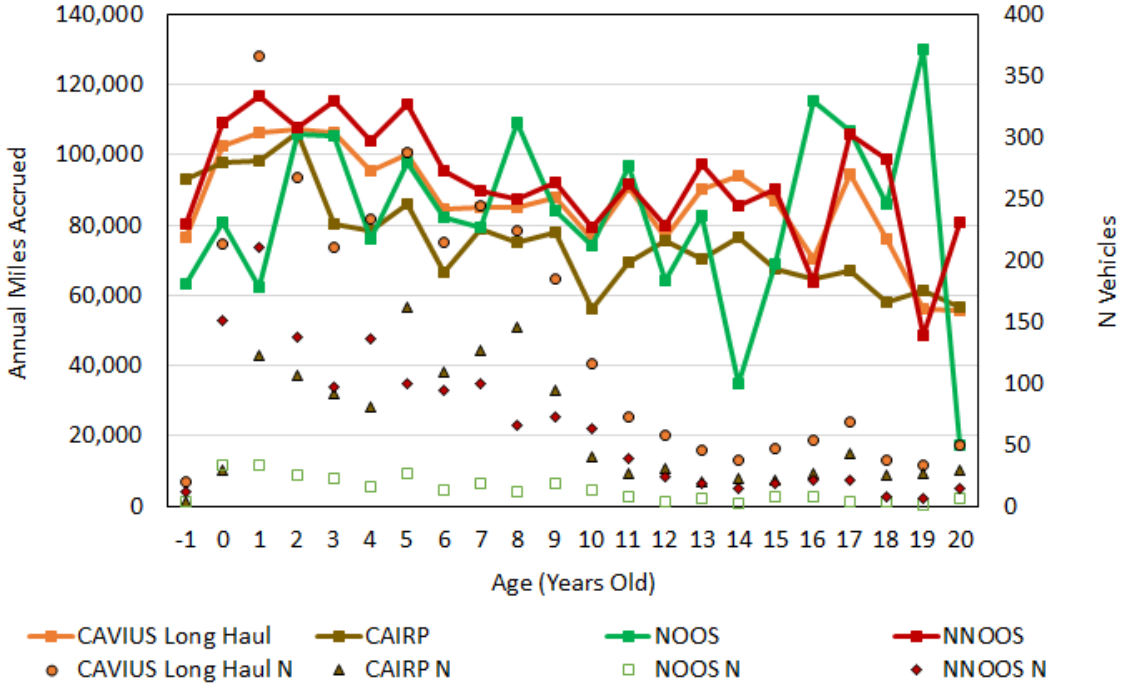


Figure 4-11. Cal-VIUS Class 7-8 Interstate Tractor CAIRP/NOOS/NNOOS Trucks

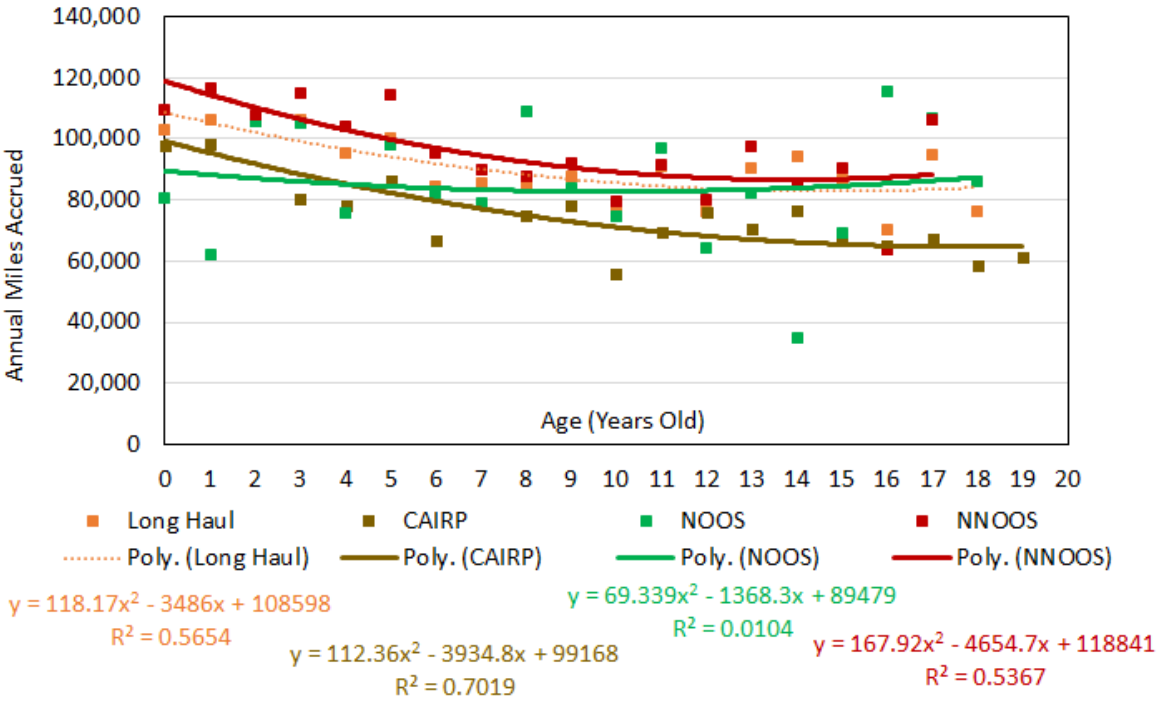


Figure 4-12. Cal-VIUS Class 7-8 Interstate Tractor CAIRP/NOOS/NNOOS Truck Trendlines

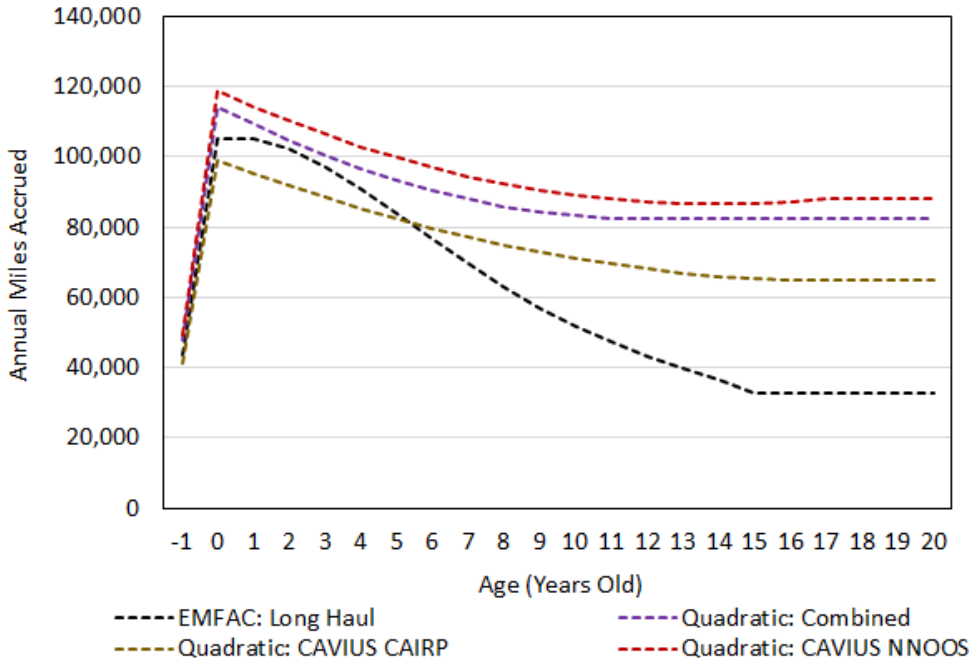


Figure 4-13. Cal-VIUS Class 7-8 Interstate Tractor CAIRP/NOOS/NNOOS Truck Profiles

Table 4-2. Accruals for Class 7-8, Interstate, Tractor, "All Long-Haul Trucks" Category

Age (years old)	EMFAC [A]	Geotab	Cal-VIUS	Combined [B]	Cal-VIUS CAIRP [C]	Cal-VIUS NNOOS [D]
-1	43,847	46,083	45,249	47,650	41,320	49,517
0	105,234	110,600	108,598	114,361	99,168	118,841
1	105,141	109,315	105,230	109,251	95,346	114,354
2	102,228	107,297	102,098	104,586	91,748	110,203
3	97,292	104,546	99,203	100,368	88,375	106,388
4	91,028	101,062	96,544	96,595	85,227	102,909
5	84,030	96,845	94,122	93,268	82,303	99,766
6	76,791	91,894	91,936	90,387	79,605	96,958
7	69,707	86,211	89,986	87,952	77,130	94,486
8	63,069	79,795	88,272	85,962	74,881	92,350
9	57,069	72,645	86,795	84,419	72,856	90,550
10	51,799	64,763	85,554	83,321	71,056	89,086
11	47,251	64,763	84,550	82,669	69,481	87,958
12	43,315	64,763	83,782	82,462	68,130	87,165
13	39,780	64,763	83,250	82,462	67,005	86,708
14	36,336	64,763	82,954	82,462	66,103	86,587

Age (years old)	EMFAC [A]	Geotab	Cal-VIUS	Combined [B]	Cal-VIUS CAIRP [C]	Cal-VIUS NNOOS [D]
15	32,572	64,763	82,895	82,462	65,427	86,802
16	32,572	64,763	83,072	82,462	64,975	87,353
17	32,572	64,763	83,486	82,462	64,748	88,240
18	32,572	64,763	84,136	82,462	64,746	88,240
19	32,572	64,763	84,136	82,462	64,968	88,240
20+	32,572	64,763	84,136	82,462	64,968	88,240

[A] EMFAC is the current assumption in the model.
[B] Combined is recommended for long haul trucks registered in neighboring out of state (NOOS) areas.
[C] Cal-VIUS CAIRP is the recommended update for long haul trucks in California IRP.
[D] Cal-VIUS NNOOS is recommended for long haul trucks operating in non-neighboring states.

4.1.4 Results for Port Trucks

Figure 4-14 shows the next Sub-Level 3 category: Port Trucks. EMFAC port trucks are Class 7 and 8 weight class, in-state travel only, with a tractor-trailer body type. EMFAC also distinguishes among drayage trucks that operate at the Port of Los Angeles (POLA), Port of Oakland (POAK), and all other ports in California. The comparison of new data with EMFAC is limited to the Cal-VIUS because Geotab data did not contain any vocation information specific enough to separate drayage trucks.

The Cal-VIUS data were filtered for the appropriate weight class, in-state travel, tractor vehicle type, a "Home Base Type" survey response of either "Terminal/port/railyard" or "Transload facility," and the "Region" survey response to distinguish among POLA (Region= "LA/INLAND EMPIRE/SD"), POAK (Region= "SACRAMENTO/BAY AREA"), and Other Ports (all other Region values). The annual miles accrued connected by solid lines for each port truck category appear noisy due to low sample size (N=77, 41, and 51 trucks for POLA, POAK, and Other Port, respectively).

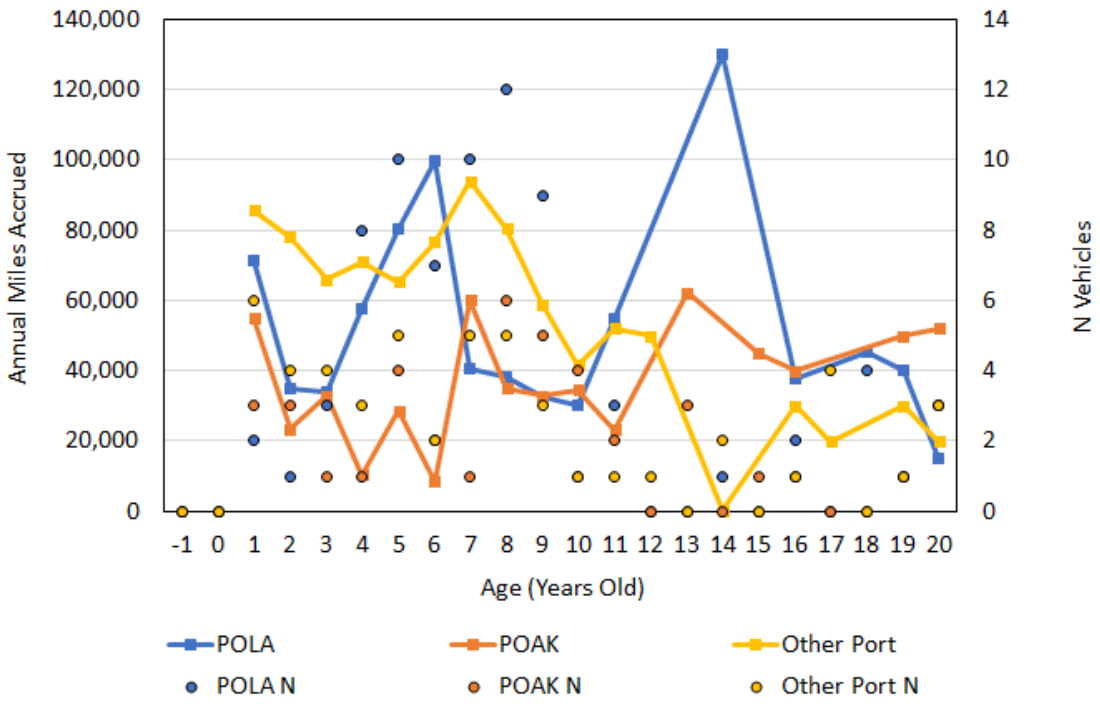


Figure 4-14. High Variability in the Class 7-8, In-State, Tractor, Port Trucks Cal-VIUS Data

Due to the high variation in annual miles accrued and the current EMFAC assumption for POAK and POLA trucks of a flat mileage value that doesn't vary by age, we propose taking the mean of the new data and applying it to all ages.

The Port of Los Angeles trucks in Figure 4-15 from the Cal-VIUS average 49,940 miles per truck per year, 18% higher than the current EMFAC assumption of 42,446 miles.

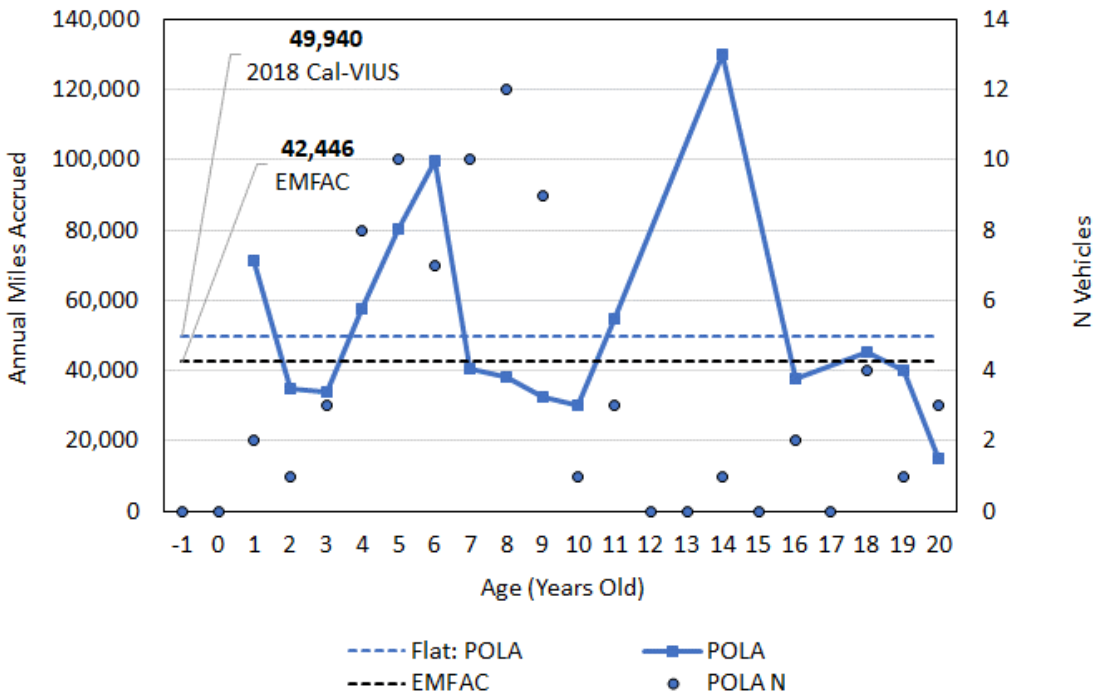


Figure 4-15. Class 7-8, In-State, Tractor, Port of Los Angeles (POLA) Trucks

The Port of Oakland trucks in Figure 4-16 average accrual rate is 36,608 miles per truck per year, only 6% lower than the current EMFAC assumption of 38,794 miles.

Other Port trucks not at POLA or POAK in Figure 4-17 compares well with the current EMFAC profile for Other Port, which is a shared HDV accrual profile that also maps to the HDVs “T6 instate heavy” and “T7 tractor. ”Because the current EMFAC profile for Other Ports is not flat, and the new Cal-VIUS data is also showing a clear mileage decline with age, the proposed trendline is the second order polynomial shown in Figure 4-17.

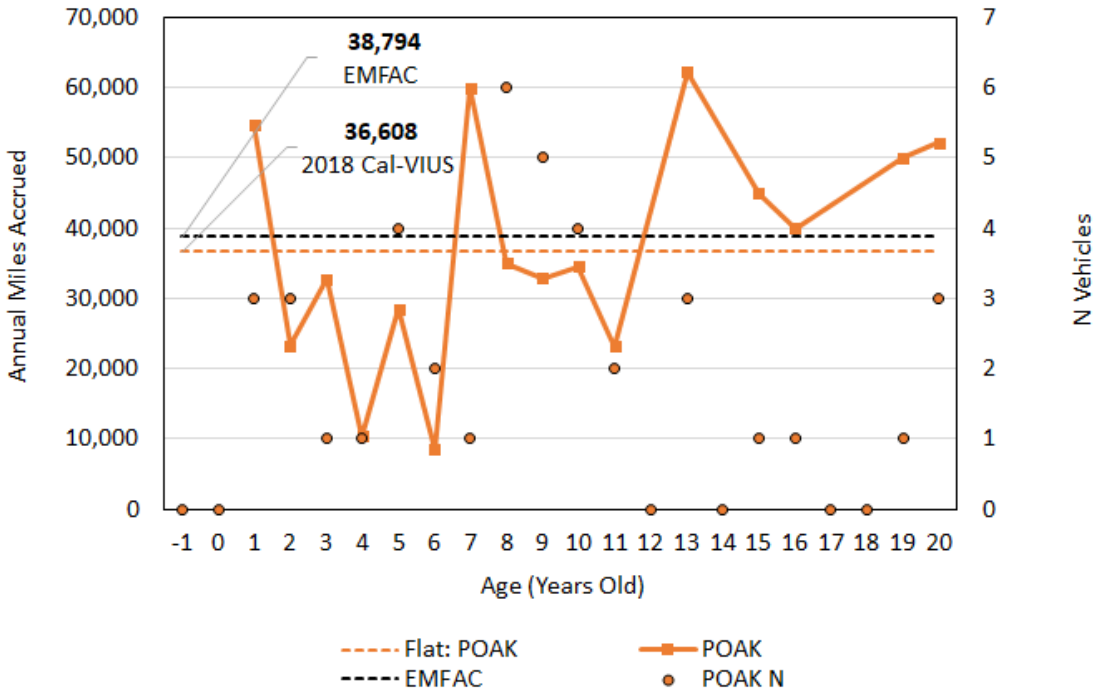


Figure 4-16. Class 7-8, In-State, Tractor, Port of Oakland (POAK) Trucks

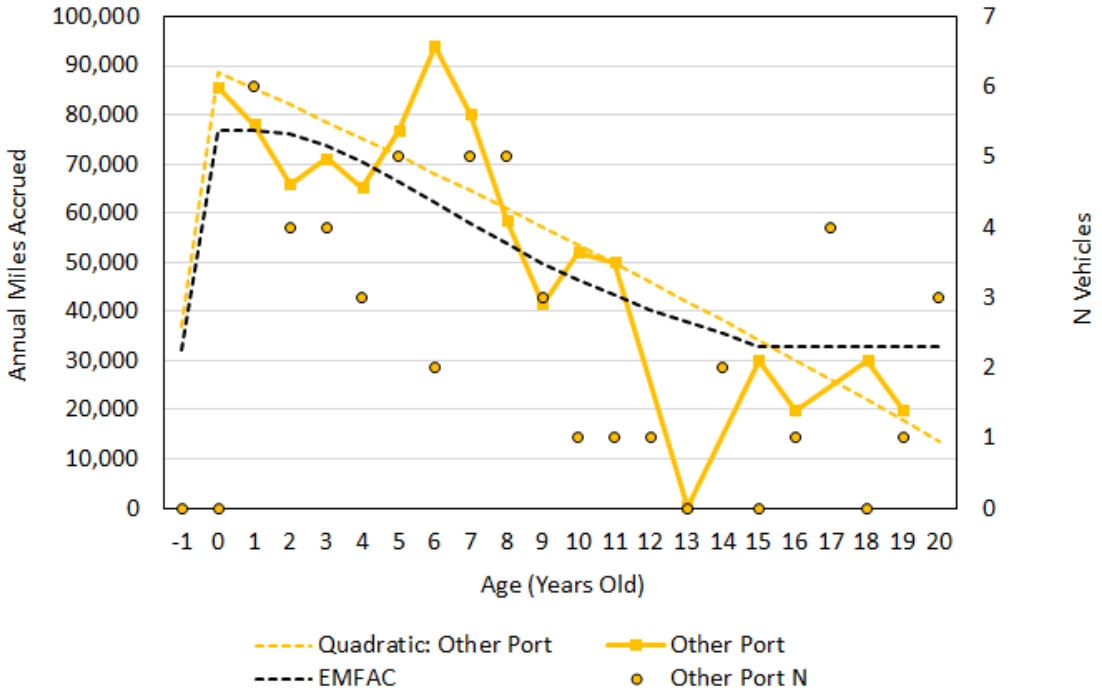


Figure 4-17. Class 7-8, In-State, Tractor, Other Port Trucks

The recommendation for this category is to update EMFAC to use the Cal-VIUS values shown in Table 4-3. While the changes are small, the Cal-VIUS data represent approximately 10 years newer data compared to the current EMFAC values that were developed at the time of the 2007 Drayage Truck Regulation (ARB, 2008).

Table 4-3. Accruals for Class 7-8, In-State, Tractor, POLA, POAK, and Other Port Trucks

Age (years old)	EMFAC POLA	Cal-VIUS POLA	EMFAC POAK	Cal-VIUS POAK	EMFAC Other Ports	Cal-VIUS Other Ports
-1	42,446	49,940	38,794	36,608	32,045	36,976
0	42,446	49,940	38,794	36,608	76,909	88,742
1	42,446	49,940	38,794	36,608	76,909	85,426
2	42,446	49,940	38,794	36,608	76,003	82,064
3	42,446	49,940	38,794	36,608	73,662	78,656
4	42,446	49,940	38,794	36,608	70,325	75,202
5	42,446	49,940	38,794	36,608	66,367	71,702
6	42,446	49,940	38,794	36,608	62,107	68,156
7	42,446	49,940	38,794	36,608	57,802	64,564
8	42,446	49,940	38,794	36,608	53,651	60,926
9	42,446	49,940	38,794	36,608	49,792	57,241
10	42,446	49,940	38,794	36,608	46,304	53,511
11	42,446	49,940	38,794	36,608	43,206	49,735
12	42,446	49,940	38,794	36,608	40,459	45,912
13	42,446	49,940	38,794	36,608	37,960	42,044
14	42,446	49,940	38,794	36,608	35,552	38,129
15	42,446	49,940	38,794	36,608	33,013	34,169
16	42,446	49,940	38,794	36,608	33,013	30,162
17	42,446	49,940	38,794	36,608	33,013	26,109
18	42,446	49,940	38,794	36,608	33,013	22,010
19	42,446	49,940	38,794	36,608	33,013	17,866
20+	42,446	49,940	38,794	36,608	33,013	13,675

4.1.5 Results for Public/Utility Truck: Class 7-8 Tractors

Figure 4-18 shows the result for the next two Sub-Level 3 categories: Tractor-type Public/Utility Trucks. In addition to Tractors for this category, we will also look at Single Unit for Class 7-8, and Single Unit for Class 4-6 trucks.

The current assumption in EMFAC profile for T7 Public/Utility has much lower miles with low mileage accrual (7,776 miles per vehicle per year) than the new data show. Like the Port Trucks, the Tractor Public/Utility trucks are Class 7 and 8 weight class, in-state travel only, and have a tractor-trailer body.

The Geotab data considered this vocation were the aggregated "Service" category, comprised mostly of "Long Stop" Geotab vocation types. Table 3-4 previously listed that the "Service" category included the five native Geotab vocation categories listed below.

Original Geotab Vocation	Examples
• All Hours Tour with Long Stop	Energy company
• Daytime Tour with Long Stop	Cable/phone/internet installers, Food and Beverage Delivery
• Nighttime Tour with Long Stop	
• Hub Spoke Long Stop	On-site service and repair
• Local at All Hours	Yard management, Mining

The Geotab data sample size for the Service vocation was N = 1,214 trucks, while the Cal-VIUS had N = 55 trucks. The Cal-VIUS data were filtered for the data field "Service Truck" value "Yes. "

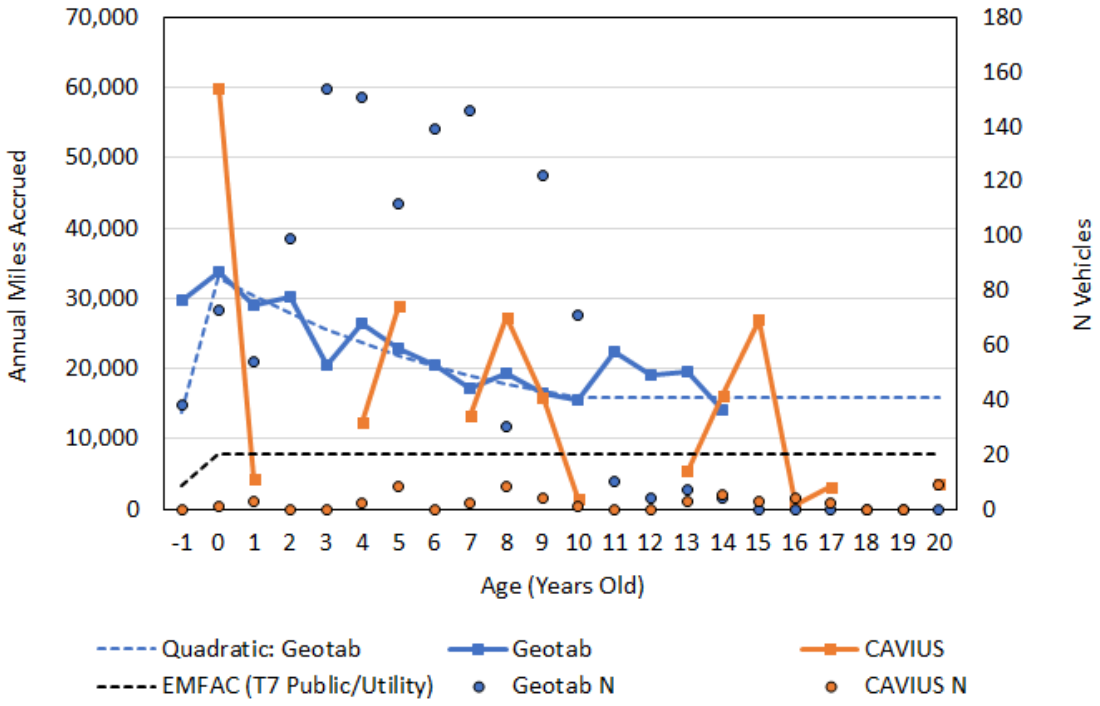


Figure 4-18. Class 7-8, In-State, Tractor-Trailer, Public/Utility Trucks

We did not calculate a trendline for Cal-VIUS nor combine it with Geotab due to small sample size for this category. The recommended accrual profile is Geotab (Table 4-4), which is a substantial increase in miles – a factor of 2 to 4 depending on age.

Table 4-4. Accruals for Class 7-8, In-State, Tractor, Public/Utility Trucks

Age (years old)	EMFAC	Geotab
-1	3,240	13,705
0	7,776	32,891
1	7,776	30,295
2	7,776	27,899
3	7,776	25,703
4	7,776	23,707
5	7,776	21,911
6	7,776	20,315
7	7,776	18,919
8	7,776	17,723
9	7,776	16,727
10	7,776	15,931
11	7,776	15,931
12+	7,776	15,931

4.1.6 Results for T6 Delivery Trucks

Figure 4-19 shows the Cal-VIUS and Geotab data for T6 (Class 4 to 7 together) delivery trucks. The T6 Delivery Truck is a potential new vocation for the EMFAC model. T6 delivery trucks include in-state travel only and defined by a single unit body type.

The Geotab vocations categorized as delivery included both “Door to Door” and “Quick Stop” (the latter of which included native Geotab vocations “Hub Spoke Quick Stop” and “Local Quick Stop”). Table 3-4 previously gave examples for these vocations that included Pizza Delivery, Parts Delivery, Courier, and Delivery. The sample size of Geotab data was N = 1,452 trucks.

The Cal-VIUS data identified as delivery were vehicles with the data field “Home Base Type” value of “Distribution center.” The Cal-VIUS sample size was less than 20% of Geotab, with N = 275 trucks. The annual miles accrued by delivery trucks in Cal-VIUS are much higher than Geotab, and so Figure 4-20 shows that the combined dataset with a trendline closer to the Geotab profile.

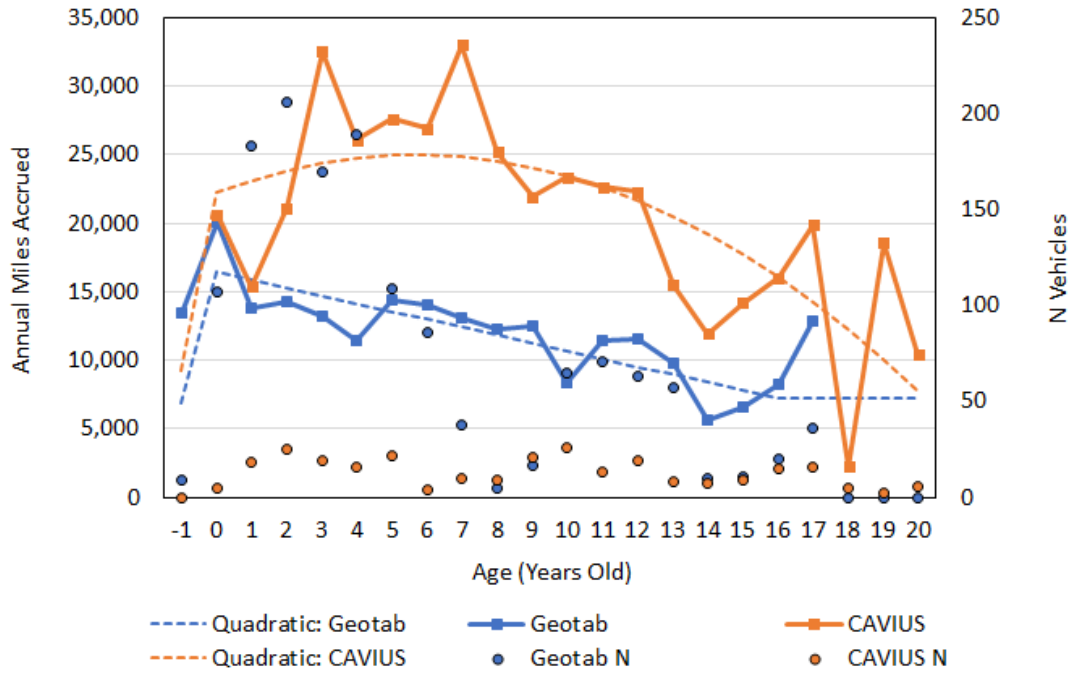


Figure 4-19. Class 4-7, In-State, Single Unit, Delivery Trucks

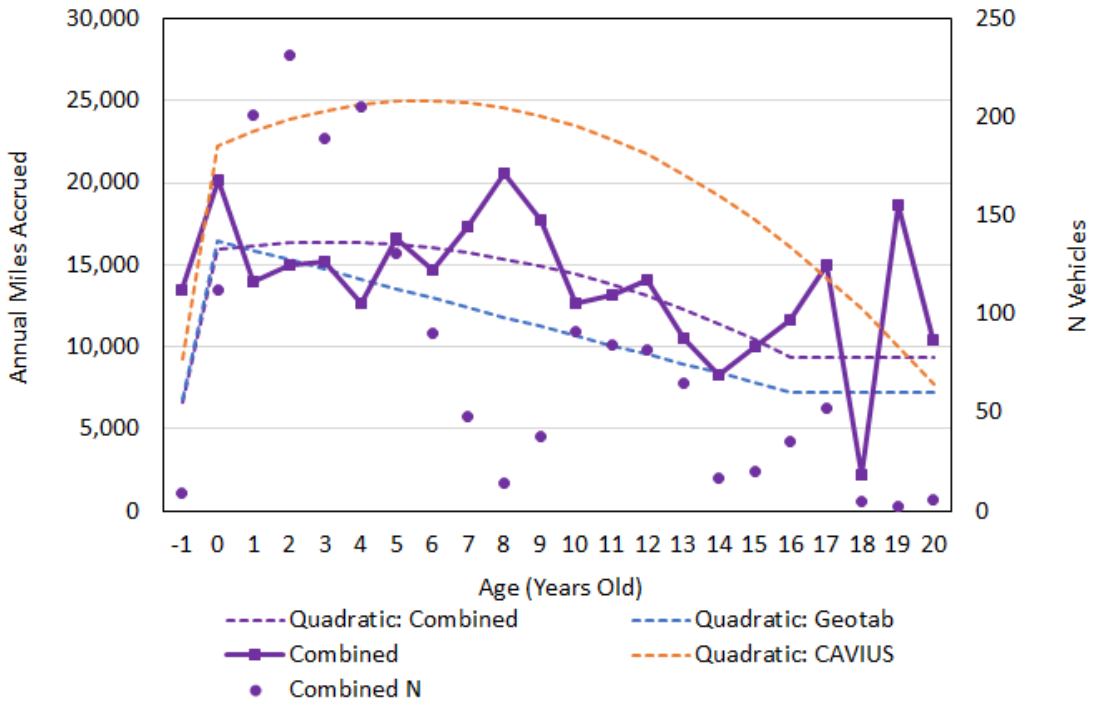


Figure 4-20. Class 4-7, In-State, Single Unit, Delivery Trucks Combined Dataset

Next, the Cal-VIUS were analyzed separately by GVW classes 4, 5, 6, and 7. After dividing into GVW class, the Cal-VIUS sample size of 275 trucks became too thin, at 55, 57, 127, and 36

trucks for Class 4, 5, 6, and 7, respectively, which left gaps in data in some age categories. Overall, trends by weight were still apparent: class 4 and 5 were similar to each other and had lower mileage than the class 6 and 7 profiles which were also similar. To remedy age gaps, we grouped the Cal-VIUS data into Class 4 to 5 and Class 6 to 7 which yielded sample sizes of 112 and 163 trucks. The Geotab T6 data were divided as finely as possible, into T6 small (Class 4-6) and T6 heavy (Class 7), which yielded respective sample sizes of 1,223 and 229 trucks. The goal of splitting the Cal-VIUS and Geotab was to prepare them for combining across the two datasets. The alignment is not perfect because the Class 6 trucks cannot be extracted from the Geotab T6 small category.

The Cal-VIUS Class 4 and 5 data were then combined with Geotab T6 small data by population-weighted average into a combined T6 small profile. Similarly, Cal-VIUS Class 6-7 and Geotab T6 heavy were averaged into a combined T6 heavy profile. Figure 4-21 shows the resulting combined profile trendlines, labeled "Combined T6 heavy" (red) and "Combined T6 small" (green) overlaid onto the previous set of three trendlines from Figure 4-20.

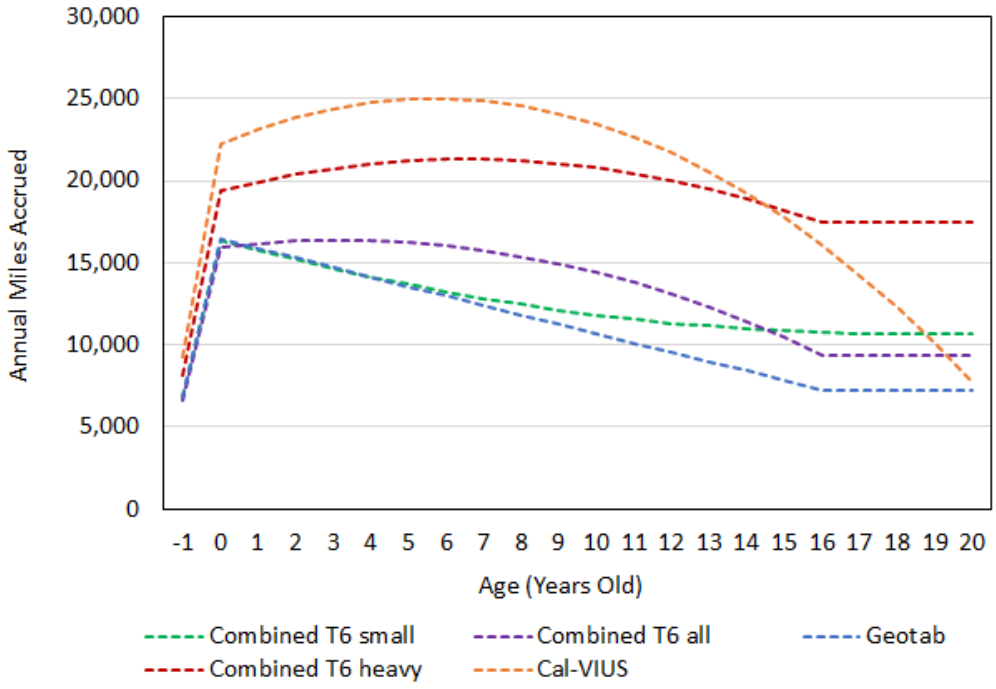


Figure 4-21. Class 4, 5, 6, and 7, In-State, Single Unit, Delivery Trucks in Cal-VIUS

ARB may define truck populations for the new T6 Delivery category for future versions of EMFAC based on the DMV body styles of Refrigerated, Parcel Delivery, Van, and Step Van. It is not yet well understood how or whether the three data sources (Geotab vocation, Cal-VIUS home base type, DMV body styles) align, so we therefore for purposes of accrual rates recommend averaging all the available data from Geotab and Cal-VIUS and using the combined profiles for T6 small vs. T6 heavy shown in Table 4-5. In the future, a more targeted study could

perhaps classify delivery trucks into meaningful categories with available data streams to support the emission inventories.

Table 4-5. Accruals for Class 4-7, In-State, Single Unit, Delivery Trucks

Age (years old)	Cal-VIUS all T6	Geotab all T6	Combined all T6	Combined T6 small [A]	Combined T6 heavy [B]
-1	9,261	6,858	6,648	6,833	8,092
0	22,227	16,459	15,956	16,398	19,420
1	23,113	15,876	16,182	15,787	19,950
2	23,829	15,295	16,323	15,210	20,392
3	24,376	14,715	16,378	14,668	20,746
4	24,754	14,135	16,349	14,160	21,014
5	24,962	13,557	16,234	13,685	21,195
6	25,001	12,979	16,035	13,245	21,288
7	24,870	12,402	15,751	12,840	21,294
8	24,570	11,827	15,381	12,468	21,213
9	24,100	11,252	14,927	12,131	21,044
10	23,461	10,679	14,387	11,828	20,789
11	22,653	10,106	13,763	11,559	20,446
12	21,675	9,534	13,054	11,324	20,016
13	20,527	8,964	12,259	11,124	19,499
14	19,210	8,394	11,380	10,957	18,894
15	17,723	7,825	10,415	10,825	18,202
16	16,067	7,257	9,366	10,727	17,424
17	14,242	7,257	9,366	10,664	17,424
18	12,247	7,257	9,366	10,664	17,424
19	10,083	7,257	9,366	10,664	17,424
20+	7,749	7,257	9,366	10,664	17,424

[A] Combined T6 small is recommended for T6 Delivery weight classes 4 through 6.
[B] Combined T6 heavy is recommended for T6 Delivery weight class 7.

4.1.7 Results for Solid Waste Refuse Trucks

Figure 4-22 shows the result for the next Sub-Level 3 category: Solid Waste Refuse Trucks. These are Class 7 and 8, in-state travel only, and have a single-unit body type. The Cal-VIUS applicable data filtering to identify these trucks was a combination of the data field "Commodity1" value set to "Waste material" and "VMT1" set to "100," meaning that 100% of the VMT for the vehicle (i.e., a dedicated truck) was from a waste-hauling. The Geotab filter to identify the vocation was "Tour Based Worker Vehicle," which Table 3-4 previously described as having "more idling than driving" and listed as examples "Utility vehicles, Garbage trucks. "

The current EMFAC profile for T7 Solid Waste Collection Vehicle (SWCV) is a flat 15,635 miles per truck per year at all ages. Both the Geotab and Cal-VIUS data show higher mileage than the EMFAC value, but both the new datasets have limitations. The Geotab trucks span only ages 0 to 4 years old. The Cal-VIUS trucks cover a broader range of ages but the sample size at each age is low and the annual mileage by age varies widely (from approximately 2,000 to 53,000 miles per year). The total sample size is similar at 103 and 100 trucks for Geotab and Cal-VIUS.

The Cal-VIUS and Geotab average accrual by age with trendlines are shown individually in Figure 4-22, and as a combined dataset in Figure 4-23. Due to the high variation in the combined data, we recommend a flat profile calculated as the population-weighted mean accrual over all ages. Table 4-6 lists the miles by age from each profile shown in Figure 4-23, including EMFAC, Cal-VIUS, Geotab, and the combined dataset trendline shown three different ways (flat or single average value, linear, and quadratic).

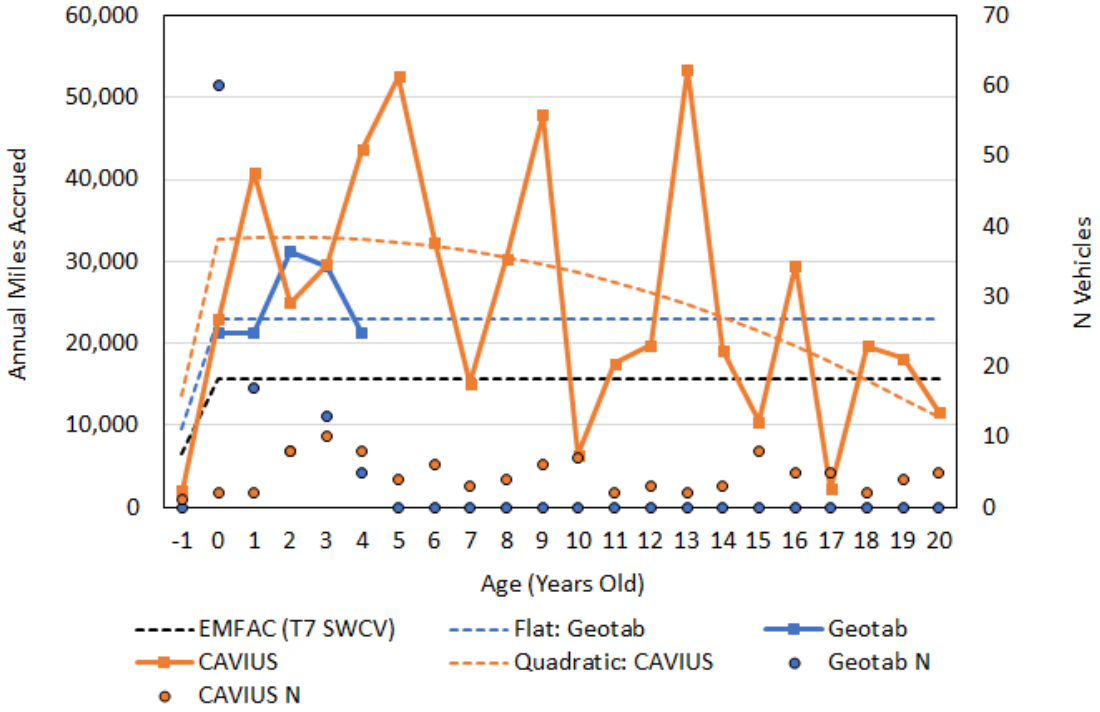


Figure 4-22. Class 7-8, In-State, Single Unit, Solid Waste Refuse Trucks

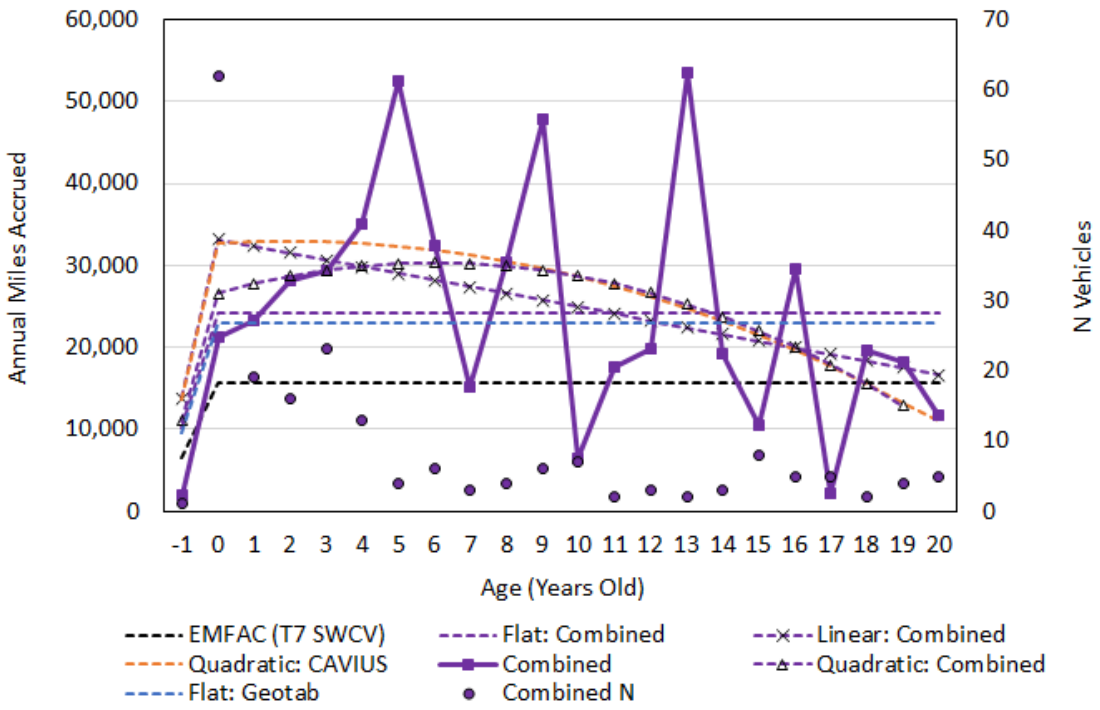


Figure 4-23. Class 7-8, In-State, Single Unit, Solid Waste Refuse Trucks Combined Dataset

Table 4-6. Accruals for Class 7-8, In-State, Single Unit, Solid Waste Refuse Trucks

Age (years old)	EMFAC [A]	Cal-VIUS	Geotab	Combined: Flat [B]	Combined: Linear	Combined: Quadratic
-1	6,515	13,604	9,590	10,091	13,805	11,078
0	15,635	32,650	23,016	24,220	33,131	26,588
1	15,635	32,853	23,016	24,220	32,308	27,728
2	15,635	32,920	23,016	24,220	31,485	28,661
3	15,635	32,851	23,016	24,220	30,661	29,387
4	15,635	32,647	23,016	24,220	29,838	29,907
5	15,635	32,307	23,016	24,220	29,015	30,220
6	15,635	31,831	23,016	24,220	28,191	30,326
7	15,635	31,220	23,016	24,220	27,368	30,226
8	15,635	30,472	23,016	24,220	26,545	29,920
9	15,635	29,590	23,016	24,220	25,722	29,406
10	15,635	28,571	23,016	24,220	24,898	28,686
11	15,635	27,417	23,016	24,220	24,075	27,760
12	15,635	26,127	23,016	24,220	23,252	26,626
13	15,635	24,701	23,016	24,220	22,428	25,287
14	15,635	23,140	23,016	24,220	21,605	23,740
15	15,635	21,443	23,016	24,220	20,782	21,987
16	15,635	19,610	23,016	24,220	19,959	20,028
17	15,635	17,642	23,016	24,220	19,135	17,861
18	15,635	15,538	23,016	24,220	18,312	15,488
19	15,635	13,298	23,016	24,220	17,489	12,909
20+	15,635	10,922	23,016	24,220	16,666	10,123

[A] EMFAC is the current assumption in the model.
[B] Combined Flat profile is the recommendation for update.

4.1.8 Results for Public/Utility Truck: Class 7-8 Single Unit

Figure 4-24 shows the result for the Sub-Level 3 category: Single Unit Public/Utility Trucks. These trucks are class 7-8, instate travel only, and have a single unit body. The EMFAC profile currently is the same as for the tractor Public/Utility trucks (flat 7,776 miles per year). The Geotab data considered this vocation were the aggregated "Service" category, while Cal-VIUS data were filtered for the data field "Service Truck" value "Yes. "

The sample sizes of Geotab and Cal-VIUS data were N = 2,280 and 171 trucks, respectively. Similar to analysis of the Public/Utility Tractor trucks, for Single Units we recommend using the Geotab based profile. Table 4-7 lists the current EMFAC and proposed Geotab trendline miles accrued by age.

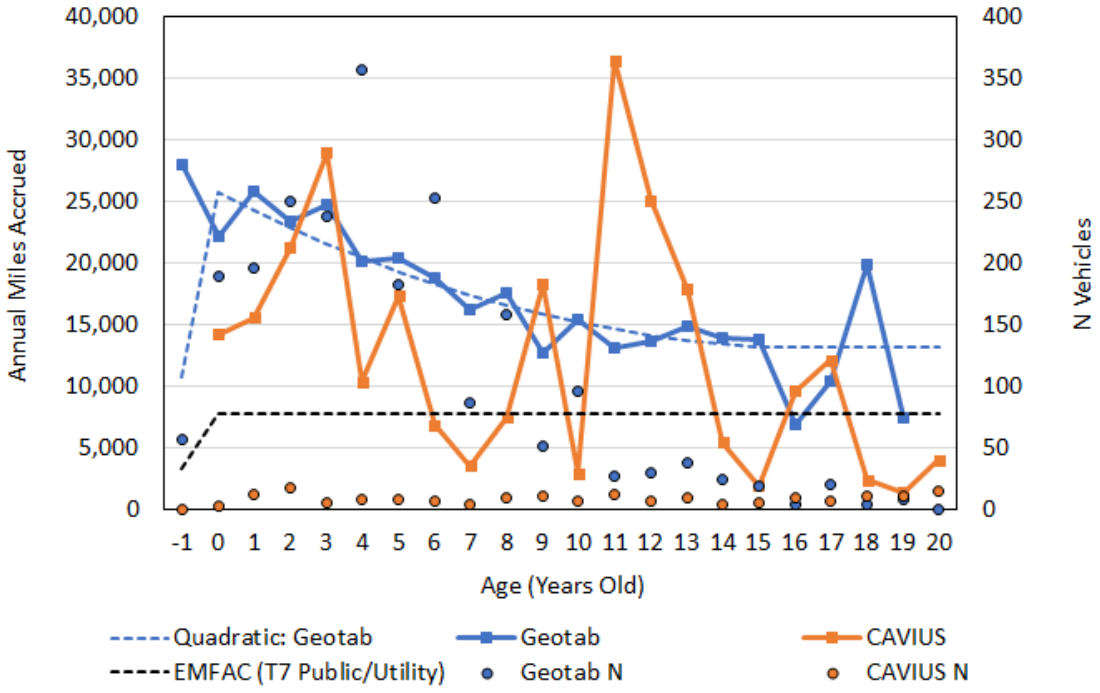


Figure 4-24. Class 7-8, In-State, Single Unit, Public/Utility Trucks

Table 4-7. Accruals for Class 7-8, In-State, Single Unit, Public/Utility Trucks

Age (years old)	EMFAC	Geotab
-1	3,240	10,698
0	7,776	25,674
1	7,776	24,218
2	7,776	22,851

Age (years old)	EMFAC	Geotab
3	7,776	21,573
4	7,776	20,384
5	7,776	19,285
6	7,776	18,275
7	7,776	17,354
8	7,776	16,523
9	7,776	15,780
10	7,776	15,127
11	7,776	14,564
12	7,776	14,089
13	7,776	13,704
14	7,776	13,408
15	7,776	13,201
16	7,776	13,201
17	7,776	13,201
18	7,776	13,201
19	7,776	13,201
20	7,776	13,201

4.1.9 Results for Public/Utility Truck: Class 4-6 Single Unit

Figure 4-25 shows the result for an additional category not included in the Sub-Level 3 categories: Class 4-6, Single Unit, Public/Utility Trucks. . The EMFAC profile (T6 Public/Utility) has very low mileage, varying between just 5,000 and 7,000 miles per year. The Geotab data considered this vocation were the aggregated “Service” category, while Cal-VIUS data were filtered for the data field “Service Truck” value “Yes. ”
The sample sizes of Geotab and Cal-VIUS data were large, at N = 3,955 and 1,058 trucks, respectively. Figure 4-25 shows close agreement between the two dataset mean accrual rates by age; therefore, we recommend combining datasets (Figure 4-26). Table 4-8 lists the current profile in EMFAC, the Cal-VIUS and Geotab options, and the recommended combined profile accrual schedules.

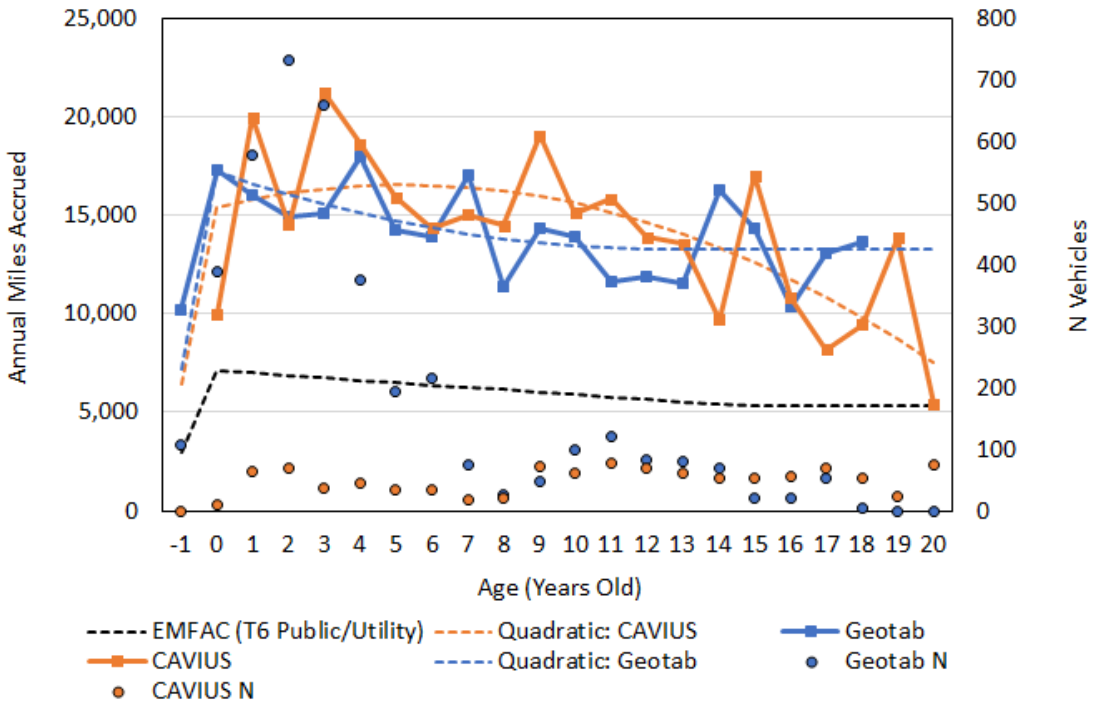


Figure 4-25. Class 4-6, In-State, Single Unit, Public/Utility Trucks

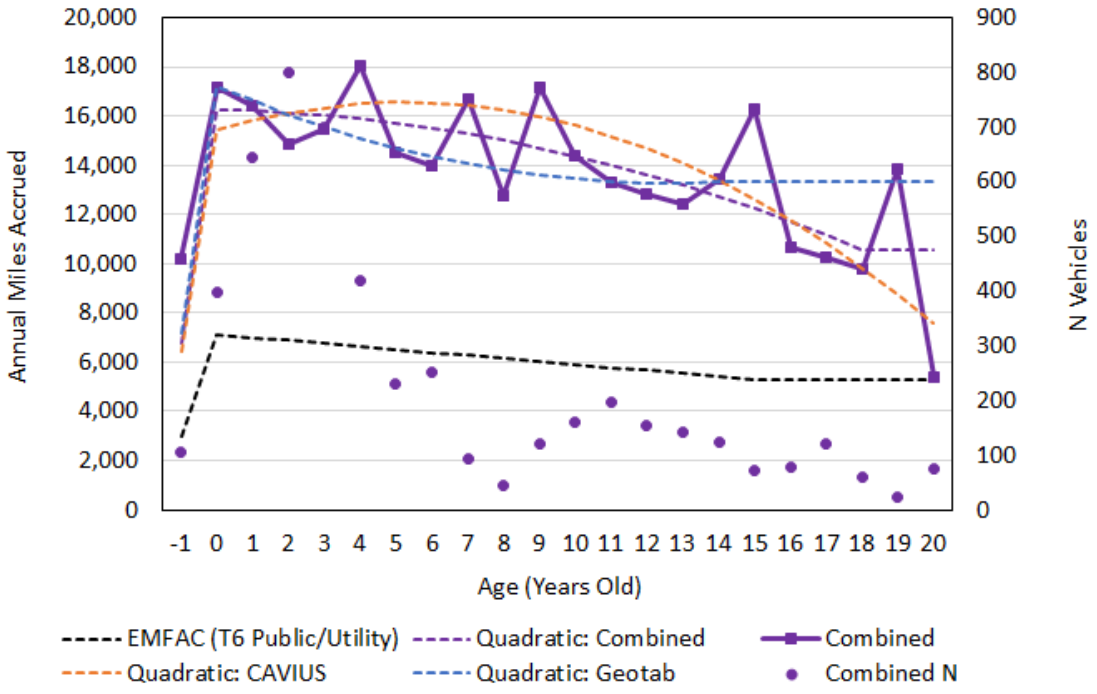


Figure 4-26. Class 4-6, In-State, Single Unit, Public/Utility Trucks Combined Dataset

Table 4-8. Accruals for Class 4-6, In-State, Single Unit, Public/Utility Trucks

Age (years old)	EMFAC [A]	Geotab	Cal-VIUS	Combined [B]
-1	2,968	7,174	6,425	6,772
0	7,122	17,218	15,421	16,253
1	7,000	16,615	15,810	16,211
2	6,879	16,061	16,118	16,136
3	6,757	15,557	16,343	16,029
4	6,636	15,104	16,486	15,890
5	6,514	14,700	16,546	15,719
6	6,392	14,347	16,524	15,515
7	6,271	14,044	16,420	15,280
8	6,149	13,791	16,233	15,012
9	6,028	13,589	15,964	14,712
10	5,906	13,436	15,612	14,380
11	5,784	13,334	15,179	14,016
12	5,663	13,281	14,662	13,619
13	5,541	13,279	14,064	13,191
14	5,420	13,327	13,383	12,730
15	5,298	13,327	12,619	12,237
16	5,298	13,327	11,774	11,712
17	5,298	13,327	10,846	11,155
18	5,298	13,327	9,835	10,565
19	5,298	13,327	8,742	10,565
20	5,298	13,327	7,567	10,565

[A] EMFAC is the current assumption in the model.

[B] Combined is the recommendation profile for update.

Due to the large number of vehicles in this category and further weight detail available in the Cal-VIUS data, we investigated the possibility of developing separate profiles by individual weight class. Figure 4-27 shows the raw data for Cal-VIUS separately for Class 4 (red), Class 5 (green), and Class 6 (blue) overlaid onto the original Cal-VIUS profile (orange). The data do not show consistent difference in miles by age. Regardless of attempts to fit the data with a linear trendline (Figure 4-28) or quadratic (Figure 4-29), the data do not show clear differences. Therefore, we recommend the combined schedule in Table 4-8 to represent all T6 small Public/Utility trucks.

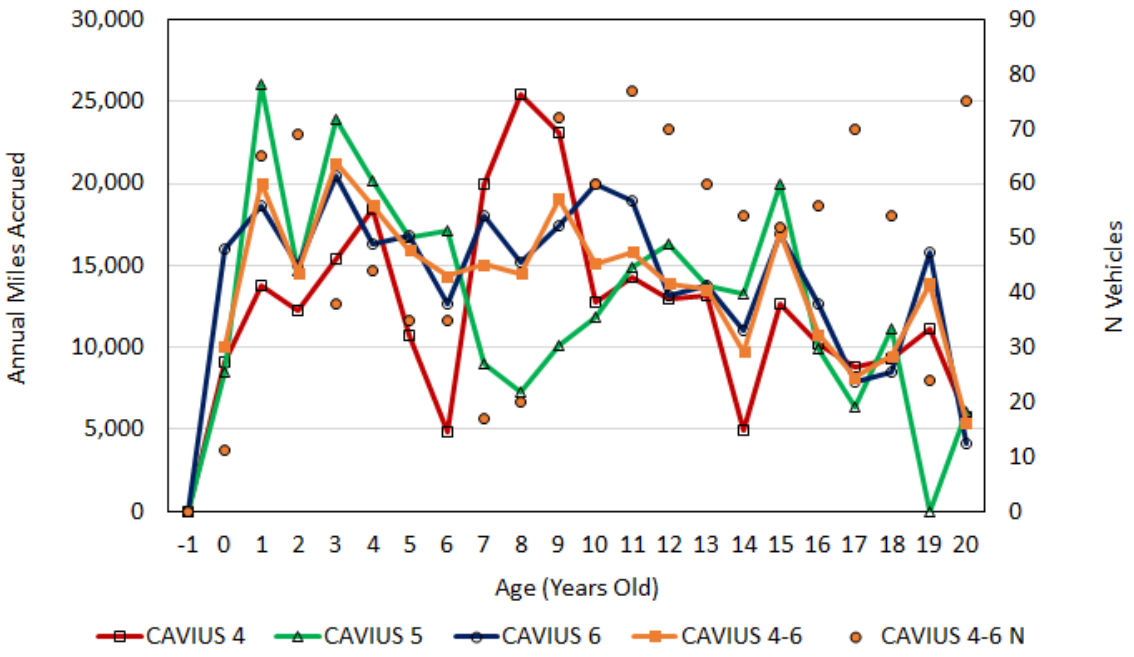


Figure 4-27. Classes 4, 5, and 6, In-State, Single Unit, Public/Utility Trucks

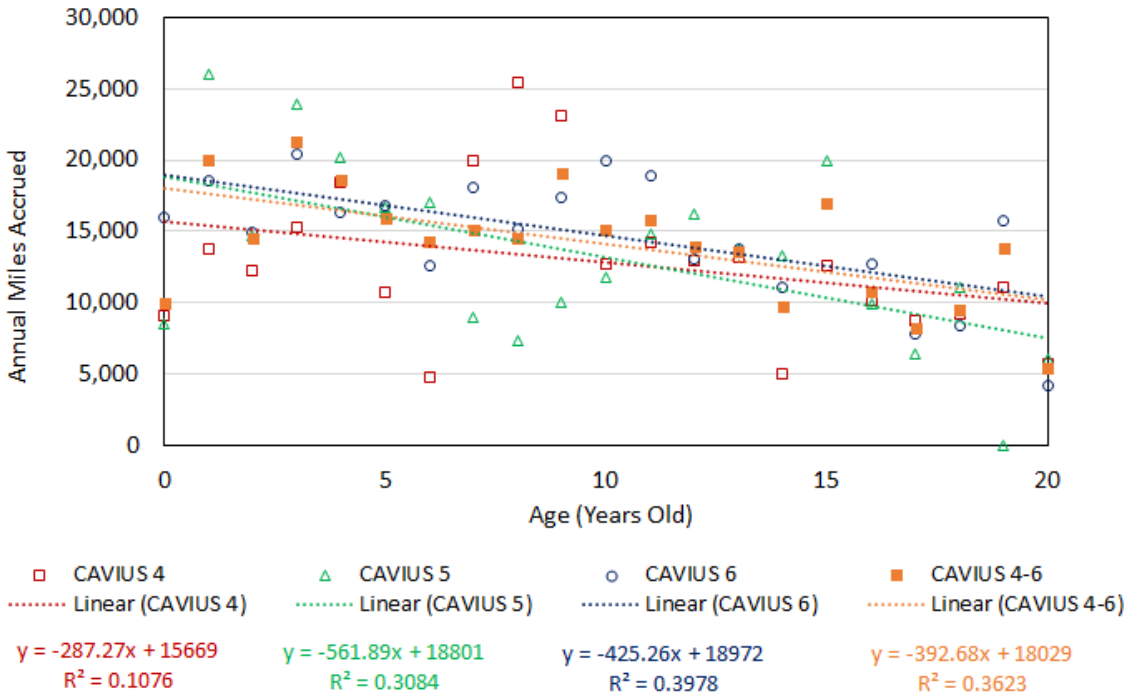


Figure 4-28. Linear Trendlines for Class 4-6 In-State Single Unit Public/Utility Trucks

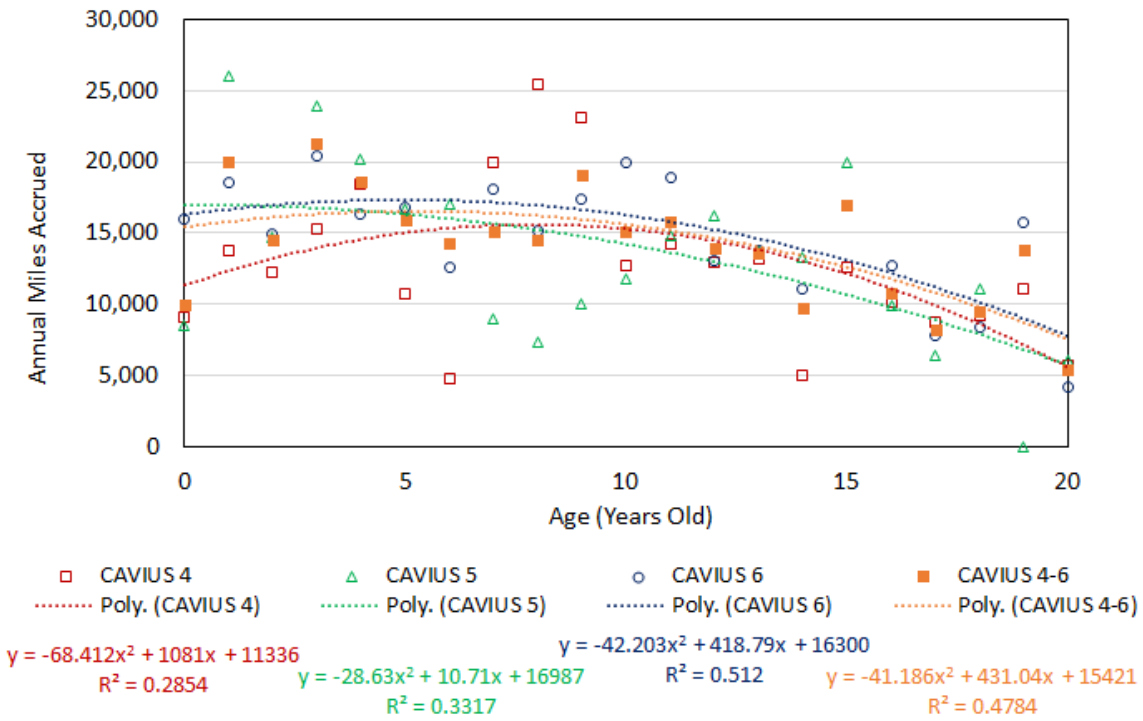


Figure 4-29. Quadratic Trendlines for Class 4-6 In-State Single Unit Public/Utility Trucks

4.1.10 Results for other T6 small in-state and out-of-state

The Geotab dataset contains thousands of T6 small (GVW Class 4 to 6) trucks that do not classify as any of the previously defined categories of school bus, delivery or public/utility truck. There are approximately 9,500 T6 small trucks that travel between California and other states (out-of-state) and another 9,000 that travel solely within California and do not have delivery or service vocations (in-state). Cal-VIUS also has trucks of these categories, but with smaller sample sizes at approximately 500 and 4,000 for out-of-state and in-state, respectively. We use this data to evaluate the current EMFAC profile that maps to a broad group of HDVs including:

- T6 CAIRP small
- T6 instate construction small
- T6 instate small
- T6 OOS small

Figure 4-30 shows the Geotab and Cal-VIUS in-state and out-of-state (OOS) mean annual mileage accruals by age and sample size by age on the secondary vertical axis. The T6 small mileage from Cal-VIUS in-state and Geotab (both in-state and OOS) are similar, while Cal-VIUS OOS stands out, and is highly variable by age.

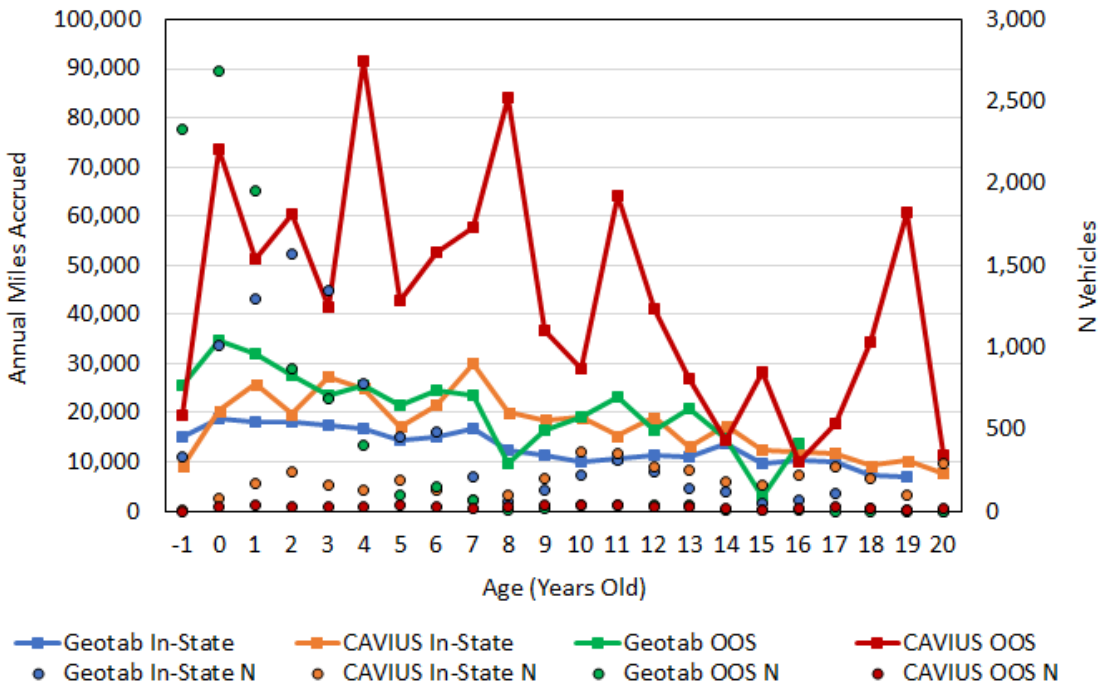


Figure 4-30. T6 Small Other In-State and Out-of-State Trucks

For the in-state T6 small trucks, we combined Geotab and Cal-VIUS datasets using a population weighted average using the sample size at each age and performed linear regression on the combined in-state truck profile to produce a second order polynomial trendline fit over ages 0 through 17.

For the OOS T6 small trucks, we combined the Geotab and Cal-VIUS data using an overall weight of approximately 95% Geotab and 5% Cal-VIUS for each age, reflecting the difference in overall sample size of 9,500 vs. 500 trucks. We used an overall population-weighted average for the OOS trucks because otherwise the high mileage Cal-VIUS profile drove the combined profile toward increasing miles with age, an artifact rather than a real trend observed in either dataset.

Figure 4-37 shows the resulting trendlines from the combined datasets for T6 small other in-state (blue) and OOS (purple), which fall below and above the current EMFAC profile for these categories. Therefore, we recommend adding the two new profiles shown in Figure 4-37 and Table 4-9.

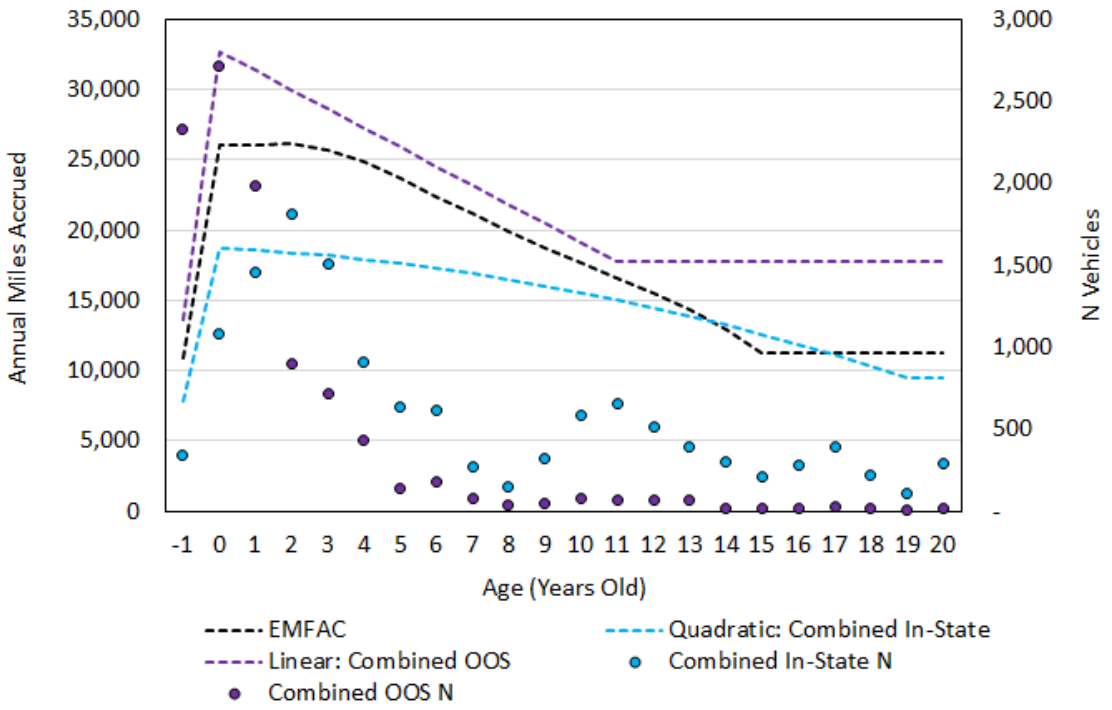


Figure 4-31. T6 Small Other In-State and Out-of-State Trucks Combined Datasets

Table 4-9. Accruals for other T6 small (Class 4-6) In-State and OOS Trucks

Age (years old)	EMFAC	Combined In-State	Combined OOS
-1	10,879	7,821	13,619
0	26,110	18,771	32,686
1	26,110	18,614	31,325
2	26,223	18,420	29,964
3	25,740	18,190	28,603
4	24,850	17,923	27,242
5	23,709	17,620	25,881
6	22,444	17,280	24,520
7	21,151	16,903	23,160
8	19,896	16,490	21,799
9	18,712	16,040	20,438
10	17,606	15,554	19,077
11	16,551	15,031	17,716
12	15,490	14,471	17,716
13	14,338	13,875	17,716
14	12,976	13,242	17,716
15	11,257	12,573	17,716
16	11,257	11,867	17,716
17	11,257	11,124	17,716
18	11,257	10,345	17,716
19	11,257	9,529	17,716
20	11,257	9,529	17,716

4.1.11 Results for other T6 heavy and T7 tractor

The Geotab dataset contained over 2,000 T6 heavy (Class 7) trucks that operate in-state and do not classify as any of the predefined categories of Port, Public/Utility, or Delivery trucks. It also contained over 4,000 trucks that are T7 tractor (Class 8), operate only in-state, and do not map to these categories. Cal-VIUS has 500 and 1,300 trucks in this situation, for T6 heavy and T7 tractor, respectively. A single EMFAC profile currently represents both of these along with T7 Other Ports (presented previously in Figure 4-17 and Table 4-3).

Figure 4-32 shows the Geotab and Cal-VIUS T6 heavy in-state (T6 hvy IS) and T7 tractor mean annual accruals by age on the primary axis and sample sizes by age on the secondary. The two T7 tractor series have higher accruals than T6 heavy in-state, indicating it may make sense to have separate profiles. Interestingly, the Cal-VIUS profile for T7 tractor (Figure 4-32) has lower accruals than the mean data for Cal-VIUS T6 small OOS (Figure 4-30), despite a similar sample size of 500 trucks in each set.

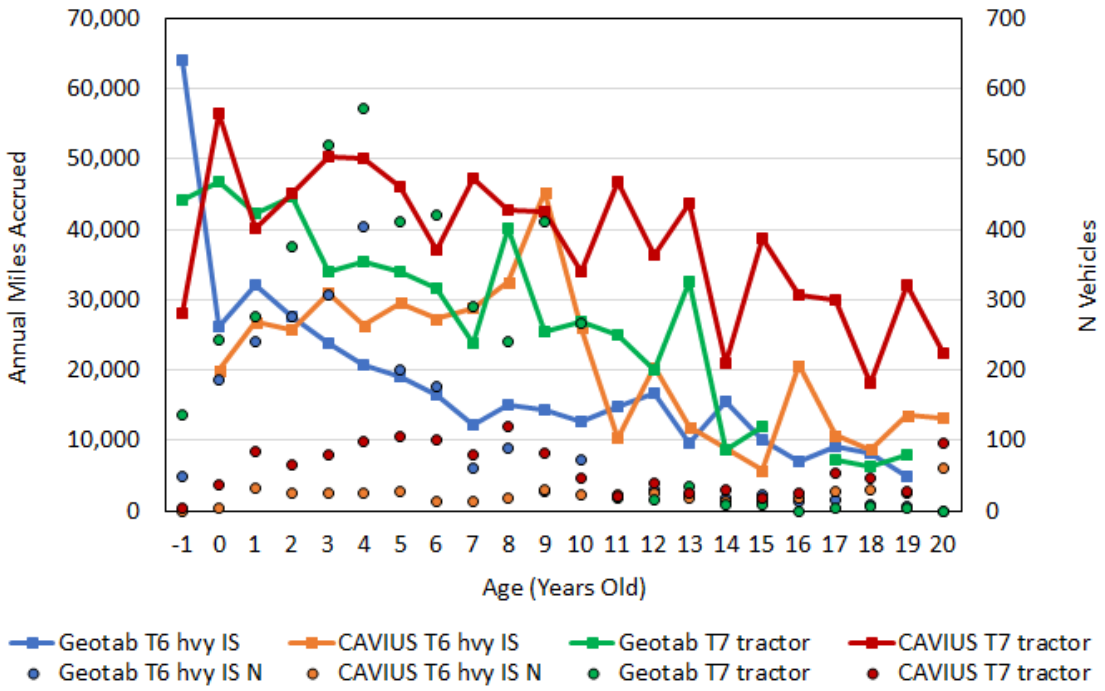


Figure 4-32. T6 Heavy In-State and T7 Tractor Trucks

Figure 4-33 shows the resulting trendlines from the combined datasets for T7 tractor (blue) and T6 heavy in-state (purple). Both profiles fall are much lower than the current EMFAC accrual profile. The T7 Other Ports trendline is included here for comparison, because the EMFAC

profile agreed well with that data. Table 4-10 lists the current EMFAC profile and recommended new profiles for the T6 heavy in-state and T7 tractor (also in-state).

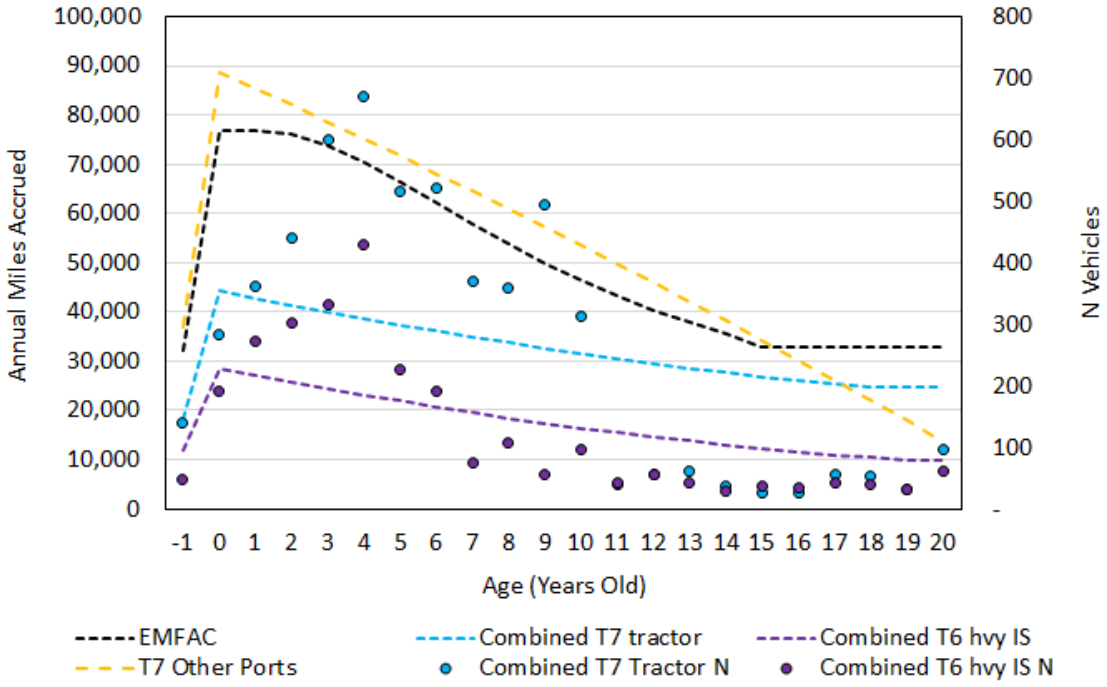


Figure 4-33. T6 Heavy In-State and T7 Tractor Trucks Combined Datasets

Table 4-10. Accruals for other T6 heavy instate and T7 tractor Trucks

Age (years old)	EMFAC	Combined T6 heavy instate	Combined T7 tractor
-1	32,045	11,906	18,466
0	76,909	28,574	44,318
1	76,909	27,128	42,823
2	76,003	25,734	41,376
3	73,662	24,392	39,977
4	70,325	23,101	38,625
5	66,367	21,862	37,322
6	62,107	20,675	36,066
7	57,802	19,540	34,858
8	53,651	18,456	33,698
9	49,792	17,424	32,586
10	46,304	16,444	31,521
11	43,206	15,516	30,504
12	40,459	14,639	29,536
13	37,960	13,814	28,615
14	35,552	13,041	27,741
15	33,013	12,319	26,916
16	33,013	11,649	26,138

Age (years old)	EMFAC	Combined T6 heavy instate	Combined T7 tractor
17	33,013	11,031	25,409
18	33,013	10,464	24,727
19	33,013	9,949	24,727
20	33,013	9,949	24,727

4.1.12 Results for other T7 single

The Geotab and Cal-VIUS datasets had respectively about 5,000 and 500 trucks that are T7 single (Class 8) trucks operating only in-state that do not map to the categories of solid waste refuse or public/utility truck. Figure 4-40 shows similar mean annual accruals by age for Geotab (blue) and Cal-VIUS (orange) for the T7 single trucks. Figure 4-35 shows the trendline from the combined datasets, which is a second order polynomial fit over age 0 to 17; this potential new profile aligns closely with the current EMFAC profile Table 4-11 lists the current EMFAC profile for T7 single and the recommended new profile based on the combined dataset.

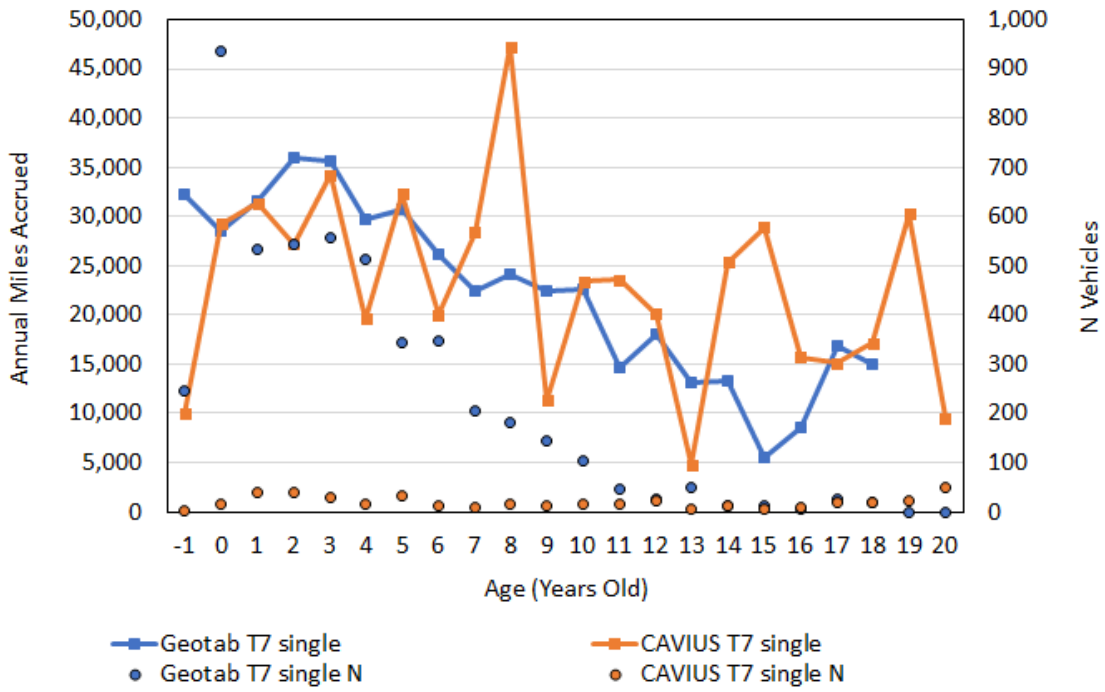


Figure 4-34. T7 Single Other Trucks

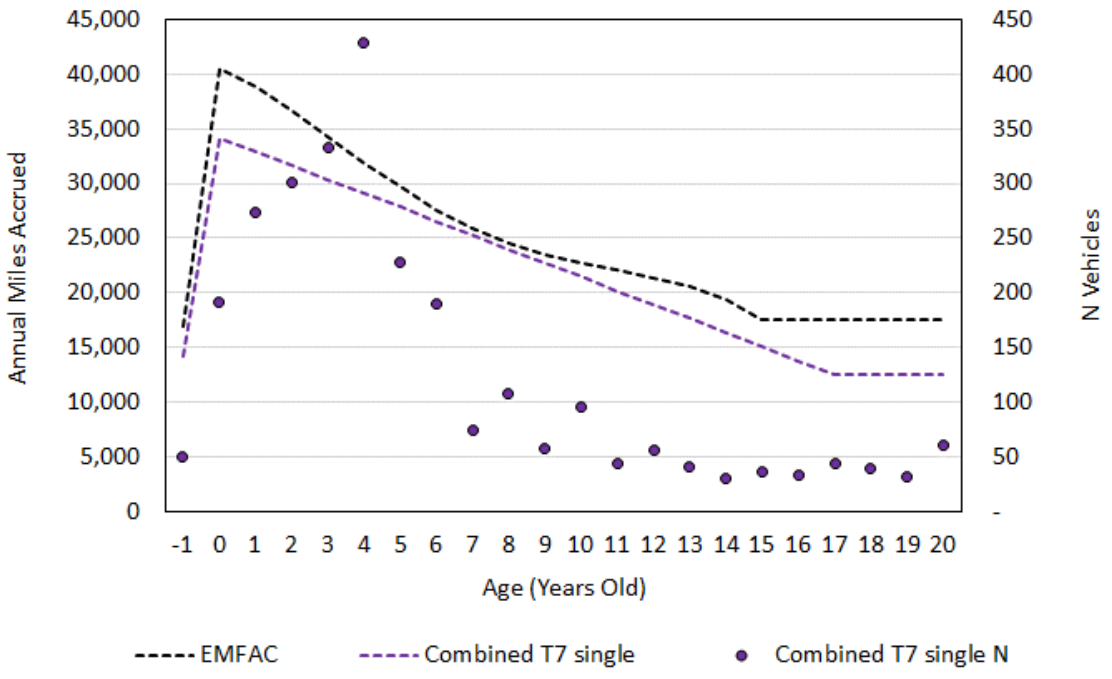


Figure 4-35. T7 Single Other Trucks Combined Dataset

Table 4-11. Accruals for other T7 Single Trucks

Age (years old)	EMFAC	Combined
-1	16,902	14,242
0	40,564	34,181
1	38,807	32,907
2	36,629	31,632
3	34,258	30,357
4	31,877	29,082
5	29,633	27,807
6	27,630	26,533
7	25,931	25,258
8	24,560	23,983
9	23,499	22,709
10	22,691	21,434
11	22,036	20,160
12	21,395	18,885
13	20,590	17,611
14	19,398	16,336
15	17,560	15,062
16	17,560	13,788
17	17,560	12,513
18	17,560	12,513
19	17,560	12,513
20+	17,560	12,513

4.1.13 Results for Variation by Sub-Region of California

Geotab's Air Basin data delivery was analyzed to identify whether any regional variation in mileage accrual rates was apparent for local trucks that operate in specific geographic sub-regions of California. For purposes of this analysis, ERG asked Geotab to identify local trucks as belonging to a sub-region Air Basin if they logged at least 85% of their annual VMT within a basin. Table 4-12 shows that over 90% of the nearly 10,000 trucks are specific to the top three air basins: South Coast, San Francisco Bay Area, and San Joaquin Valley. Therefore, we focus on these areas.

Table 4-12. Truck Counts by Weight and Air Basin

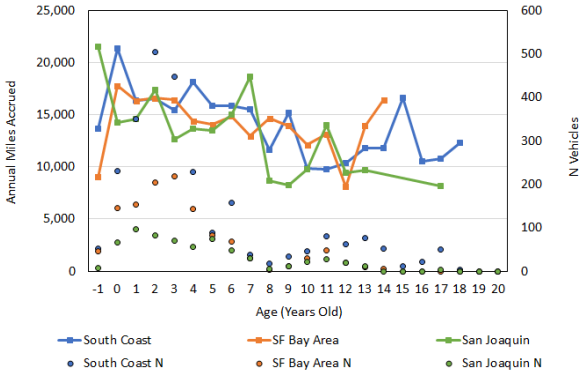
Air Basin	T6 small Trucks	T6 heavy Trucks	T7 Trucks	Total
SOUTH COAST	2,550	558	2,673	*5,781*
SAN FRANCISCO BAY AREA	1,215	158	314	*1,687*
SAN JOAQUIN VALLEY	636	150	678	*1,464*
SAN DIEGO COUNTY	321	33	119	*473*
SACRAMENTO VALLEY	198	38	90	*326*
SOUTH CENTRAL COAST	71	11	29	*111*
MOJAVE DESERT	10	-	-	*10*
NORTH CENTRAL COAST	4	4	-	*8*
MOUNTAIN COUNTIES	4	-	-	*4*
SALTON SEA	3	-	-	*3*
Total	***5,012***	***952***	***3,903***	***9,867***

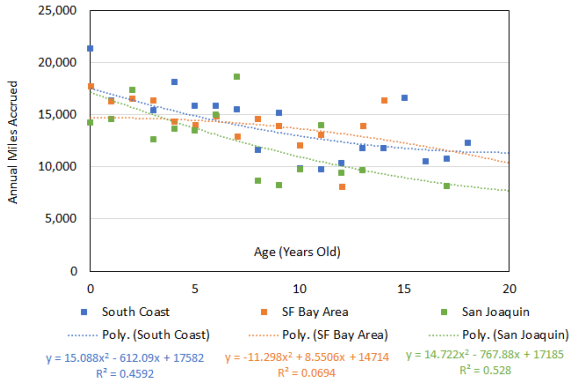
The highest sample size weight category T6 small was made up of the five vocations in Table 4-13, ranked from largest to smallest number of trucks. No matter which vocation examined, and even looking all T6 small trucks together, there wasn't significant variation among the air basins. The following two pages contain sets of plots where the left plot in the set shows the mean annual miles accrued and sample size for the South Coast (blue), San Francisco Bay Area (orange), and San Joaquin Valley (green). The right plot in each set shows quadratic trendlines. The data series all overlap by air basin without any clear trends emerging by geography. A similar observation can be made for the T7 trucks (all vocations).

Table 4-13. T6 Small Truck Counts by Vocation for Top 3 Air Basins

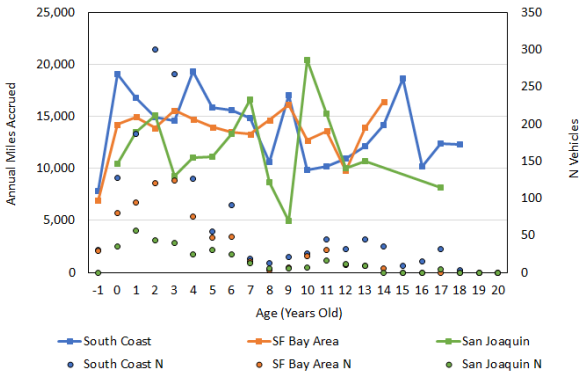
Vocation	South Coast	San Francisco Bay Area	San Joaquin Valley	Total
Service	1,474	719	325	2,518
Long Distance	623	310	194	1,127
Quick Stop	287	118	73	478
Door-To-Door	161	57	44	262
Local School Transport	5	11	-	16
Total	***2,550***	***1,215***	***636***	***4,401***

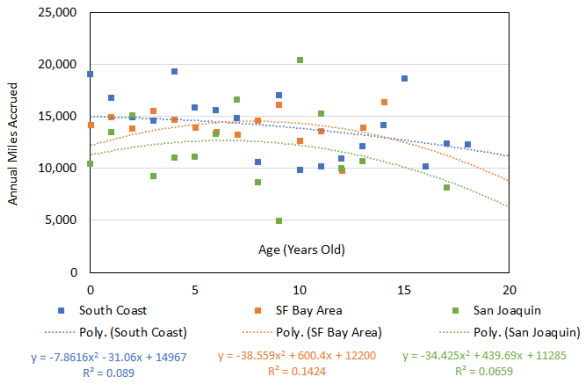
T6 Small, Single Unit, All Vocations



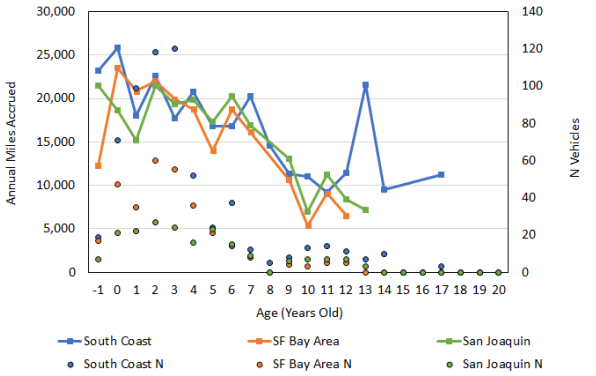


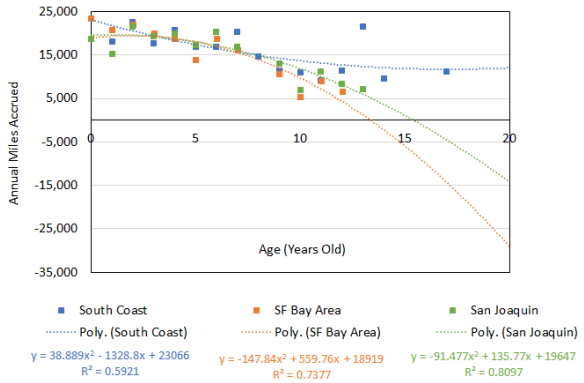
T6 Small, Single Unit, Service Trucks (Public/Utility)



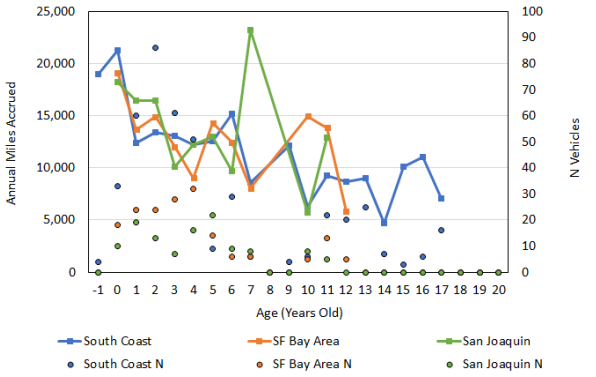


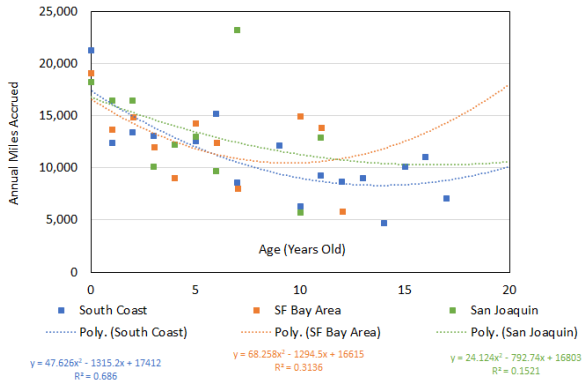
T6 Small, Single Unit, “Long Distance” vocation



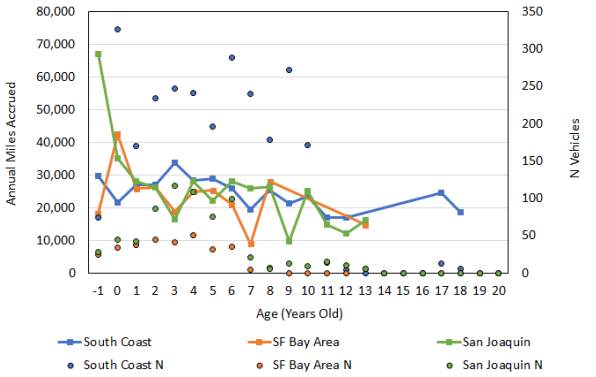


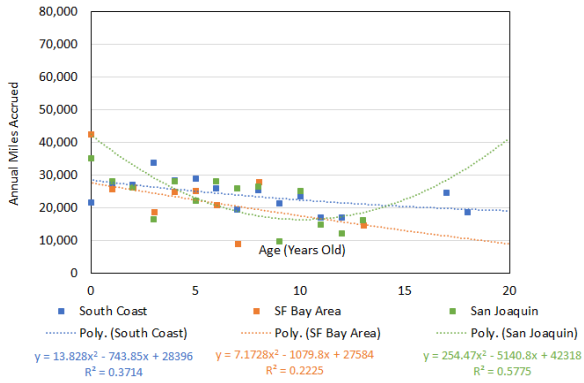
T6 Small, Single Unit, Quick Stop + Door-To-Door (Delivery)





T7, Single and Tractor, All Vocations





4.2 School Bus Fleet Survey Analysis

To evaluate EMFAC’s school bus (SBUS) mileage accrual profile, Figure 4-36 presents the 2016 ARB School Bus Fleet Survey average accrual by engine model year (blue) and Geotab mean

annual mileage accrual by age (green). The Geotab data were selected from the in-state main analysis with a vocation of "Local School Transport," which totaled 295 vehicles. The ARB School Bus Fleet Survey sample size was 352 buses. Both new datasets suggest the current EMFAC profile is too high. Although, four of the datapoints fall above the current EMFAC accrual schedule for SBUS, most of the mean accruals by age are lower. Therefore, we recommend combining the new datasets and fitting with a quadratic trendline shown in Figure 4-36. Table 4-14 lists the recommended mileage accrual by age shown in the figure.

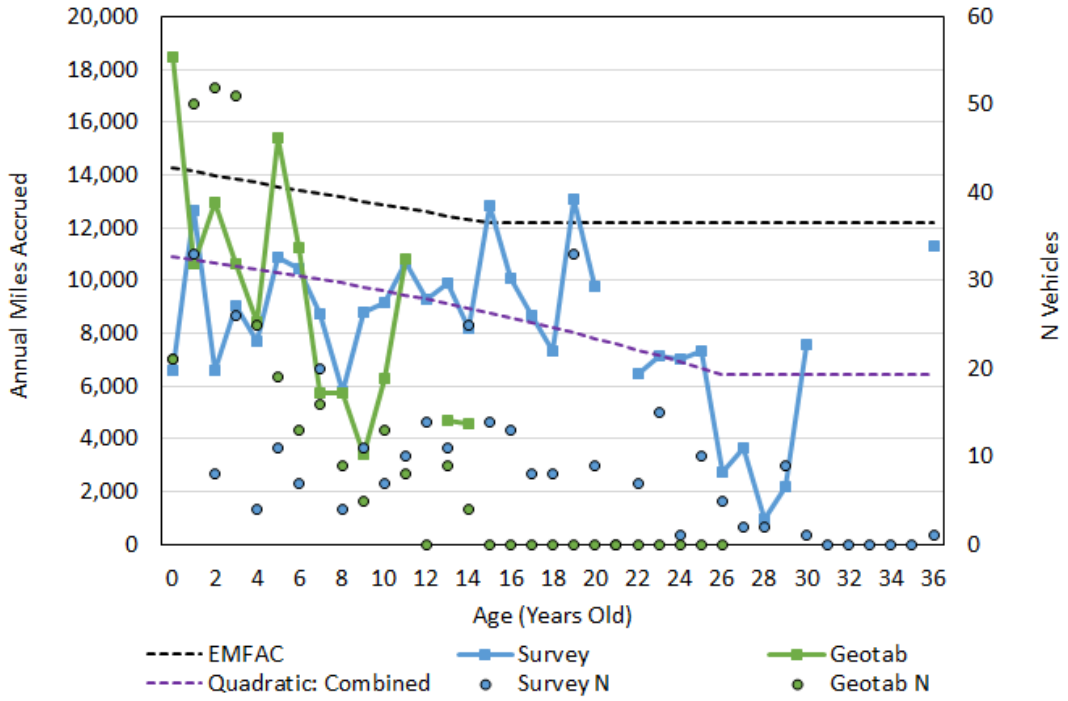


Figure 4-36. Evaluation of School Bus Fleet Survey Mileage Accruals by Age

Table 4-14. Accruals for School Buses

Age (years old)	EMFAC	Combined Geotab and ARB Survey
-1	5,945	4,538
0	14,269	10,890
1	14,130	10,787
2	13,990	10,679
3	13,851	10,565
4	13,712	10,446
5	13,572	10,322
6	13,433	10,192
7	13,293	10,057
8	13,154	9,917
9	13,015	9,771
10	12,875	9,620

Age (years old)	EMFAC	Combined Geotab and ARB Survey
11	12,736	9,463
12	12,596	9,301
13	12,457	9,134
14	12,318	8,961
15	12,178	8,783
16	12,178	8,600
17	12,178	8,411
18	12,178	8,217
19	12,178	8,018
20	12,178	7,813
21	12,178	7,603
22	12,178	7,388
23	12,178	7,167
24	12,178	6,941
25	12,178	6,709
26	12,178	6,472
27+	12,178	6,472

4.3 State Inspection Data Analysis

The analysis of the Colorado and New Jersey HDV inspection data was limited to odometer, and not accrual rates like the analyses of the telematics and survey data. We began by looking at the cumulative mileage at each age (odometer), because it was the most direct way of using the inspection mileage data. While accrual rates are possible to calculate from multiple test dates for the same VIN, the rates would not have been specific to one single age (e.g., 3 years old), because multiple years elapse between consecutive odometer readings. Due to this limitation, and the fact that the vehicles were not California-specific, efforts to understand accrual rates were not performed here and instead focused on the preceding data types.

The analysis to compare state odometer to EMFAC odometer by age was straightforward. After categorizing the state VINs into the seven categories (Section 3.4), we overlaid the mean odometer by age with the corresponding EMFAC values on the same plot.
Table 4-15 summarizes the evaluation of EMFAC odometer profiles by comparison to the state data. “Low” indicates that the Colorado and New Jersey data were higher than EMFAC odometer profiles, suggesting the model could be too low. Similarly, “High” indicates a judgment that EMFAC profiles showed higher odometer than similar vehicles in other states. It should be noted that often the EMFAC vehicle vocations were more specific (e.g., Utility or Public Truck) than available from the inspection databases, and so meaningful, direct comparison is not possible.

Table 4-15. Evaluation of EMFAC Odometer using the Out of State Inspection Data

Figure Number	EMFAC Vehicle Odometer Profile [A]	Low	Match	High	Comparison to EMFAC
4-37	Other Bus		X		No changes.

Figure Number	EMFAC Vehicle Odometer Profile [A]	Low	Match	High	Comparison to EMFAC
4-38	Motor Coach			X	Consider reducing mileage and capping earlier.
4-39	School Bus			X	Consider reducing mileage.
4-40	T6 Ag			X	No changes because the EMFAC vehicle categories are more specific than inspection dataset.
	T6 Utility	X			
	T6 Public	X			
4-41	T6 (labeled "T6 LongHaul" in the plot.)		X		No changes.
4-42	T7 Ag			X	No changes.
	T7 Single		X		
	T7 SWCV		X		
	T7 Public	X			
	T7 Utility	X			
4-43	T7 IRP			X	Consider reducing odometer, based on inspection data. However, Cal-VIUS and Geotab suggest accrual rates are already too low in EMFAC for older vehicles.
	T7 Tractor			X	

[A] Provided by ARB in the file EMFAC_HD_Odometer.csv

Figures 4-37 through 4-43 show the EMFAC odometer by age and the state data mean, 5th percentile, and 95th percentile. The state data color schemes are the same on all 7 plots: blue for Colorado and green for New Jersey.

Overall, the seven figures indicate that for newer vehicles aged 0 to 20 years old, the EMFAC odometer values are generally bounded by the 5th and 95th percentiles of the state data. Beyond 20 years old, the sample size in the state data is low and the profiles become noisy as a result. Appendix A and B show the sample size by vehicle age for the state data.

Figures 4-37 and 4-38 show the "Non-School Bus" category comparisons, starting with Figure 4-37 for shorter haul operations. The state data here either did not appear in the IRP database (Colorado) or did not have an apportioned license plate (New Jersey). The EMFAC "Other Bus" category is generally in agreement with the short-haul bus state mean odometer by age, especially New Jersey through age 10 years old.

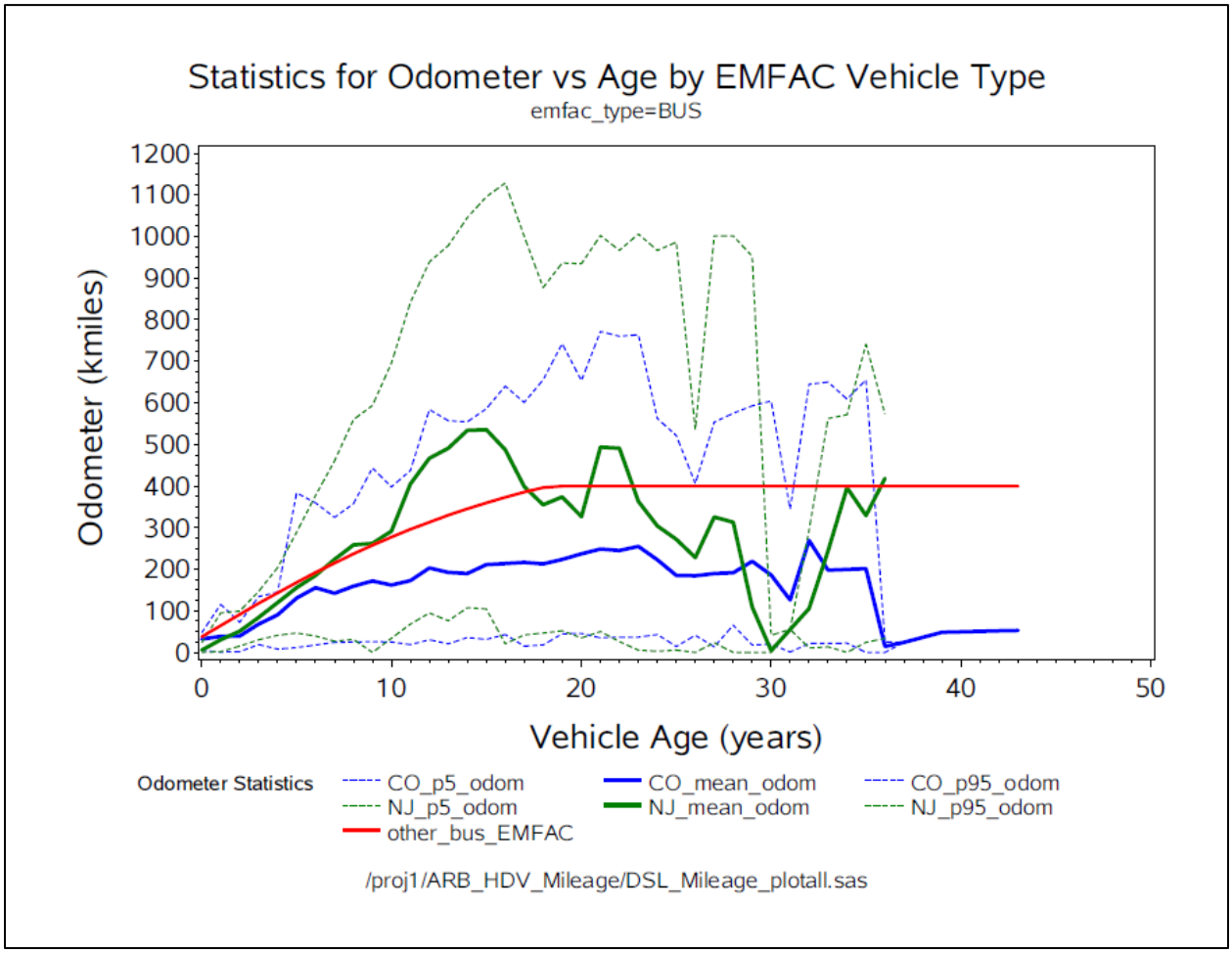


Figure 4-37. Non-School Bus (Short haul) Cumulative VMT by Age Comparison

EMFAC's "Motor Coach" odometer profile (Figure 4-38) appears too high relative to the long-haul non-school bus state data, because it exceeds the New Jersey 95th percentile for 0-6 years old, though for age 7+ years the odometer profile falls between the states' mean and 95th percentiles.

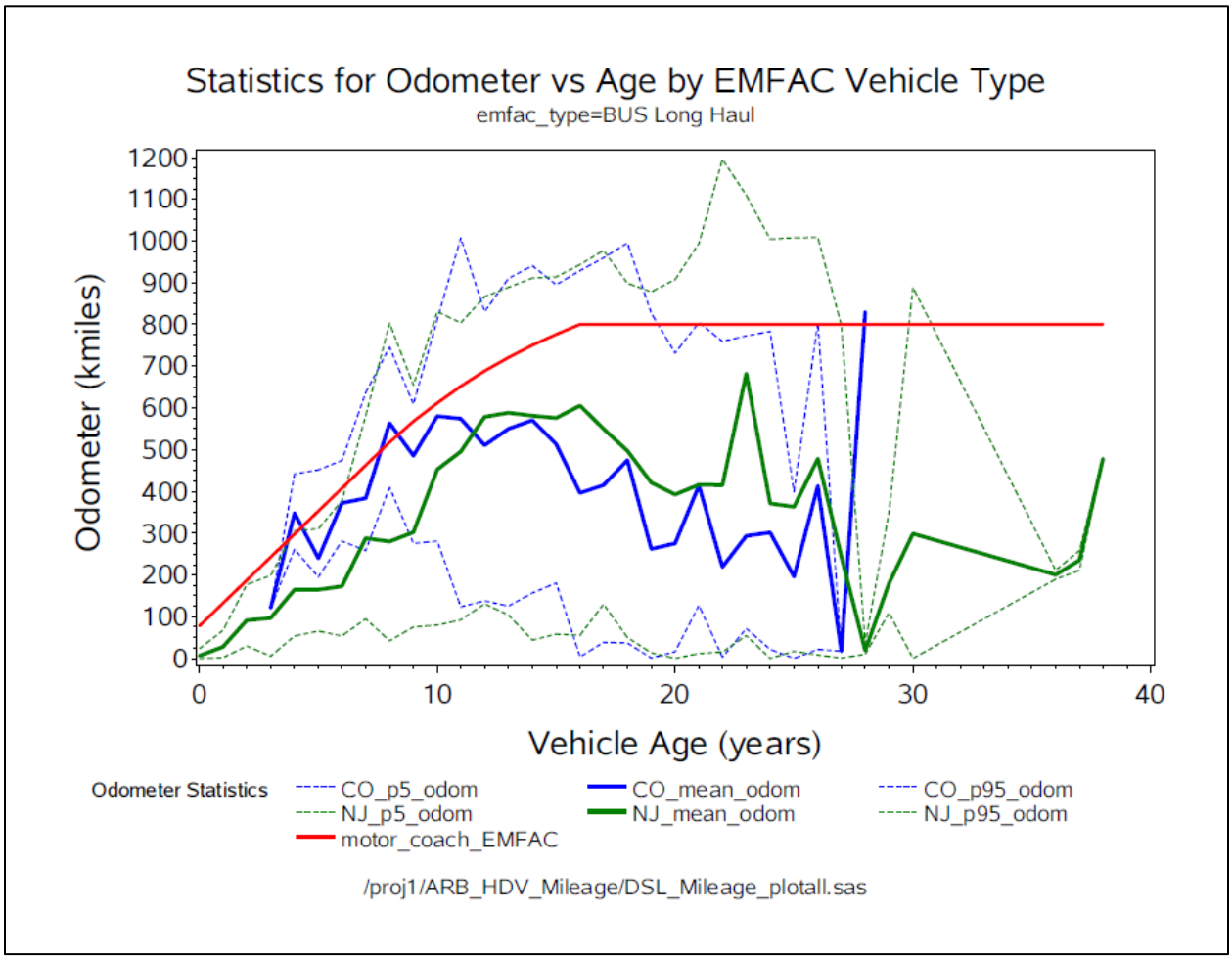


Figure 4-38. Non-School Bus (Long-haul) Cumulative VMT by Age Comparison

Figure 4-39 shows the "School Bus" category comparisons. EMFAC school bus odometer values look slightly higher than the other states odometer, for ages 0-20 years. Beyond 20 years vehicle age, the Colorado data become less smooth due to smaller sample size (see Appendix A, Figure A-2, secondary Y-axis), and the New Jersey data also become so scarce that Figure 4-39 shows that the mean, and 5th and 95th percentiles are nearly the same after 21 years old. While the EMFAC odometer values are higher than the 2016 School Bus Survey reported annual mileage (purple series in Figure 4-39), they track similarly in that they continue accruing mileage past age 20, suggesting EMFAC is capping the odometer at a reasonable point in a vehicle's life.

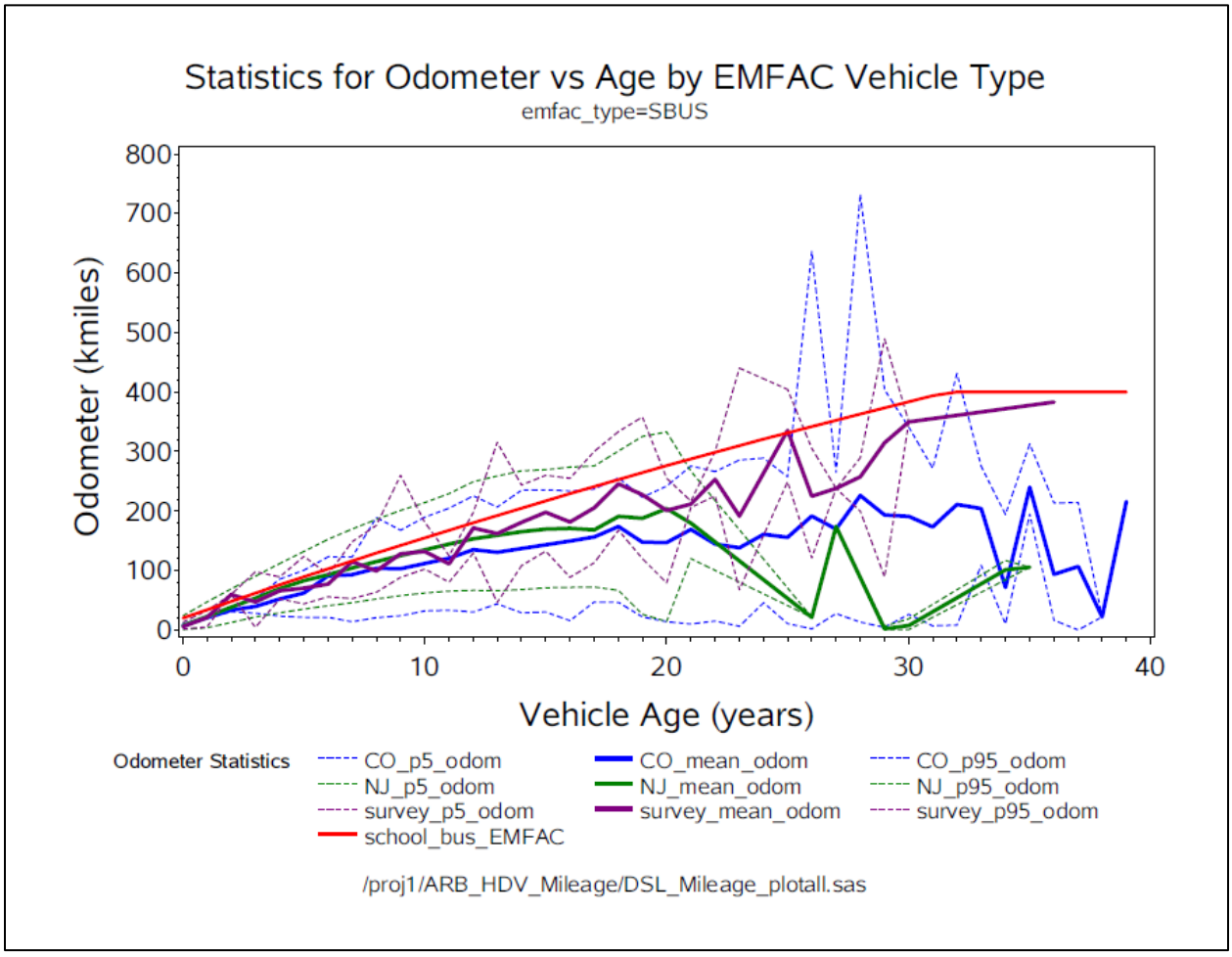


Figure 4-39. School Bus Cumulative VMT by Age Comparison

Figure 4-40 shows the "T6 Short-haul Truck" category comparisons. This vehicle group refers to heavy-duty trucks with GVW between 14,000 and 33,000 lbs., and the state data is filtered to exclude trucks that are registered under Colorado's IRP program or have a New Jersey apportioned license plate type. EMFAC doesn't explicitly label HDVs as short- or long-haul, so we apply our best judgement in selecting HDVs for the comparison. Figure 4-40 includes HDVs that EMFAC identifies as agriculture, public, and utility trucks. The state data does not include enough detail to draw specific conclusions about EMFAC short-haul T6 trucks by vocation; however, the EMFAC profiles look reasonable overall. EMFAC T6 Agricultural Trucks (red series) falls above the state mean while EMFAC T6 Utility and Public Trucks (pink and yellow, overlapping) are lower than the mean.

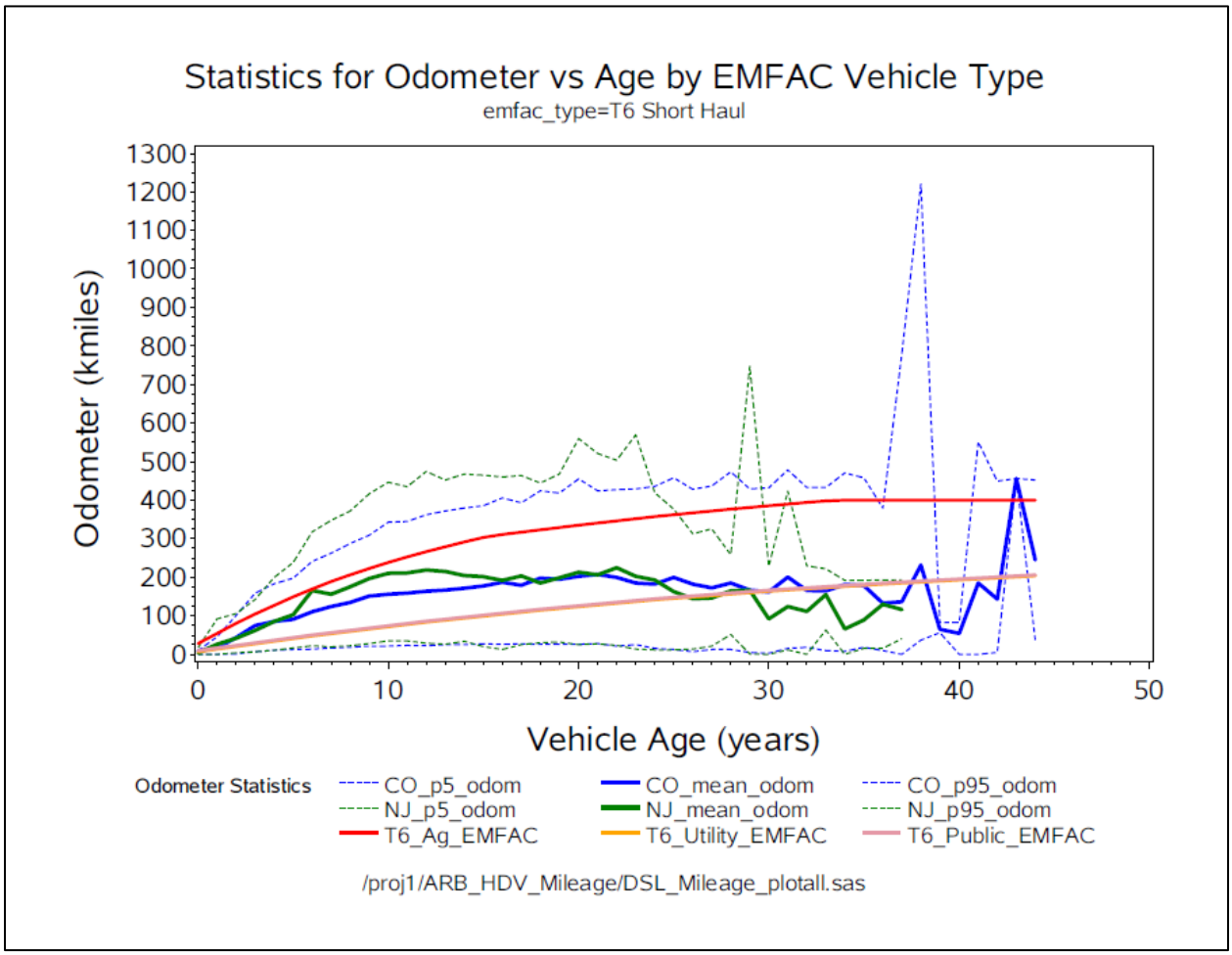


Figure 4-40. T6 Short-haul Truck Cumulative VMT by Age Comparison

Figure 4-41 displays the "T6 Long-haul Truck" category comparisons. The state data sample size here is low; most long-haul trucks tended to be T7 (above 33,000 lbs. GVW). EMFAC "T6" odometer values are shown in the red series; this vehicle class maps to many truck classes in EMFAC including "T6 In-state Heavy," "T6 CAIRP Heavy," and "CAIRP Small" which have a high portion of their annual VMT inside the state, and the categories of "OOS Heavy," and "OOS Small" which have a low portion of annual travel within California.

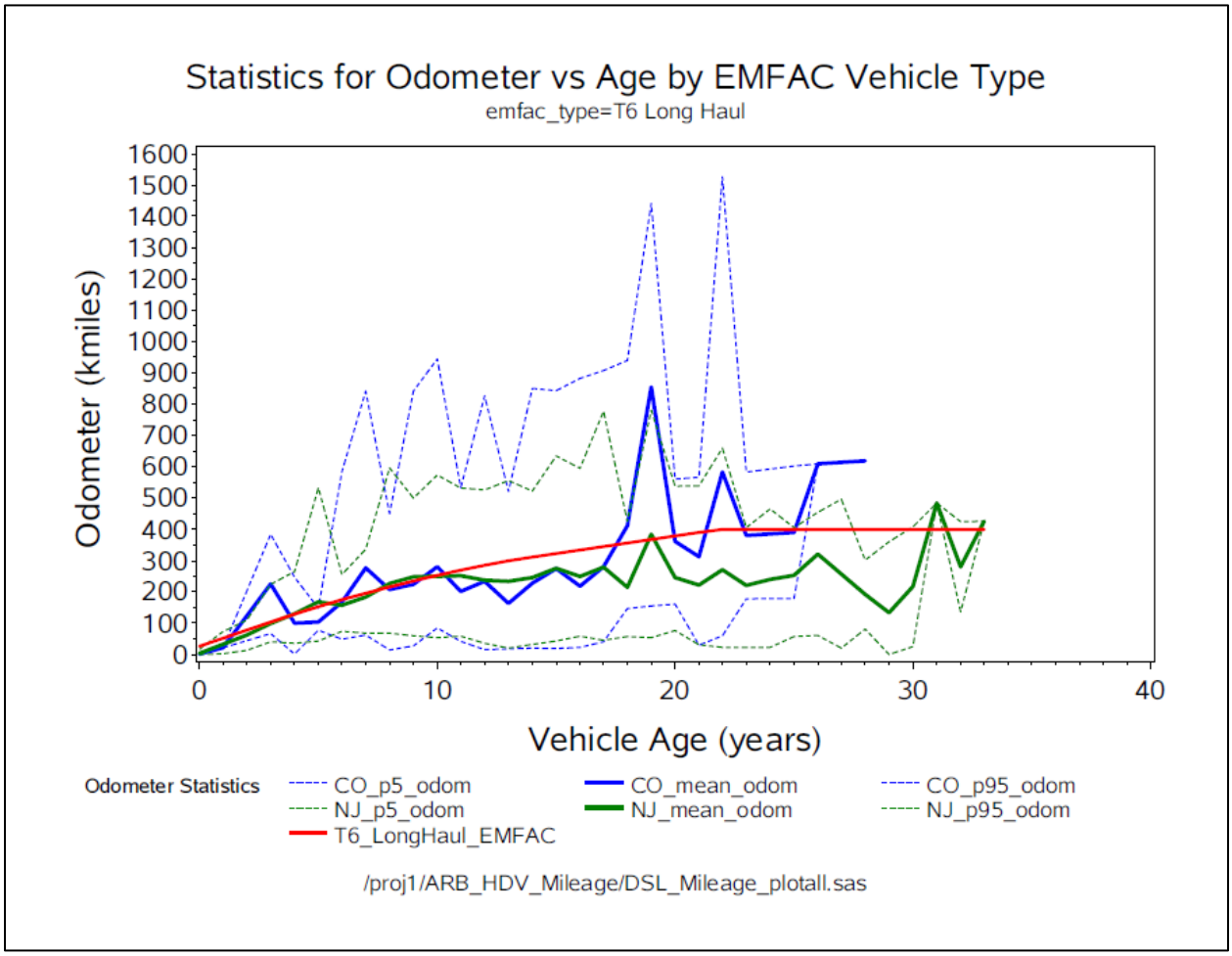


Figure 4-41. T6 Long-haul Truck Cumulative VMT by Age Comparison

Figure 4-42 shows the "T7 Short-haul Truck" category comparisons. The T7 Ag truck (red series) shows higher odometer than the state means, while T7 single (light purple) tracks closely with Colorado's mean odometer (blue). T7 SWCV (Solid Waste Collection Vehicle; light pink) tracks with New Jersey's mean through age 15. T7 Public and T7 Utility (yellow series, overlapping) have odometer profiles by age that are below both states' means. Like the T6 Short-haul truck comparisons (Figure 4-40), the state inspection data does not include the same level of detail as EMFAC to be able to draw specific conclusions about these model categories.

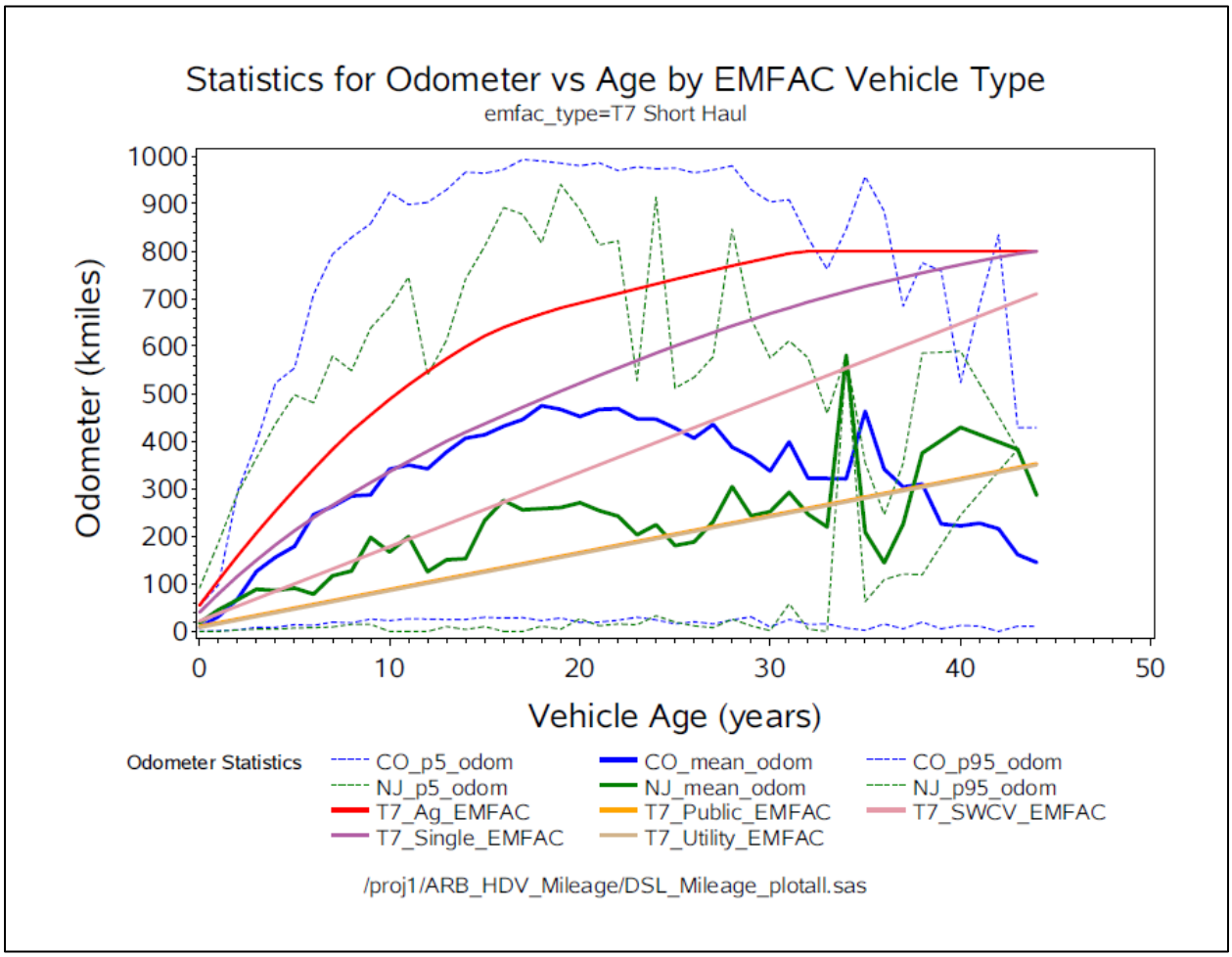


Figure 4-42. T7 Short-haul Truck Cumulative VMT by Age Comparison

Figure 4-43 shows the "T7 Long-haul Truck" category comparisons. The two EMFAC HDV categories T7 IRP (red series) and T7 Tractor (yellow) are higher than the both Colorado and New Jersey mean odometer values but lower than their 95th percentiles.

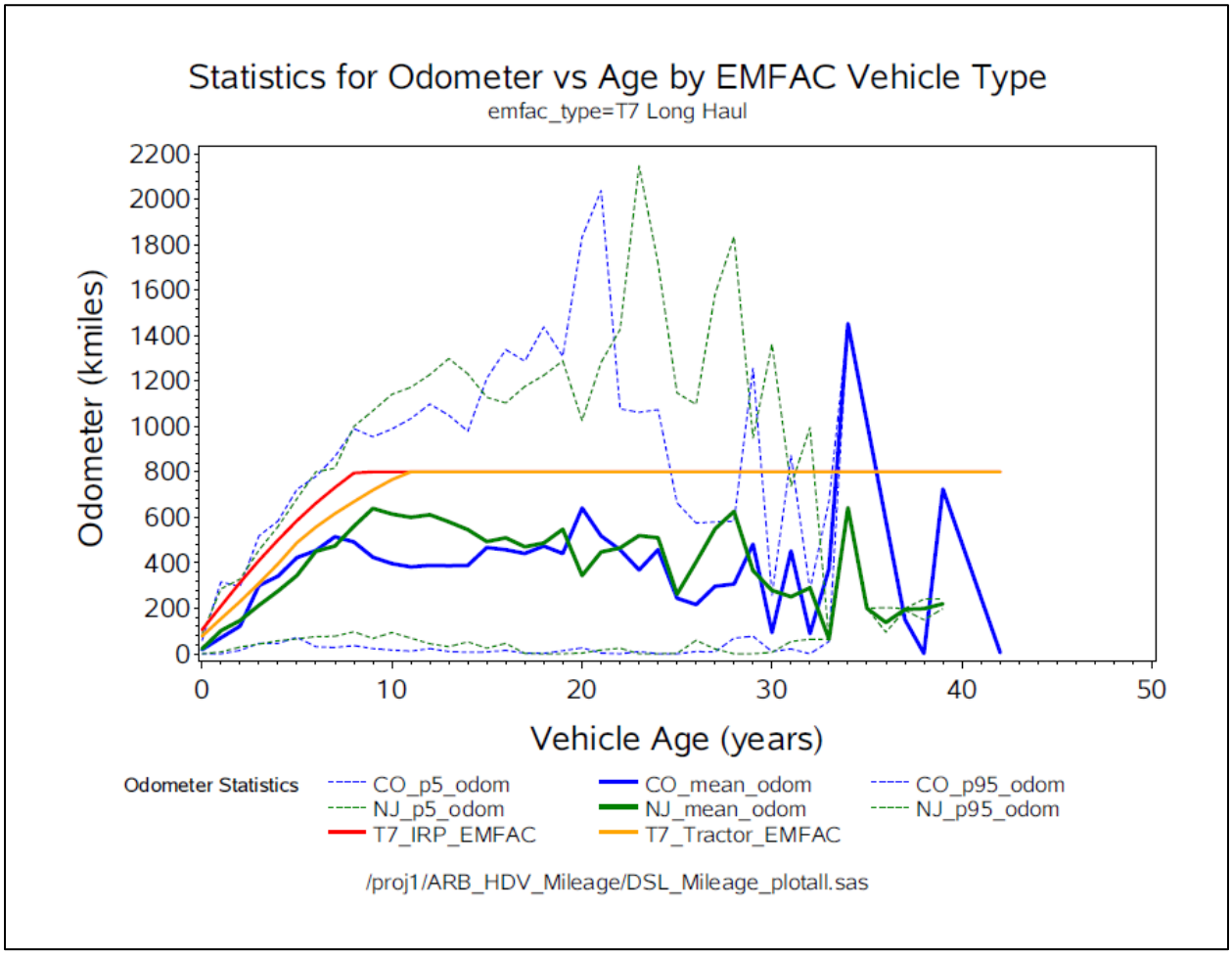


Figure 4-43. T7 Long-haul Truck Cumulative VMT by Age Comparison

5.0 Recommended EMFAC Updates and Future Work

This work produced 18 new accrual profiles for consideration in the next EMFAC. The recommended new profiles are based on data that are California-specific and recent (from years 2016 to 2018).

1. Class 7-8 Interstate Tractor Long-Haul Trucks – NOOS (Neighboring States)
2. Class 7-8 Interstate Tractor Long-Haul Trucks – CAIRP
3. Class 7-8 Interstate Tractor Long-Haul Trucks – NNOOS (Non-Neighboring States)
4. Class 7-8 In-state Tractor Port Trucks Operating at Port of Los Angeles
5. Class 7-8 In-state Tractor Port Trucks Operating at Port of Oakland
6. Class 7-8 In-state Tractor Port Trucks Operating at Other Ports in California
7. Class 7-8 In-state Tractor Public/Utility Trucks
8. Class 4-6 (T6 small) In-State Single Unit Delivery Trucks
9. Class 7 (T6 heavy) In-State Single Unit Delivery Trucks
10. Class 7-8 In-state Single Unit Solid Waste Refuse Trucks
11. Class 7-8 In-state Single Unit Public/Utility Trucks
12. Class 4-6 In-state Single Unit Public/Utility Trucks
13. Other Class 4-6 (T6 small) In-state Trucks
14. Other Class 4-6 (T6 small) OOS Trucks
15. Other Class 7 (T6 heavy) In-state Trucks
16. Other Class 8 (T7) Tractor In-state Trucks
17. Other Class 8 (T7) Single Unit In-state Trucks
18. All GVW Class In-state School Bus

In nearly all cases, the recommended profile is an average of the annualized Geotab data with the direct Cal-VIUS, using the number of trucks from each source to weight the miles accrued by age. The proposed profiles keep the current EMFAC assumption for the "-1" year old aged vehicles (e.g., 2019 model year in calendar year 2018), whereby the age -1 miles are a 5/12 fraction of the age 0 vehicle's annual miles.

The proposed new profiles have second order polynomial trendlines (except for a few categories where it made sense to use flat and linear models, described throughout Section 4.1). The trendlines are fit from age 0 through the age at which 97% of the cumulative sample size is reached; after this age, the profile is capped – reflecting that the oldest vehicles have uncertain mileage accrual rates. This uncertainty is caused by smaller sample size for the oldest vehicles. The following 11 tables list the current EMFAC profile alongside the recommended update for each of the 18 profiles listed above.

Table 5-1. Recommendation for Class 7-8 Interstate Tractor Long-Haul Trucks

Age (years old)	EMFAC	NOOS	CAIRP	NNOOS
-1	43,847	47,650	41,320	49,517
0	105,234	114,361	99,168	118,841
1	105,141	109,251	95,346	114,354

Age (years old)	EMFAC	NOOS	CAIRP	NNOOS
2	102,228	104,586	91,748	110,203
3	97,292	100,368	88,375	106,388
4	91,028	96,595	85,227	102,909
5	84,030	93,268	82,303	99,766
6	76,791	90,387	79,605	96,958
7	69,707	87,952	77,130	94,486
8	63,069	85,962	74,881	92,350
9	57,069	84,419	72,856	90,550
10	51,799	83,321	71,056	89,086
11	47,251	82,669	69,481	87,958
12	43,315	82,462	68,130	87,165
13	39,780	82,462	67,005	86,708
14	36,336	82,462	66,103	86,587
15	32,572	82,462	65,427	86,802
16	32,572	82,462	64,975	87,353
17	32,572	82,462	64,748	88,240
18	32,572	82,462	64,746	88,240
19	32,572	82,462	64,968	88,240
20+	32,572	82,462	64,968	88,240

Table 5-2. Recommendation for Class 7-8 Instate Tractor Port Trucks

Age (years old)	EMFAC POLA	Cal-VIUS POLA	EMFAC POAK	Cal-VIUS POAK	EMFAC Other Ports	Cal-VIUS Other Ports
-1	42,446	49,940	38,794	36,608	32,045	36,976
0	42,446	49,940	38,794	36,608	76,909	88,742
1	42,446	49,940	38,794	36,608	76,909	85,426
2	42,446	49,940	38,794	36,608	76,003	82,064
3	42,446	49,940	38,794	36,608	73,662	78,656
4	42,446	49,940	38,794	36,608	70,325	75,202
5	42,446	49,940	38,794	36,608	66,367	71,702
6	42,446	49,940	38,794	36,608	62,107	68,156
7	42,446	49,940	38,794	36,608	57,802	64,564
8	42,446	49,940	38,794	36,608	53,651	60,926
9	42,446	49,940	38,794	36,608	49,792	57,241
10	42,446	49,940	38,794	36,608	46,304	53,511
11	42,446	49,940	38,794	36,608	43,206	49,735
12	42,446	49,940	38,794	36,608	40,459	45,912
13	42,446	49,940	38,794	36,608	37,960	42,044
14	42,446	49,940	38,794	36,608	35,552	38,129
15	42,446	49,940	38,794	36,608	33,013	34,169
16	42,446	49,940	38,794	36,608	33,013	30,162
17	42,446	49,940	38,794	36,608	33,013	26,109
18	42,446	49,940	38,794	36,608	33,013	22,010
19	42,446	49,940	38,794	36,608	33,013	17,866
20+	42,446	49,940	38,794	36,608	33,013	13,675

Table 5-3. Recommendation for Class 7-8 Instate Tractor Public/Utility Trucks

Age (years old)	EMFAC	Geotab
-1	3,240	13,705
0	7,776	32,891
1	7,776	30,295
2	7,776	27,899
3	7,776	25,703
4	7,776	23,707
5	7,776	21,911
6	7,776	20,315
7	7,776	18,919
8	7,776	17,723
9	7,776	16,727
10	7,776	15,931
11	7,776	15,931
12 to 20+	7,776	15,931

Table 5-4. Recommendation for Class 4-6 and Class 7 Instate Single Unit Delivery Trucks

Note: There is no existing EMFAC profile shown because delivery truck is a new category.

Age (years old)	Combined T6 small	Combined T6 heavy
-1	6,833	8,092
0	16,398	19,420
1	15,787	19,950
2	15,210	20,392
3	14,668	20,746
4	14,160	21,014
5	13,685	21,195
6	13,245	21,288
7	12,840	21,294
8	12,468	21,213
9	12,131	21,044
10	11,828	20,789
11	11,559	20,446
12	11,324	20,016
13	11,124	19,499
14	10,957	18,894
15	10,825	18,202
16	10,727	17,424
17	10,664	17,424
18	10,664	17,424
19	10,664	17,424
20+	10,664	17,424

Table 5-5. Recommendation for Class 7-8 Instate Single Unit Solid Waste Refuse Trucks

Age (years old)	EMFAC	Combined
-1	6,515	10,091
0	15,635	24,220
1	15,635	24,220
2 to 20+	15,635	24,220

Table 5-6. Recommendation for Class 7-8 Instate Single Unit Public/Utility Trucks

Age (years old)	EMFAC	Geotab
-1	3,240	10,698
0	7,776	25,674
1	7,776	24,218
2	7,776	22,851
3	7,776	21,573
4	7,776	20,384
5	7,776	19,285
6	7,776	18,275
7	7,776	17,354
8	7,776	16,523
9	7,776	15,780
10	7,776	15,127
11	7,776	14,564
12	7,776	14,089
13	7,776	13,704
14	7,776	13,408
15	7,776	13,201
16	7,776	13,201
17	7,776	13,201
18	7,776	13,201
19	7,776	13,201
20+	7,776	13,201

Table 5-7. Recommendation for Class 4-6 Instate Single Unit Public/Utility Trucks

Age (years old)	EMFAC	Combined
-1	2,968	6,772
0	7,122	16,253
1	7,000	16,211
2	6,879	16,136
3	6,757	16,029
4	6,636	15,890
5	6,514	15,719
6	6,392	15,515
7	6,271	15,280
8	6,149	15,012
9	6,028	14,712
10	5,906	14,380
11	5,784	14,016

Age (years old)	EMFAC	Combined
12	5,663	13,619
13	5,541	13,191
14	5,420	12,730
15	5,298	12,237
16	5,298	11,712
17	5,298	11,155
18	5,298	10,565
19	5,298	10,565
20+	5,298	10,565

Table 5-8. Recommendation for Other T6 small instate and OOS Trucks

Age (years old)	EMFAC	Combined In-State	Combined OOS
-1	10,879	7,821	13,619
0	26,110	18,771	32,686
1	26,110	18,614	31,325
2	26,223	18,420	29,964
3	25,740	18,190	28,603
4	24,850	17,923	27,242
5	23,709	17,620	25,881
6	22,444	17,280	24,520
7	21,151	16,903	23,160
8	19,896	16,490	21,799
9	18,712	16,040	20,438
10	17,606	15,554	19,077
11	16,551	15,031	17,716
12	15,490	14,471	17,716
13	14,338	13,875	17,716
14	12,976	13,242	17,716
15	11,257	12,573	17,716
16	11,257	11,867	17,716
17	11,257	11,124	17,716
18	11,257	10,345	17,716
19	11,257	9,529	17,716
20+	11,257	9,529	17,716

Table 5-9. Recommendation for Other T6 heavy instate and T7 tractor Trucks

Age (years old)	EMFAC	Combined T6 heavy instate	Combined T7 tractor
-1	32,045	11,906	18,466
0	76,909	28,574	44,318
1	76,909	27,128	42,823
2	76,003	25,734	41,376
3	73,662	24,392	39,977
4	70,325	23,101	38,625
5	66,367	21,862	37,322
6	62,107	20,675	36,066
7	57,802	19,540	34,858

Age (years old)	EMFAC	Combined T6 heavy instate	Combined T7 tractor
8	53,651	18,456	33,698
9	49,792	17,424	32,586
10	46,304	16,444	31,521
11	43,206	15,516	30,504
12	40,459	14,639	29,536
13	37,960	13,814	28,615
14	35,552	13,041	27,741
15	33,013	12,319	26,916
16	33,013	11,649	26,138
17	33,013	11,031	25,409
18	33,013	10,464	24,727
19	33,013	9,949	24,727
20+	33,013	9,949	24,727

Table 5-10. Recommendation for Other T7 single Trucks

Age (years old)	EMFAC	Combined
-1	16,902	14,242
0	40,564	34,181
1	38,807	32,907
2	36,629	31,632
3	34,258	30,357
4	31,877	29,082
5	29,633	27,807
6	27,630	26,533
7	25,931	25,258
8	24,560	23,983
9	23,499	22,709
10	22,691	21,434
11	22,036	20,160
12	21,395	18,885
13	20,590	17,611
14	19,398	16,336
15	17,560	15,062
16	17,560	13,788
17	17,560	12,513
18	17,560	12,513
19	17,560	12,513
20+	17,560	12,513

Table 5-11. Recommendation for School Buses

Age (years old)	EMFAC	Combined Geotab and ARB Survey
-1	5,945	4,538
0	14,269	10,890
1	14,130	10,787
2	13,990	10,679
3	13,851	10,565
4	13,712	10,446
5	13,572	10,322
6	13,433	10,192
7	13,293	10,057
8	13,154	9,917
9	13,015	9,771
10	12,875	9,620
11	12,736	9,463
12	12,596	9,301
13	12,457	9,134
14	12,318	8,961
15	12,178	8,783
16	12,178	8,600
17	12,178	8,411
18	12,178	8,217
19	12,178	8,018
20	12,178	7,813
21	12,178	7,603
22	12,178	7,388
23	12,178	7,167
24	12,178	6,941
25	12,178	6,709
26	12,178	6,472
27+	12,178	6,472

Future Work

The categorization of delivery vehicles was a major source of uncertainty in this work. The descriptions available from Geotab vocations don't necessarily align with the filters applied to the Cal-VIUS data to separate the delivery trucks. As a result, the accrual rate schedules look very different from each other in Figure 4-19. Geotab vocations we associated with "delivery truck" for this work describe last mile operation because the trips are described as quick stop and door-to-door in Table 3-4, associated with several stops before returning to a central hub. It's less clear whether Cal-VIUS delivery trucks (home base type = distribution center) are making many stops, or hauling goods over longer distances (e.g., between regional and local distribution hubs). If the latter, the Cal-VIUS may be representing more of the "first mile" portion of the supply and distribution chain.

The American Transportation Research Institute describes changing retailer business models with the emergence of e-commerce (e.g., Amazon and EBay) as well as onmi-channel retailing, whereby customers can have goods shipped from warehouses to brick-and-mortar stores, their offices, or homes (ATRI, 2019). The ATRI report describes the effect of these changes as shrinking the “last mile” distance, while increasing the number of trips, and extensive build-out of regional and local distribution centers close to urban areas, including Stockton, California.

ERG recommends further study on the delivery truck category as it appears to be becoming an important category in future versions of EMFAC. For the current work, ERG and Geotab were limited to working within existing Geotab vocation categories. However, Geotab could help ARB further categorize their customers into trucks specific to different parts of delivery chain (e.g., first mile vs. last mile) using business name or possibly by analyzing trip patterns between distribution centers. More research could be done in the future to understand delivery truck activity.

6.0 Acknowledgements

The authors acknowledge project leaders Sherrie Sala-Moore and Sam Pournazeri for devising project objectives and providing technical guidance. We also thank Geotab for their willingness to provide several iterations of aggregated mileage summaries of their HDV telematics data. Geotab data has demonstrated that telematics can be used to improve annual mileage accrual rates in on-road vehicle emissions models. In addition, Caltrans provided the California Vehicle Inventory and Use Survey (Cal-VIUS) and ARB provided the 2016 School Bus Fleet Survey results.

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6. CADOT, 2018. "Final Report, California Vehicle Inventory and Use Survey, Volume I: Truck Survey. " Prepared by Cambridge Systematics, Inc. for the California Department of Transportation. April.

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Appendix A

Colorado Diesel I/M Program Mean (Mn), Median (Md), and Percentiles (P5, P25, P75, P95), and Sample Size, by Vehicle Age

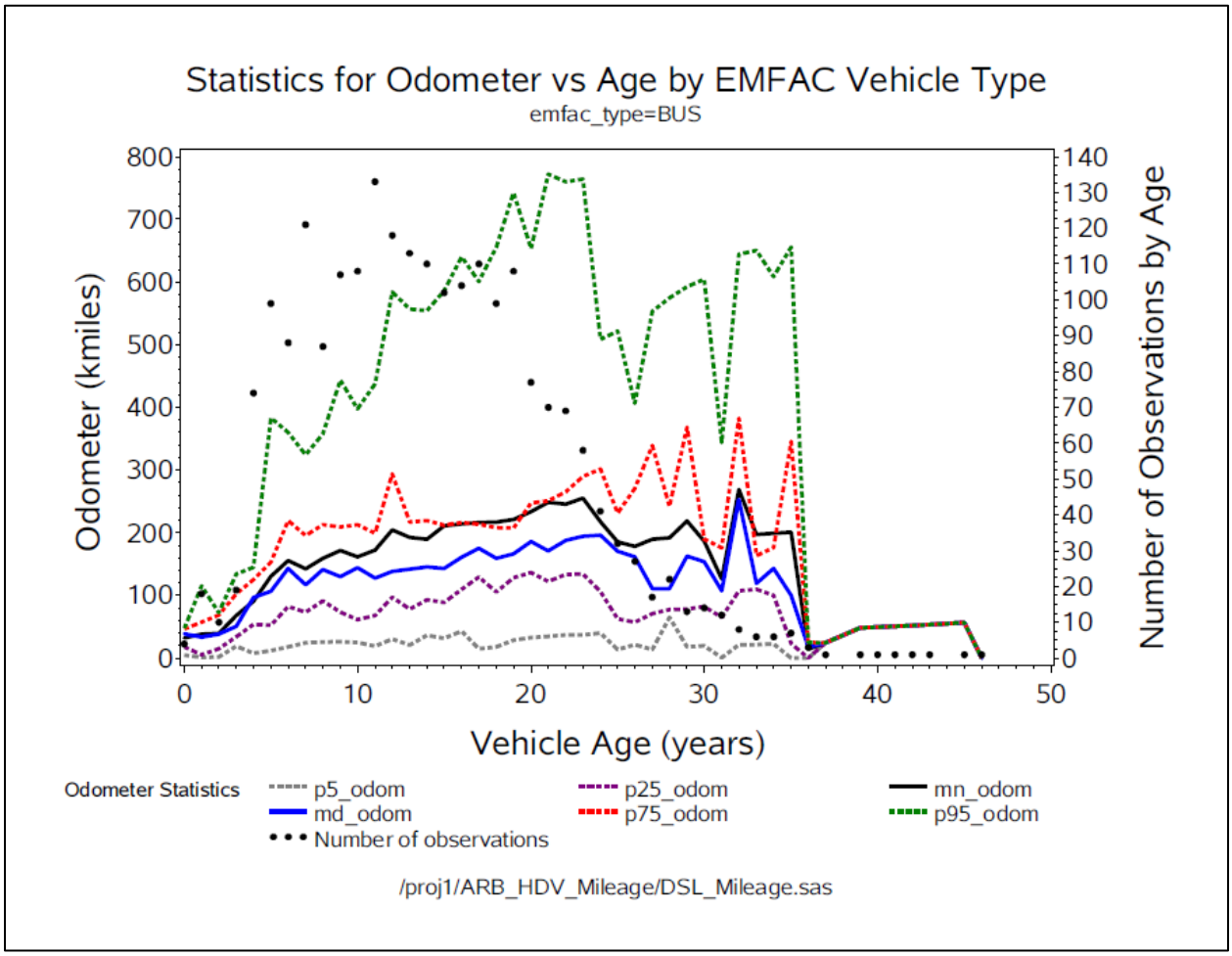

Figure A-1. Colorado Non-School Bus Odometer by Age

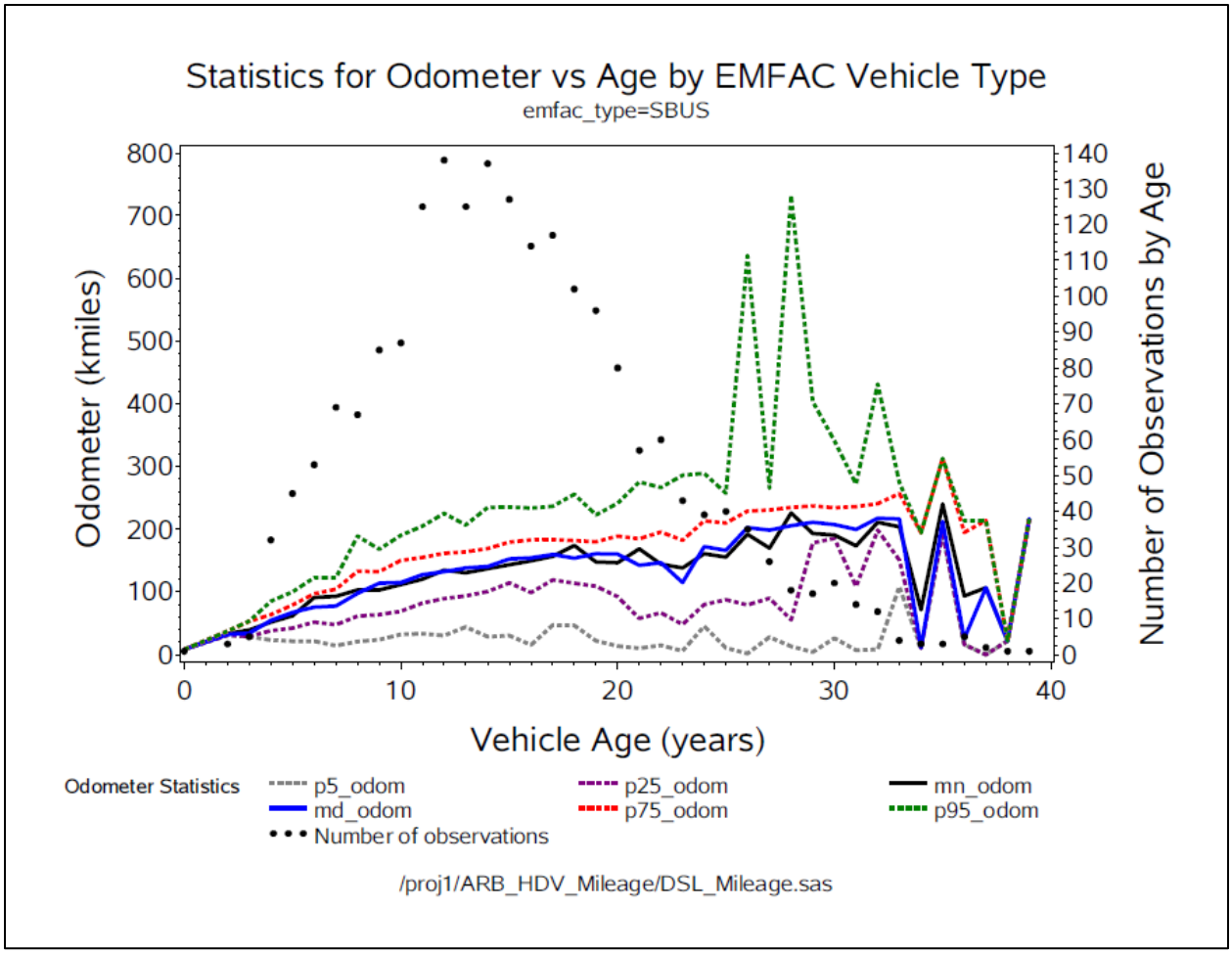

Figure A-2. Colorado School Bus Odometer by Age

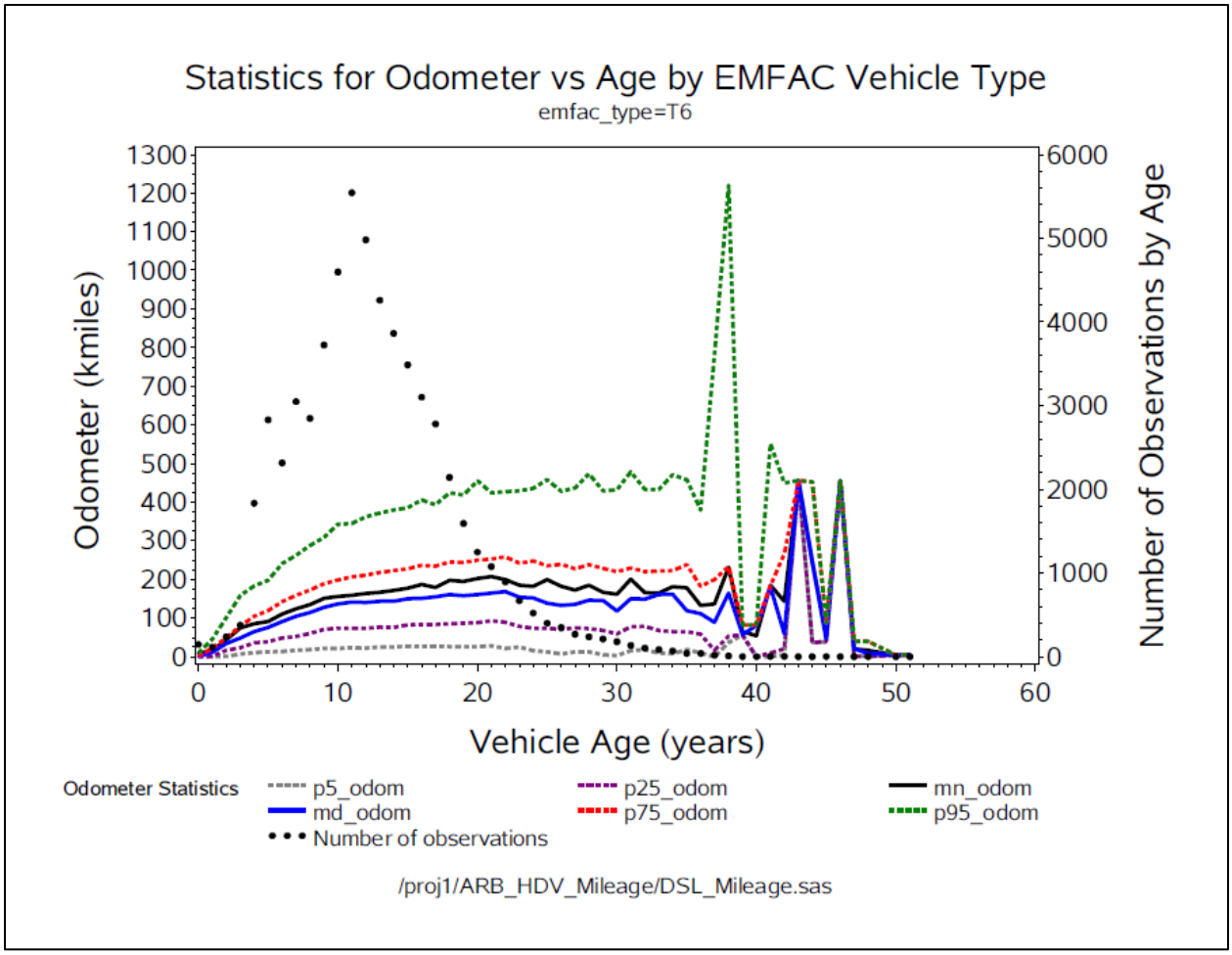

Figure A-3. Colorado T6 Short-haul Truck Odometer by Age

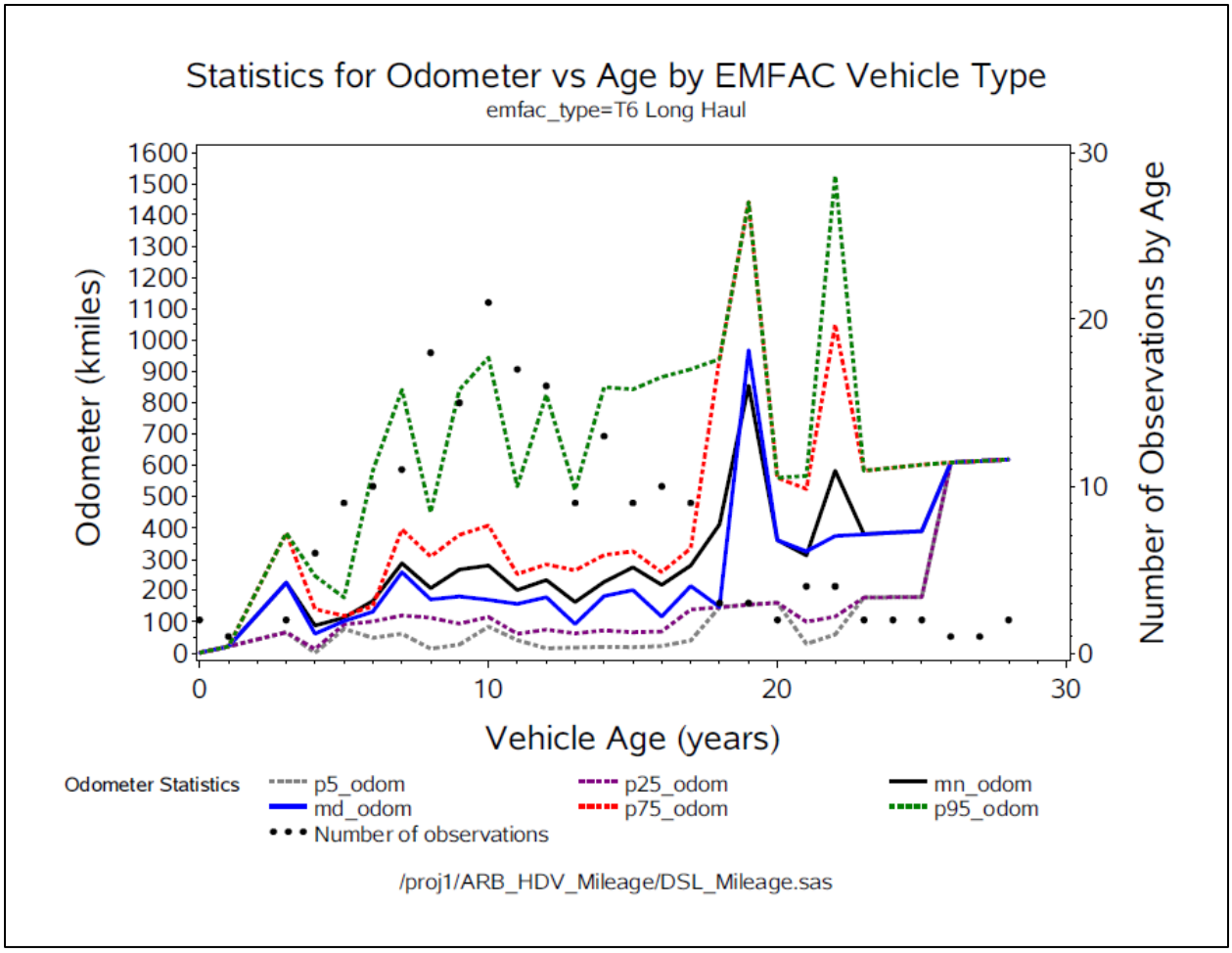

Figure A-4. Colorado T6 Long-haul Truck Odometer by Age

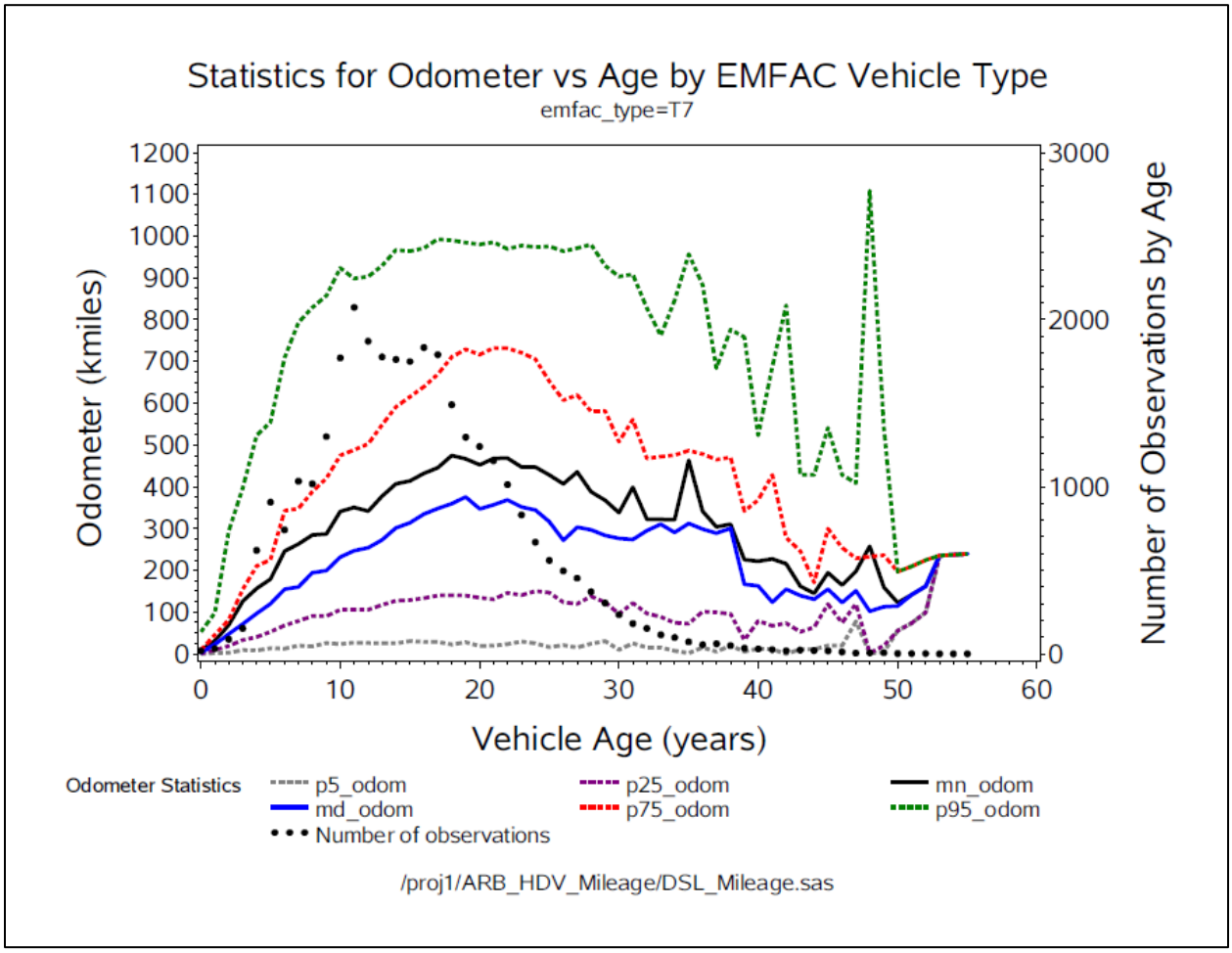

Figure A-5. Colorado T7 Short-haul Truck Odometer by Age

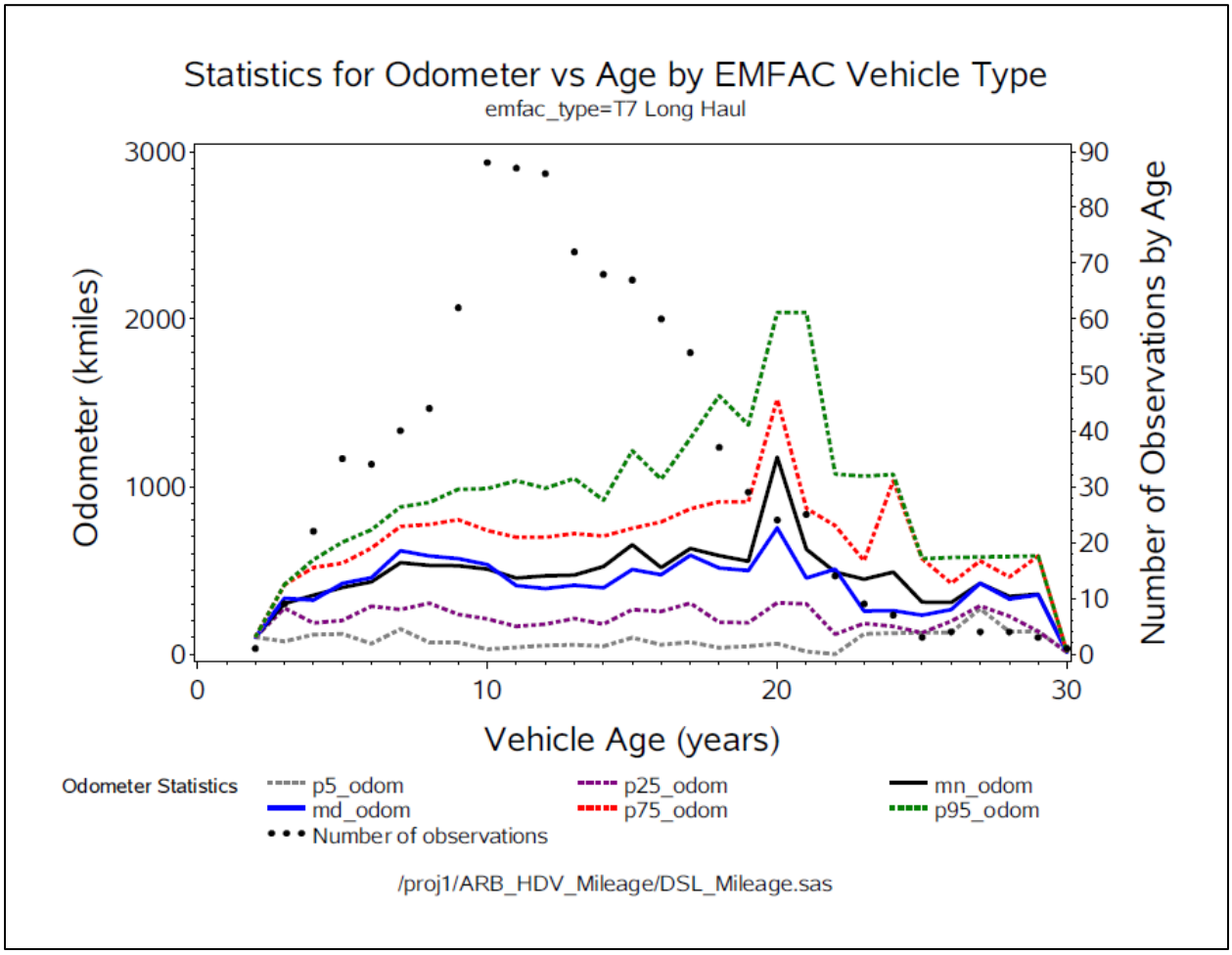

Figure A-6. Colorado T7 Long-haul Truck Odometer by Age

Appendix B

New Jersey Diesel I/M Program Mean (Mn), Median (Md), and Percentiles (P5, P25, P75, P95), and Sample Size, by Vehicle Age

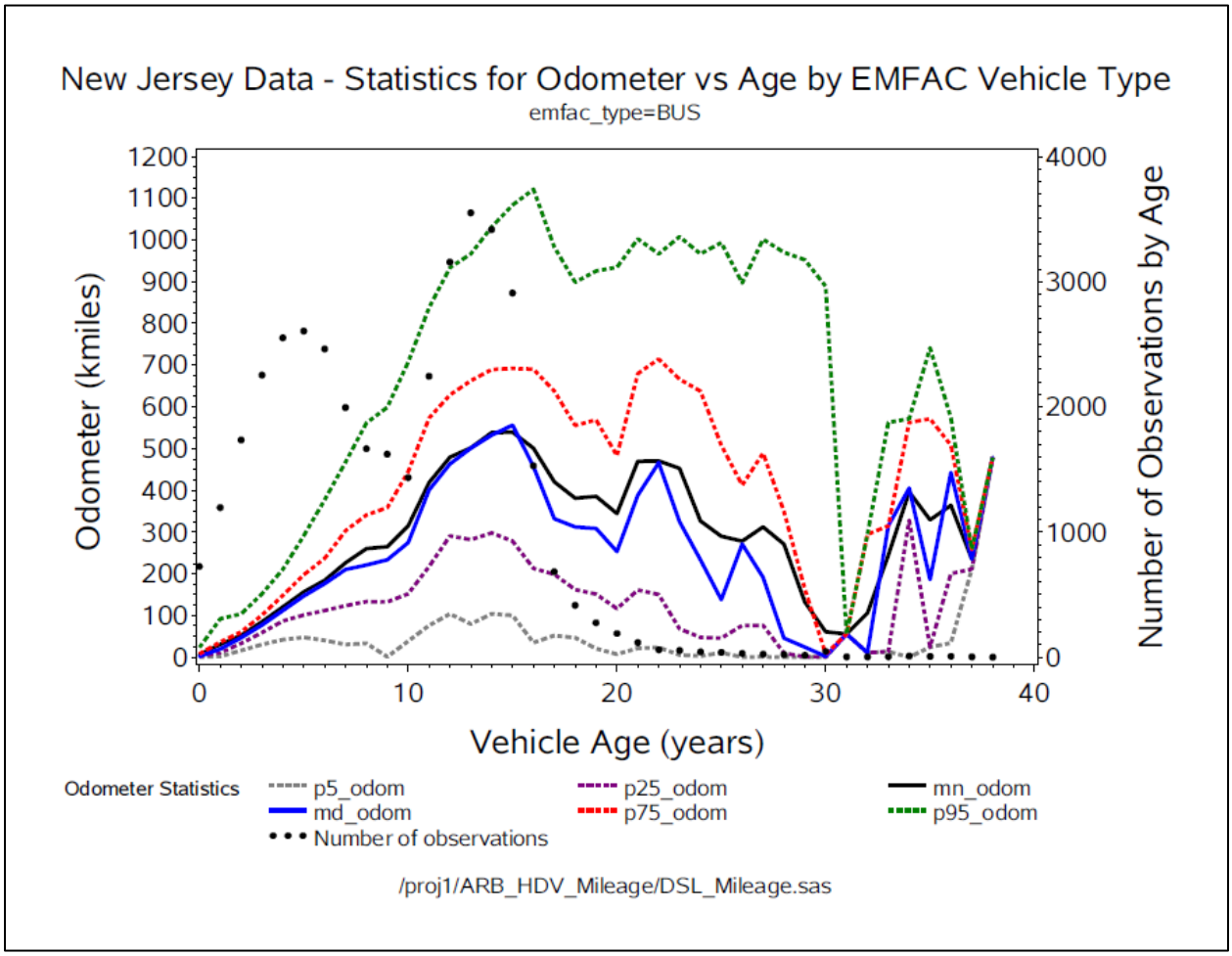

Figure B-1. New Jersey Non-School Bus Odometer by Age

Appendix B
New Jersey Diesel I/M Program

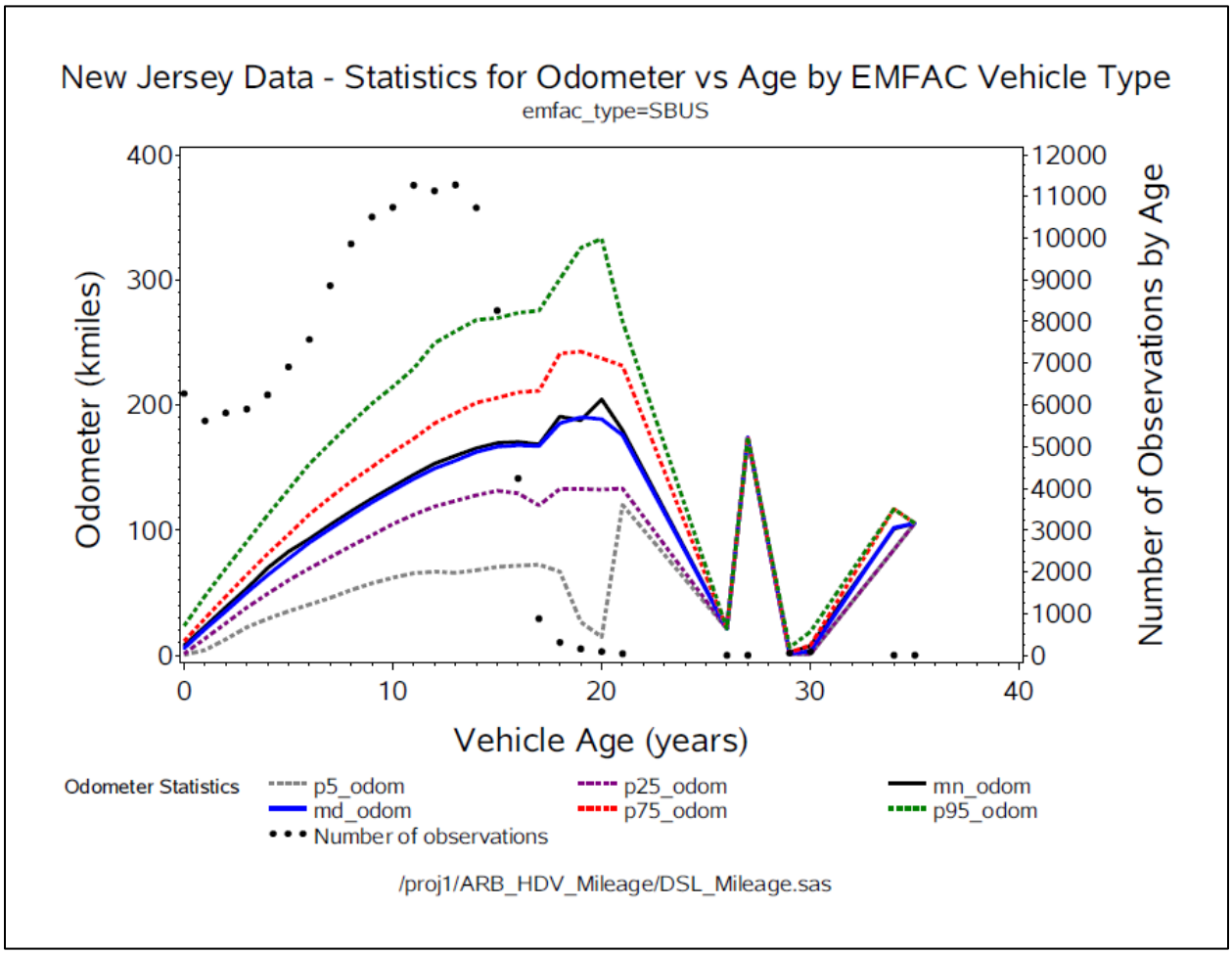

Figure B-2. New Jersey School Bus Odometer by Age

Appendix B
New Jersey Diesel I/M Program

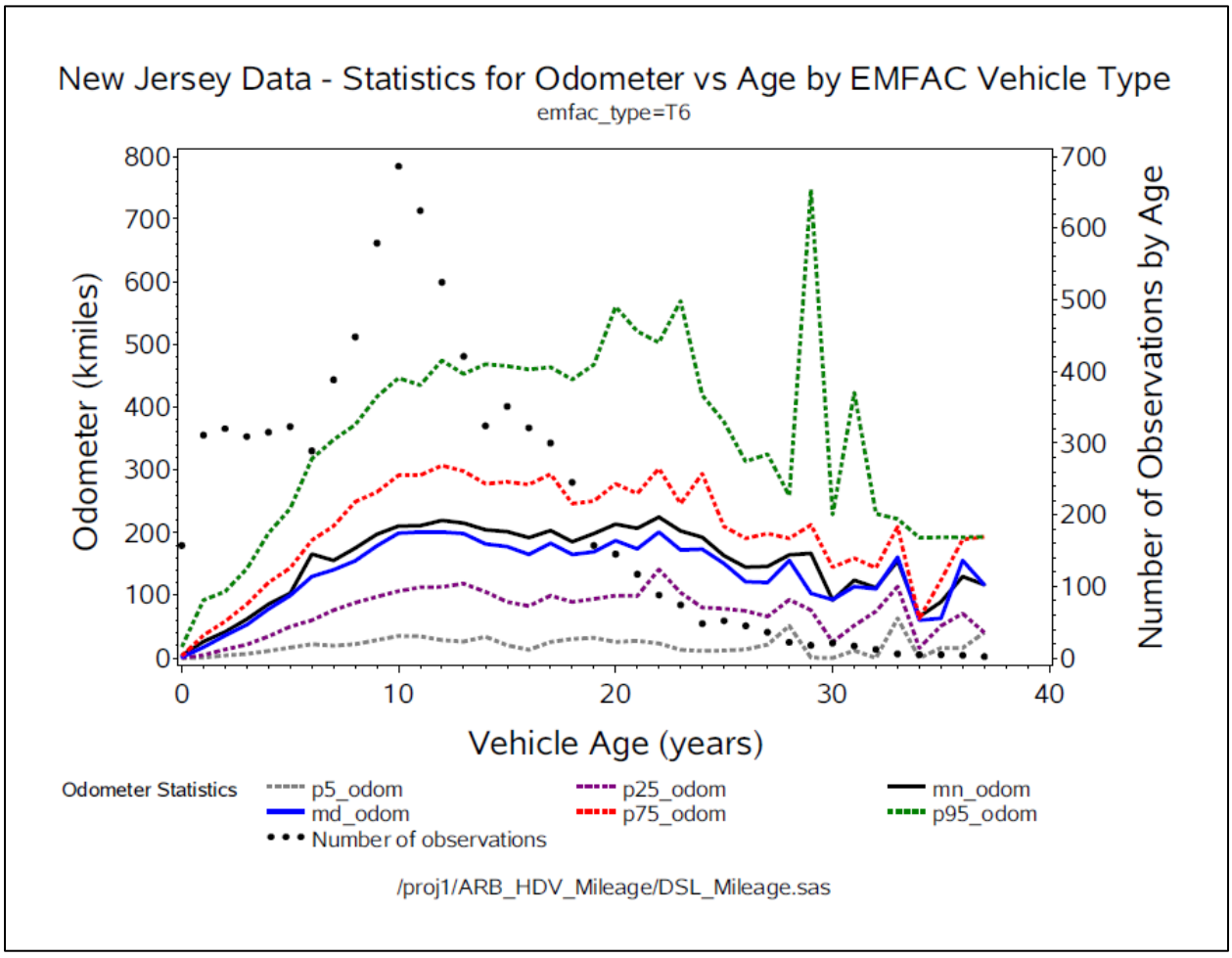

Figure B-3. New Jersey T6 Short-haul Truck Odometer by Age

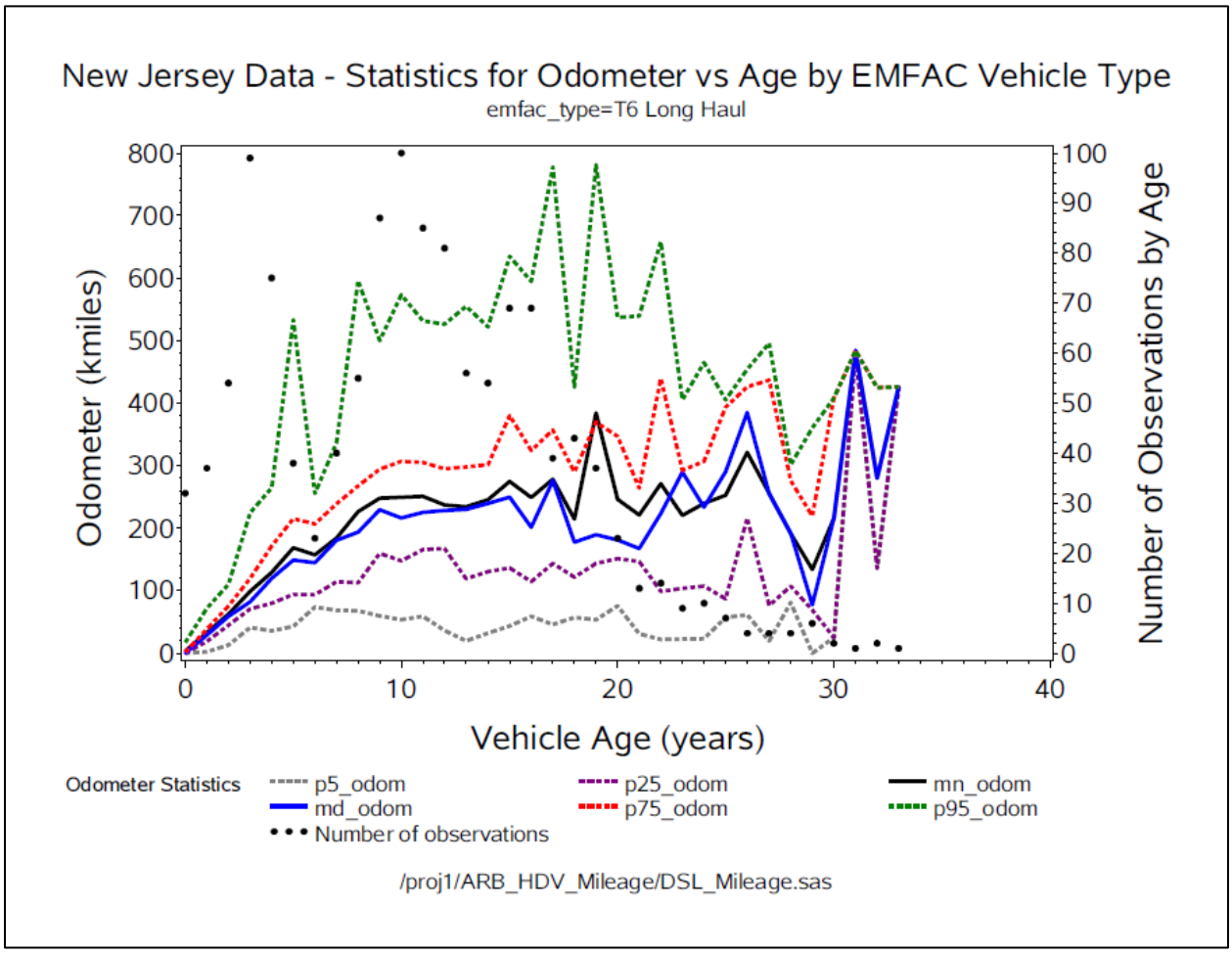

Figure B-4. New Jersey T6 Long-haul Truck Odometer by Age

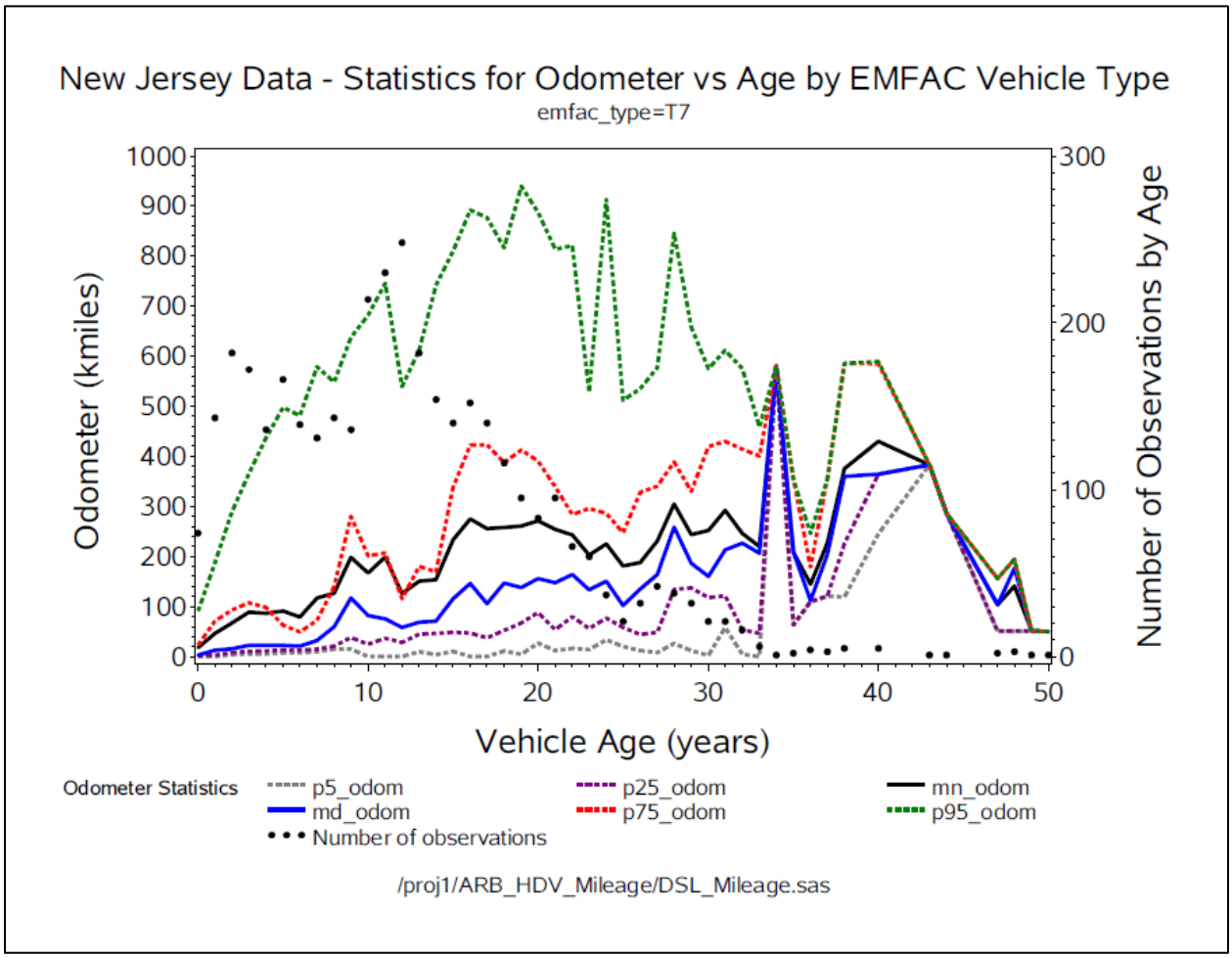

Figure B-5. New Jersey T7 Short-haul Truck Odometer by Age

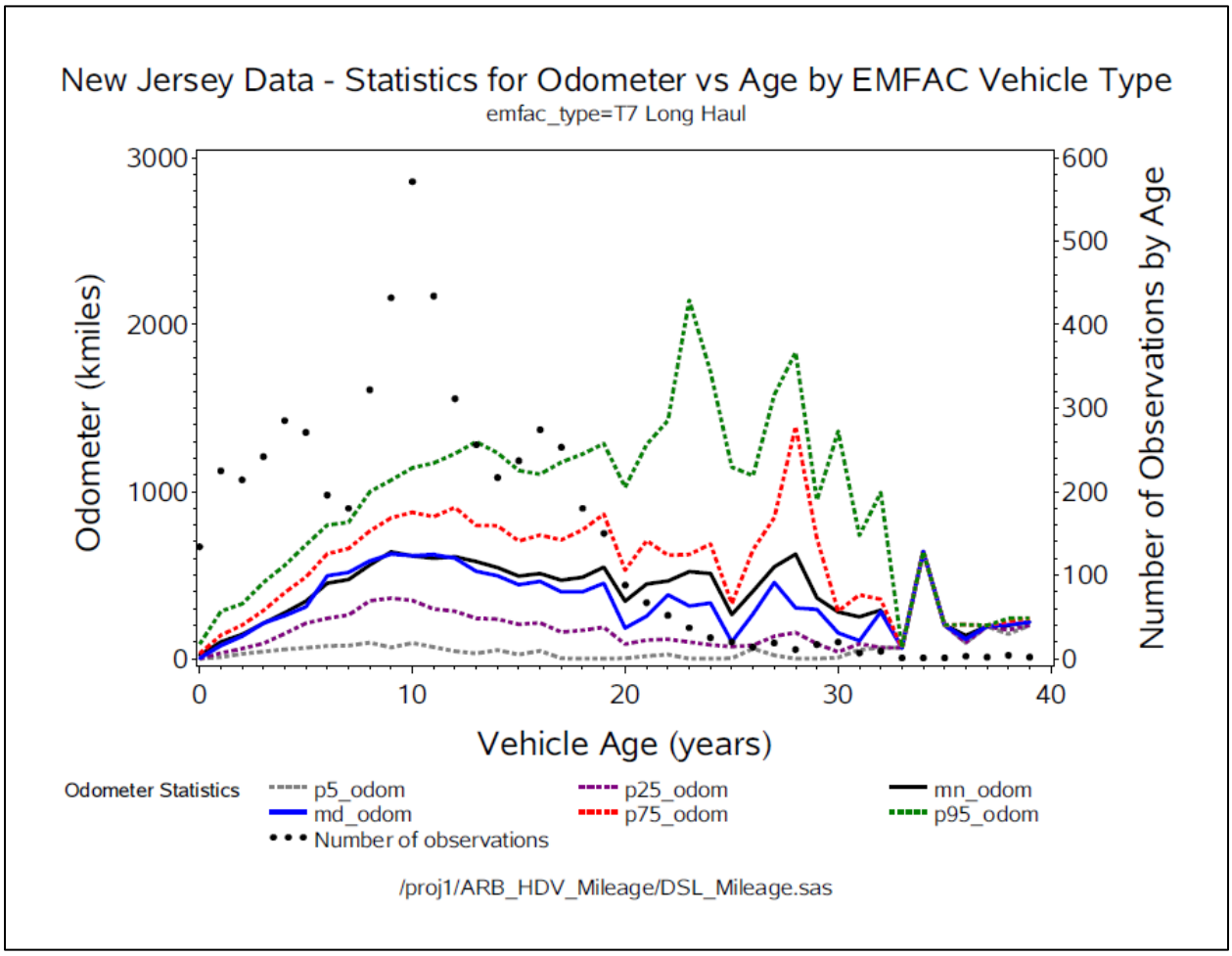

Figure B-6. New Jersey T7 Long-haul Truck Odometer by Age

Memorandum

To: **Sherrie Sala-Moore, ARB**

From: **Allison DenBleyker, ERG**

Date: **February 4, 2021**

Re: **Addendum to Final Report on HDV Accruals**

This document is an addendum to the ERG Final Report, "Heavy-Duty Vehicle Accrual Rates."

After the conclusion of the Final Report linked above, ARB and ERG split out an additional vehicle category "T6 Instate Heavy Tractors" from the larger category "Other T6 Instate Heavy," which included tractors and single unit trucks grouped together. Table 5-9 of the report provided recommended accrual rates for "Other T6 Instate Heavy" and "T7 Tractor" trucks. The revised table below adds the new category for tractors. The revisions are italicized.

Revised* Table 5-1. Recommendation for Other T6 heavy instate, T7 tractor Trucks, *and T6 Instate Heavy Tractors

Age (years old)	EMFAC	Combined T6 heavy instate	Combined T7 tractor	*Combined T6 heavy instate tractor*
-1	32,045	11,906	18,466	*14,080*
0	76,909	28,574	44,318	*33,793*
1	76,909	27,128	42,823	*32,419*
2	76,003	25,734	41,376	*31,082*
3	73,662	24,392	39,977	*29,782*
4	70,325	23,101	38,625	*28,518*
5	66,367	21,862	37,322	*27,291*
6	62,107	20,675	36,066	*26,100*
7	57,802	19,540	34,858	*24,945*
8	53,651	18,456	33,698	*23,827*
9	49,792	17,424	32,586	*22,745*
10	46,304	16,444	31,521	*21,700*
11	43,206	15,516	30,504	*20,692*
12	40,459	14,639	29,536	*19,719*
13	37,960	13,814	28,615	*18,783*
14	35,552	13,041	27,741	*17,884*
15	33,013	12,319	26,916	*17,021*
16	33,013	11,649	26,138	*16,195*
17	33,013	11,031	25,409	*16,195*
18	33,013	10,464	24,727	*16,195*
19	33,013	9,949	24,727	*16,195*
20+	33,013	9,949	24,727	*16,195*

Note that "Combined" in the table header refers to combined data sources Geotab and Cal-VIUS as described in the Final Report.