Vehicle Weight Safety Study Academic Report

DRAFT REPORT

December 20, 2024

Updated: June 25, 2025

Draft Deliverables Included:

TASK 2. Summarize trends in passenger vehicle weight, height, hood height, and collision safety features.

Agreement Number CTC-C-25-008

by

Matthew Raifman, Jon Atkins, Celia Johnson, and Julia Griswold (PI)

UC Berkeley SafeTREC

for

California Transportation Commission

3.1 History of American vehicle weight and fuel economy standards

The average curb weight[1] of vehicles on America's roads is similar now to what it was 50 years ago, around 4,000 pounds. That similarity obscures a period of dramatic transition in vehicle weight and form factor driven, at least in part, by fuel economy standards. In addition to providing context on the evolution of larger vehicles in the U.S., the history of fuel economy regulation and its impact on vehicle size is also suggestive that regulatory signals and vehicle taxes – even when indirectly related to weight - impact vehicle design and consumer preferences.

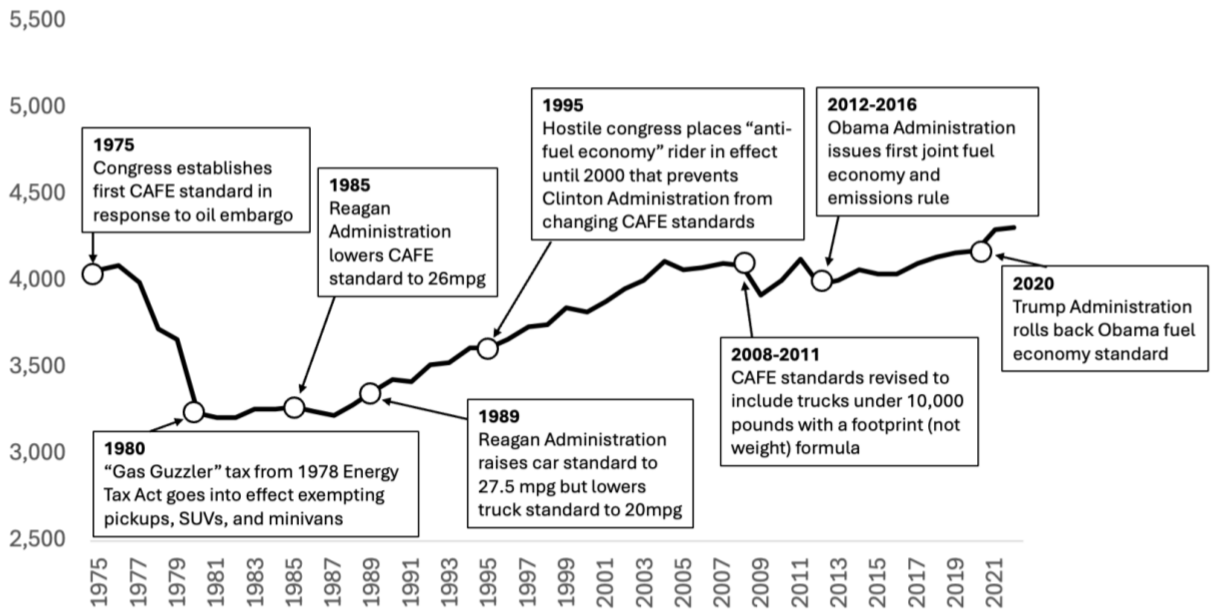

Figure 1.Average Curb Weight of U.S. Vehicle Sales by Model Year. Data: USEPA.

In 1975, Congress established the first Corporate Average Fuel Economy (CAFE) standard that went into effect in the late 1970s in response to the 1973 oil embargo. To meet the new fuel economy standard, manufacturers initially responded with reductions in weight and power, resulting in an approximately 25 percent decrease in average vehicle curb weight over five years.[1,2] In 1982, an additional "Gas Guzzler Tax" went into effect as part of the 1978 Energy Tax Act that was meant to further improve fuel economy of the American vehicle fleet. However, exemptions for larger vehicles embedded in the CAFE standard and the 1978 Energy Tax Act, alongside stricter standards for smaller vehicles, catalyzed a transition towards larger vehicles.

The differential treatment of vehicle type embedded in the CAFE standards affected more than just fuel economy. The initial CAFE standard for passenger cars was set at 18.0 mpg in

---

[1] Curb weight of the vehicle is its weight with full tank of fuel and standard equipment (no optional equipment), but no passengers or cargo.

1978 ramping up to 27.5 in 1985. From the first CAFE standard, however, trucks were to meet a different standard. Initially, the 1978 standard was similar to passenger vehicles at 15.8 mpg for 4WD trucks and 17.2 mpg for 2WD trucks compared to 19.0 mpg for passenger vehicles.[3] By 1985, however, the standard was much less strict for trucks (19.5 combined 4WD and 2WD) compared to passenger vehicles (27.5 mpg)

Vehicle Weight Definitions

Unladen Weight: weight of the vehicle only, not including fuel, passengers, cargo, spare wheel and/or tools (if applicable), or anything else.

Curb Weight: weight of the vehicle with full tank of fuel and standard equipment (no optional equipment), but no passengers or cargo.

Gross Vehicle Weight: weight of the vehicle when it is fully loaded with passengers, cargo, and any fluids.

Gross Vehicle Weight Rating: maximum weight rating of vehicle when fully loaded, including passengers, cargo, fuel, and trailer tongue weight.

Figure 2. Different definitions of vehicle weight.

The Gas Guzzler Tax, implemented in 1980, further instituted differential treatment of passenger vehicles and trucks. Manufacturers of vehicles that failed to meet the minimum CAFE standard of 22.5 mpg had to pay a penalty. The collection schedule increased inversely with fuel economy from $1000 for vehicles with 21.5 – 22.5 mpg to $7700 for vehicles with less than 12.5 mpg.[4] However, the penalty treated large vehicles differently, in this case exempting trucks, minivans, and sport utility vehicles entirely because they were “not widely available in 1978 and were rarely used for non-commercial purposes.”[4] Following the implementation of the Gas Guzzler Tax, the declining trend in average curb weight of the American fleet halted.

While standards accelerated technological improvements that improved the fuel economy to weight ratio, average vehicle weight grew substantially following the nadir in 1987.[5] During the 1980s, the Reagan administration signaled twice (once in 1985 and once in 1989) that it would take a light touch with fuel economy standards and that trucks would continue to be treated differently. When the Clinton Administration sought to increase fuel economy for all vehicles, the Republican controlled congress implemented an “anti-fuel economy rider” to preempt executive action.[6] The pace of vehicle growth slowed after changes were implemented by the Bush Administration to create a footprint-based fuel standard for trucks under 10,000 pounds and with the Obama Administration's first joint fuel economy and greenhouse gas emissions rule that increased the standard to 54.5 mpg for cars and trucks by Model Year 2025. Following the Trump Administration's 2020 repeal of the Obama-era standards, average vehicle weight again increased in 2021.[7]

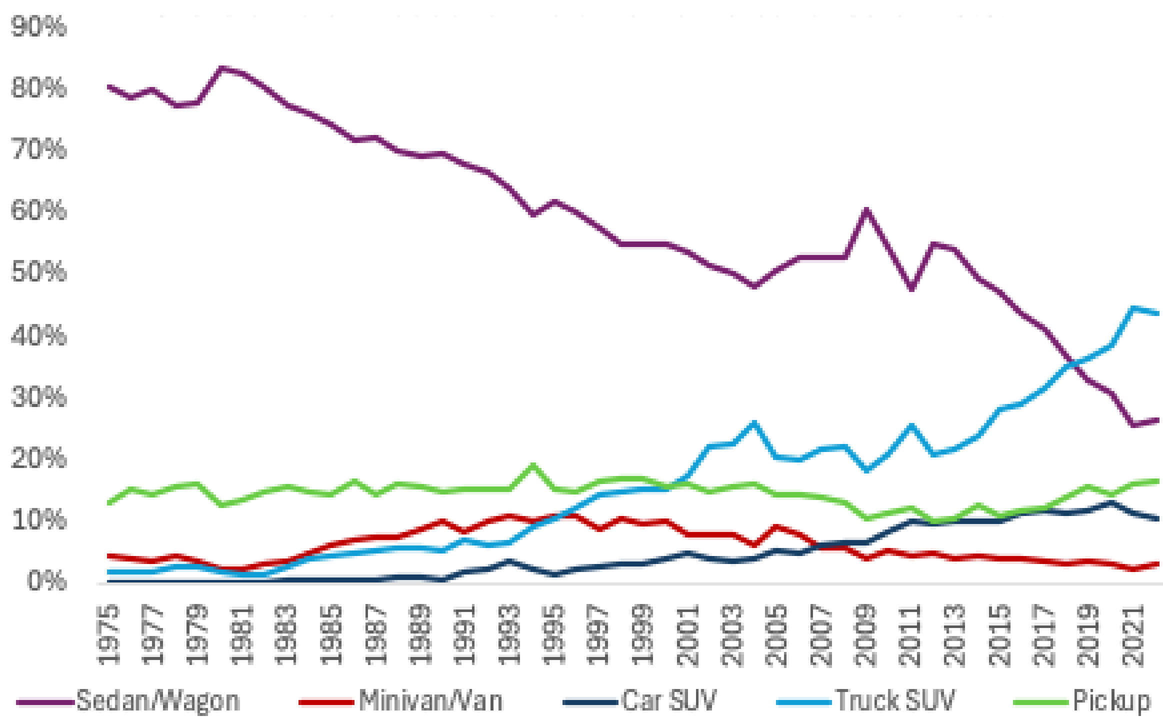

Figure 3. Share of total production volume delivered for sale in the U.S. Data: USEPA.

During this period, the composition of the American vehicle fleet also shifted towards larger vehicles (Figure 3). The special treatment for minivans, SUVs, and pickup trucks coincides in 1980 with the beginning of rapid decline in the share of vehicles produced for sale in the U.S. that were passenger cars (i.e. sedans and wagons).[8] In 1984, truck-based minivans were introduced by Chrysler to exploit the CAFE loophole created for larger vehicles, which were marketed as an alternative to station wagons.[9] That same year the Jeep Cherokee SUV, often called the first modern SUV, was introduced to the market. In late 1984, the *New York Times* added "light trucks" to its automotive sales report for the first time recognizing "the increasing personal use of vehicles such as small pickups and mini-vans, making them more of a consumer than a commercial product."[10] These vehicles were larger, safer for their occupants, and more comfortable to travel in. From 1980 to 2022, the share of vehicles produced for sale in America that were sedans or wagons declined from 83.5% to 26.5%. This market share was replaced primarily by truck SUVs and to a lesser extent car SUVS (vehicles with an SUV form factor built on a car chassis).

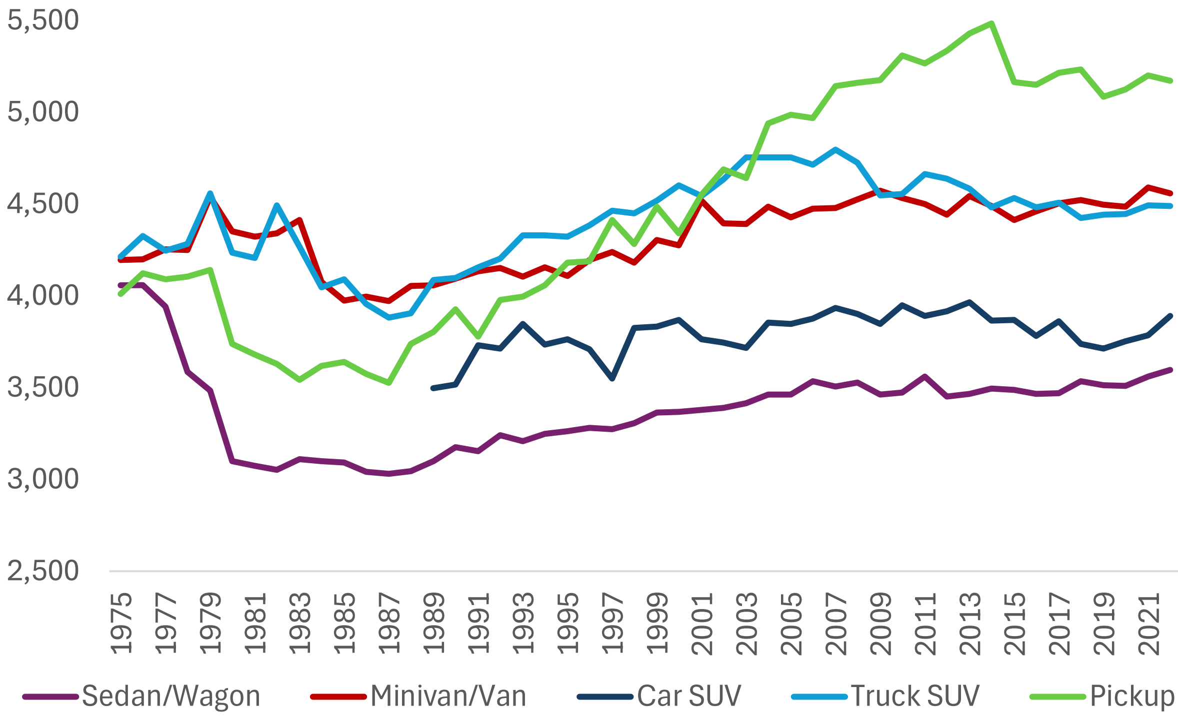

Figure 4. Average Curb Weight of U.S. Vehicle Sales by Vehicle Type. Data: USEPA.

Not only did the American fleet transition to larger vehicles, but these vehicle classes also grew in size over the past 35 years. While all vehicle classes have gotten heavier since 1985, larger vehicles have grown more rapidly. In particular, pickup trucks have increased in curb weight dramatically from around 3,500 pounds on average in the mid-1980s to over 5,000 pounds in 2022. Truck SUVs and vans have also increased in size compared to passenger vehicles. Recognizing the relationship between vehicle mass, kinetic energy, and risk of passenger injury in a collision, the transition from smaller sedans to larger trucks and SUVs over the past four decades brings with it concerns for road safety in America, particularly for vulnerable road users.

3.2 California Vehicle Fleet

In our national analysis above, we used national vehicle production data from USEPA to analyze how both weight and vehicle type of new model year vehicles have shifted over time. National production data is helpful because it is available as far back as 1975 and helps to convey long-term shifts of vehicles sold by year. On the other hand, national production data is limited by two factors: 1) it does not necessarily reflect conditions in California; and 2) it only captures new vehicles sold and not the make-up of the existing fleet on the road, which may be dominated by older vehicles. To address these deficiencies, we constructed a dataset of the vehicles attributes for all vehicles registered in the state of California over the past 14 years. Using these data, it is possible for us to present insights on how the vehicles registered to drive on California's roads have changed over the past decade, with sub-analyses by vehicle type and by county of registration.

Methodology

We received annual registration data from the California Department of Motor Vehicles (DMV) for all available years (2010-2023, excluding 2012 which the DMV was not able to share). We joined 10-digit truncated VIN numbers from the registration data with a separate dataset from Teoalida[11] that includes vehicle curb weight, height, and ground clearance using model year, make, model, and trim as common attributes. We used the NHTSA vPIC VIN decoder[12] to fill gaps in VIN-vehicle model matching. With the exception of 2010, fewer than 10 percent of all registrations were not matched to a vehicle model year, make, model, and trim. While we use the most complete data possible, some of the vehicles were missing height, ground clearance, and/or curb weight information. For both vehicle height and curb weight, completeness ranged from roughly 75% to 90% depending on the registration year and the vehicle type considered. Ground clearance was less complete in our joined dataset with 50% to 75% coverage over the time period.

For analyses by vehicle type, we used the FTP NHTSA vPIC decoder to batch decode unique 10-digit truncated VINs and pull vehicle type information (variable "bodyclass"). We then aggregated body type into five vehicle types for analysis: car, pickup, SUV, van, and other. For the urbanicity analyses, we coded each county in California with a urbanicity value (i.e. urban, suburban, or rural) based on the California State Association of Counties County Caucuses list.[13] We then used the county registration field available in the registration data provided by DMV to categorize each registration with respect to urbanicity.

The DMV's method for classifying vehicles (i.e. personal, commercial, government, and rental) by ownership has shifted over time. To eliminate the impacts of these changes on our analysis, we analyze the entire California registered fleet across the 2010 to 2023 time period.

Total Vehicles Registrations by Year

In 2023, there were just under 31 million vehicles registered in California, or approximately 1.42 vehicles registered for every resident of California.[14] The number of registered vehicles statewide has increased 12.6 percent from 2010 to 2023, increasing at a rate faster than population growth (in 2010, there were 1.35 registered vehicles for every California).

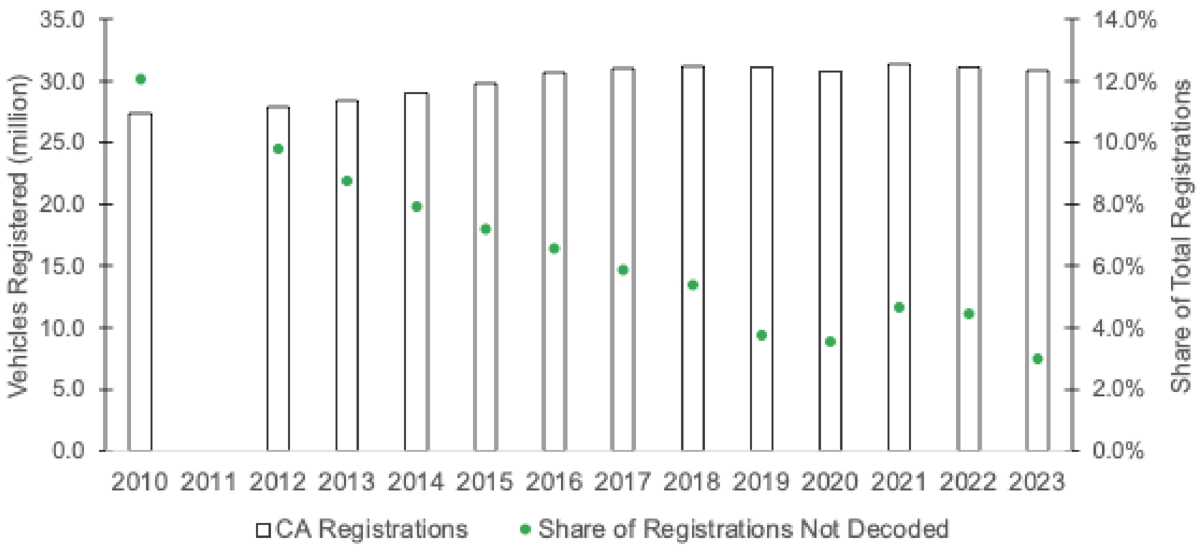

Figure 5. Total number of vehicle registrations in California by year and share of registrations that were not matched to a model year, make, model, and trim.

In 2023, the vehicle fleet was primarily comprised of personal vehicles (88.8%) followed by commercial vehicles (8.7%), with government and rental vehicles each accounting for a little over one percent of registrations. This pattern is observed across all years studied. By DMV definition, commercial vehicles are defined as those that “are designed, used, or maintained primarily to transport property or people for hire, compensation, or profit.”[15]

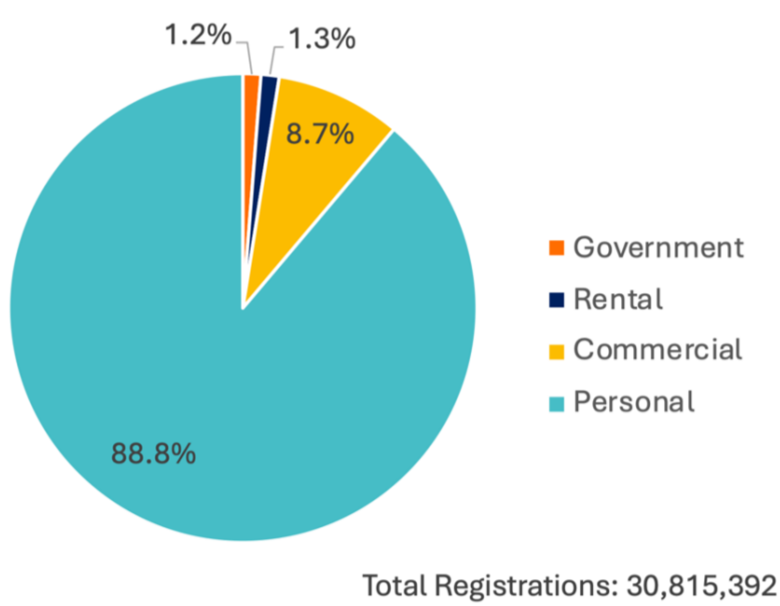

Figure 6. Distribution of California Vehicle Registrations by Ownership Type, 2023.

Vehicles Registrations by Year by Vehicle Type

As discussed in the previous section, national vehicle production data indicates that there has been a transition over the past two decades from cars to, primarily, sport utility vehicles. These sales data, however, do not reflect the distribution of the actual vehicle fleet on the road as it can take more than a decade for a vehicle to be retired from operation.

In Figure 7, we present the share of total California vehicle registrations by vehicle type, with a focus on the four vehicle types with the largest share of registrations: car, SUV, pickup, and van. We can see that the makeup of the California vehicle fleet is indeed shifting away from cars. The high occurred in 2015, when cars (defined as: sedans, convertibles, wagons, and hatchbacks) accounted for 44.7 percent of vehicles on the road. Over the past 14 years, the share of California registrations that are sport utility vehicles has increased concurrently, from 19.6 percent in 2010 to 32.5 percent in 2023. Pickup truck share has grown more modestly from 14.5 percent in 2010 to 14.9 percent in 2023 while van share has dropped from 6.6 percent to 4.7 percent. In the following sections, we explore what this transition from cars to SUVs means for the weight and size of the vehicle fleet.

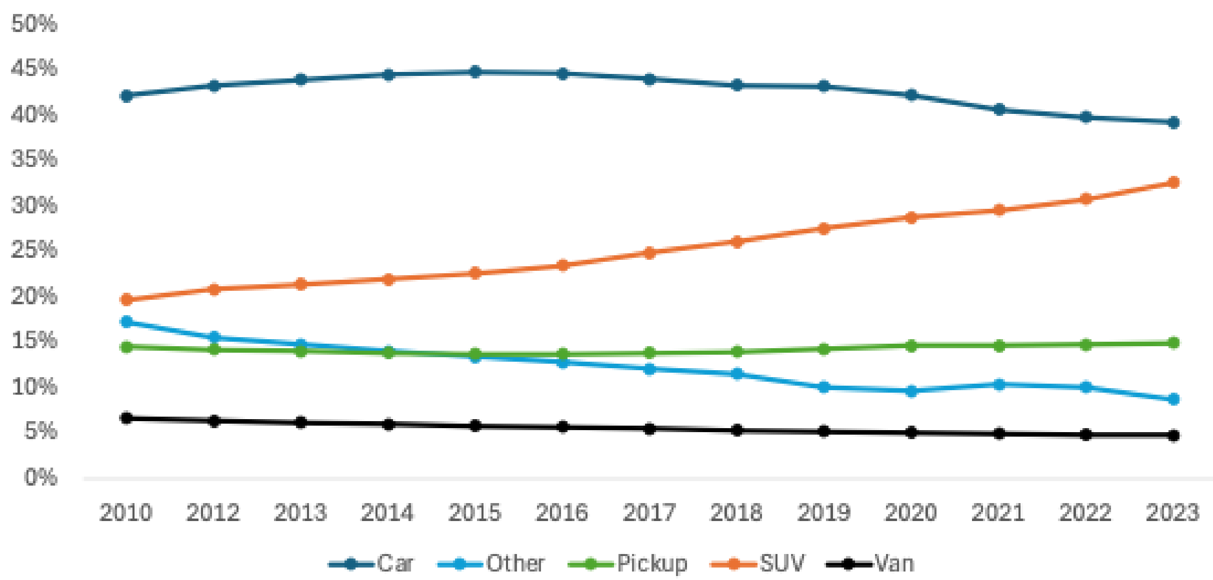

Figure 7. California Vehicle Registrations by Year and Vehicle Type.

As of 2023, the car is still the most popular vehicle type on California's roads. With the current trajectories, however, SUVs are likely to overtake cars sometime in this decade in terms of number of registrations. The dominance of cars in the California vehicle fleet is also demonstrated when examining the top 15 vehicles sold by year.

Rank	2010	2010	2012	2013	2014	2015	2016
1	Honda Accord		Honda Accord	Honda Accord	Honda Accord	Honda Accord	Honda Accord
2	Toyota Camry		Toyota Camry	Honda Civic	Honda Civic	Honda Civic	Honda Civic
3	Honda Civic		Honda Civic	Toyota Camry	Toyota Camry	Toyota Camry	Toyota Camry
4	Toyota Corolla		Toyota Corolla	Toyota Corolla	Toyota Corolla	Toyota Corolla	Toyota Corolla
5	Ford F-150		Ford F-150	Ford F-150	Ford F-150	Toyota Tacoma	Toyota Tacoma
6	Toyota Tacoma		Toyota Tacoma	Toyota Tacoma	Toyota Tacoma	Ford F-150	Ford F-150
7	Ford Explorer		Nissan Altima	Nissan Altima	Nissan Altima	Nissan Altima	Nissan Altima
8	Nissan Altima		Chevy Silverado 1500	Chevy Silverado 1500	Chevy Silverado 1500	Toyota Prius	Toyota Prius
9	Chevy Silverado 1500		Ford Explorer	Honda CR-V	Toyota Prius	Honda CR-V	Honda CR-V
10	Ford Ranger		Honda CR-V	Ford Explorer	Honda CR-V	Chevy Silverado 1500	Chevy Silverado 1500
11	Ford Mustang		Ford Ranger	Toyota Prius	Ford Explorer	Toyota Sienna	Toyota Sienna
12	Toyota 4runner		Toyota Prius	Toyota Sienna	Toyota Sienna	Ford Explorer	Nissan Sentra
13	Ford Expedition		Toyota Sienna	Ford Ranger	Honda Odyssey	Honda Odyssey	Ford Explorer
14	Toyota Sienna		Toyota 4runner	Honda Odyssey	Nissan Sentra	Nissan Sentra	Honda Odyssey
15	Dodge Ram 1500		Ford Mustang	Toyota 4runner	Toyota Tundra	Toyota Tundra	Toyota RAV4

Rank	2017	2018	2019	2020	2021	2022	2023
1	Honda Accord	Honda Civic	Honda Civic	Honda Civic	Honda Civic	Honda Civic	Honda Civic
2	Honda Civic	Honda Accord	Honda Accord	Honda Accord	Honda Accord	Toyota Camry	Toyota Camry
3	Toyota Camry	Toyota Camry	Toyota Camry	Toyota Camry	Toyota Camry	Honda Accord	Honda Accord
4	Toyota Corolla	Toyota Corolla	Toyota Corolla	Toyota Corolla	Toyota Corolla	Toyota Corolla	Toyota Corolla
5	Toyota Tacoma	Toyota Tacoma	Toyota Tacoma	Toyota Tacoma	Toyota Tacoma	Toyota Tacoma	Toyota Tacoma
6	Ford F-150	Ford F-150	Ford F-150	Ford F-150	Ford F-150	Ford F-150	Honda CR-V
7	Honda CR-V	Honda CR-V	Honda CR-V	Honda CR-V	Honda CR-V	Honda CR-V	Ford F-150
8	Toyota Prius	Toyota Prius	Toyota Prius	Toyota RAV4	Toyota RAV4	Toyota RAV4	Toyota RAV4
9	Chevy Silverado 1500	Nissan Altima	Nissan Altima	Toyota Prius	Toyota Prius	Toyota Prius	Toyota Prius
10	Nissan Altima	Toyota RAV4	Toyota RAV4	Nissan Altima	Chevy Silverado 1500	Chevy Silverado 1500	Chevy Silverado 1500
11	Toyota Sienna	Chevy Silverado 1500	Chevy Silverado 1500	Chevy Silverado 1500	Nissan Altima	Nissan Altima	Nissan Altima
12	Toyota RAV4	Toyota Sienna	Toyota Sienna	Toyota Sienna	Toyota Sienna	Toyota Sienna	Toyota Sienna
13	Nissan Sentra	Nissan Sentra	Nissan Sentra	Nissan Sentra	Nissan Sentra	Lexus RX	Tesla Model 3
14	Honda Odyssey	Honda Odyssey	Honda Odyssey	Toyota Tundra	Lexus RX	Toyota Tundra	Lexus RX
15	Toyota Tundra	Toyota Tundra	Toyota Tundra	Lexus RX	Toyota Tundra	Nissan Sentra	Toyota Tundra

Legend	Sedan	Van	SUV	Pickup

Figure 8. Top 15 most popular vehicles registered in California by registration year.

The most popular vehicles registered in California have consistently been a mix of cars, pickup trucks, SUVs, and vans for the full 2010-2023 period. For every year analyzed, the top four most registered vehicles were a mix of Honda and Toyota compact and full-size sedans. Comparing 2023 to 2010, seven of the top 15 registered vehicles were sedans in 2023 and six were sedans in 2010. Pickup trucks are also consistently popular in the California vehicle fleet. The number five and six most popular vehicles were consistently pickup trucks; five of the top 15 vehicles were pickups in 2010 and four were pickup trucks in 2023. Finally, while SUVs have remained population throughout the period, we also observe a transition in the most common SUV registrations from large SUVs built on a truck platform early in the period (e.g. Toyota 4runner and Ford Expedition) to smaller SUVs built on a car platform (e.g. Honda CR-V and Toyota RAV4).

Vehicles Registrations by Urbanicity and by Vehicle Type

To better understand the potential drivers of these inter-county differences in trends, we analyzed how the distribution of vehicle types differs in rural vs urban counties. We also explore how the distribution of vehicles has shifted over time by comparing 2010 to 2023 vehicle registration data (see Figure 9).

We found that pickup trucks account for approximately twice the share of vehicle registrations in rural counties compared to urban counties. In 2010, 24.4 percent of rural county registrations were pickup trucks compared to only 12.9 percent of urban county registrations. Further, over the past 14 years, the share of urban county registrations that are pickup trucks has held steady at 12.9 percent whereas the share in rural counties has grown to 27.4 percent.

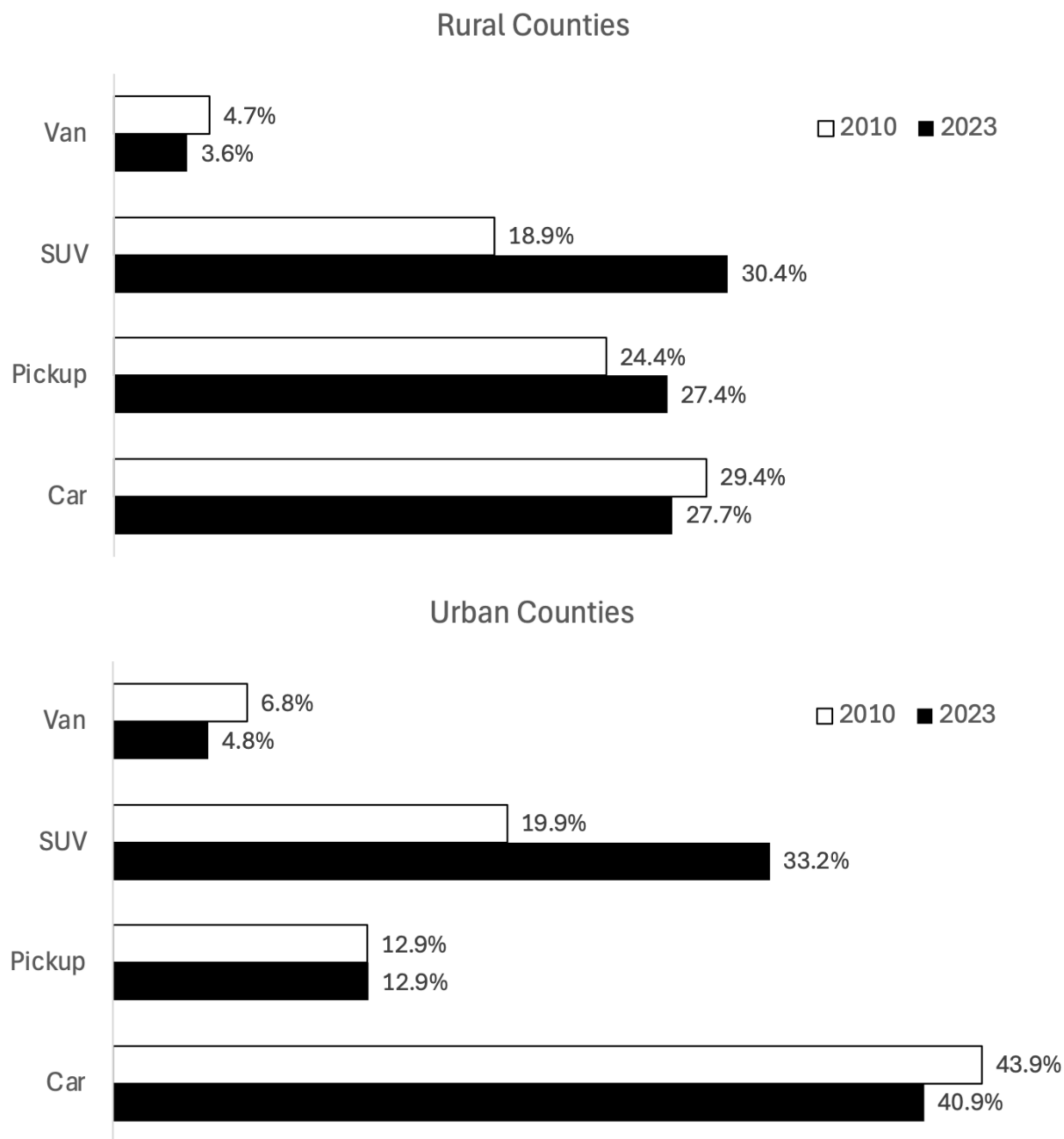

Figure 9. Distribution of Registered Vehicle Types by Urbanicity of County and Year.

Conversely, cars account for a larger share of urban vehicle registrations than rural (43.9 percent vs 29.4 percent in 2010). The share of both urban and rural registrations that are cars has declined by roughly three percentage points in both from 2010 to 2023. Similarly, both urban and rural counties have also seen a dramatic shift in SUV registrations.

Interestingly, SUVs appear to the be the only vehicle type for which the share of vehicle registrations is the same for urban and rural counties. In 2010, 18.9 percent of rural registrations were SUVs compared to 19.9 percent in urban counties. Over the 2010 to 2023 period, the share increased 50 percent in both county types to 30.4 percent of all registrations in rural counties and 33.2 percent in urban counties.

Overall, the key differences between urban and rural counties are that pickup truck registrations are much higher in rural areas and car registrations are much higher in urban areas. SUVs seem to transcend urban-rural divides and represent a similar share of total registrations in both types of counties. Registrations in suburban counties, not visualized here, reflect the middle of the urban-rural distribution. In 2023, 35.1 percent of suburban registrations were cars, 20.7 percent pickups, 30.4 percent SUVs, and 4.1 percent vans.

Change in Vehicle Size Attributes of the California Vehicle Fleet

The shift from cars and vans to SUVs and pickup trucks is likely to have implications for the size and weight of the California vehicle fleet as these types of vehicles are larger. Using 2023 data, we can see that the mean height, ground clearance, and curb weight differs by vehicle type (see Figure 10). At the most extreme, the average pickup truck registered in California is 47 percent heavier, 26 percent taller, and 59 percent higher than the average car. While smaller, SUVs are also considerably larger than cars. The average SUV registered in California is 27 percent heavier, 19 percent taller, and 42 percent higher than the average car.

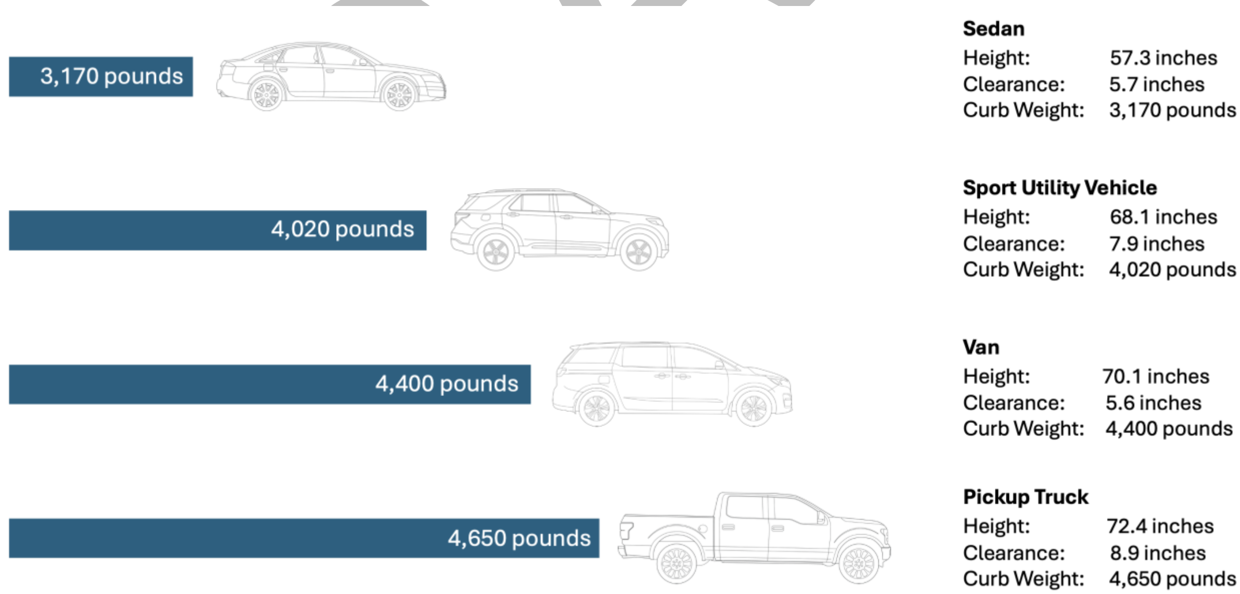

Figure 10. Average height, ground clearance, and curb weight by vehicle type in 2023 for the California vehicle fleet.

These vehicle attributes matter for road safety. As discussed in earlier section of this report, the differential in vehicle size is an important factor in the severity of vehicle crashes, particularly in crashes that involve a vehicle and vulnerable road user. Higher vehicles with more ground clearance have higher impact points, which are associated with higher risk of serious injury for pedestrians.[16–18] A large clearance differential in two-vehicle crashes may increase the likelihood of an overlap crash where the higher vehicle moves up and over the lower vehicle. When a heavier vehicle strikes a lighter one, the risk of fatality increases as the transfer of kinetic energy is greater.[19] Heavier vehicles are also more likely to injure vulnerable road users in a crash.[2,20,21]

To explore the implications of a changing vehicle fleet further, we used the vehicle registration data to calculate the height, ground clearance, and curb weight of every vehicle registered in California. We then aggregated these data by registration year to understand how the vehicle fleet is shifting over time. We observe that the California vehicle fleet, in aggregate, has increased in the average height (2.3 percent), ground clearance (2.5 percent), and curb weight (4.8 percent) over the 2010 to 2023 period (see Figure 11).

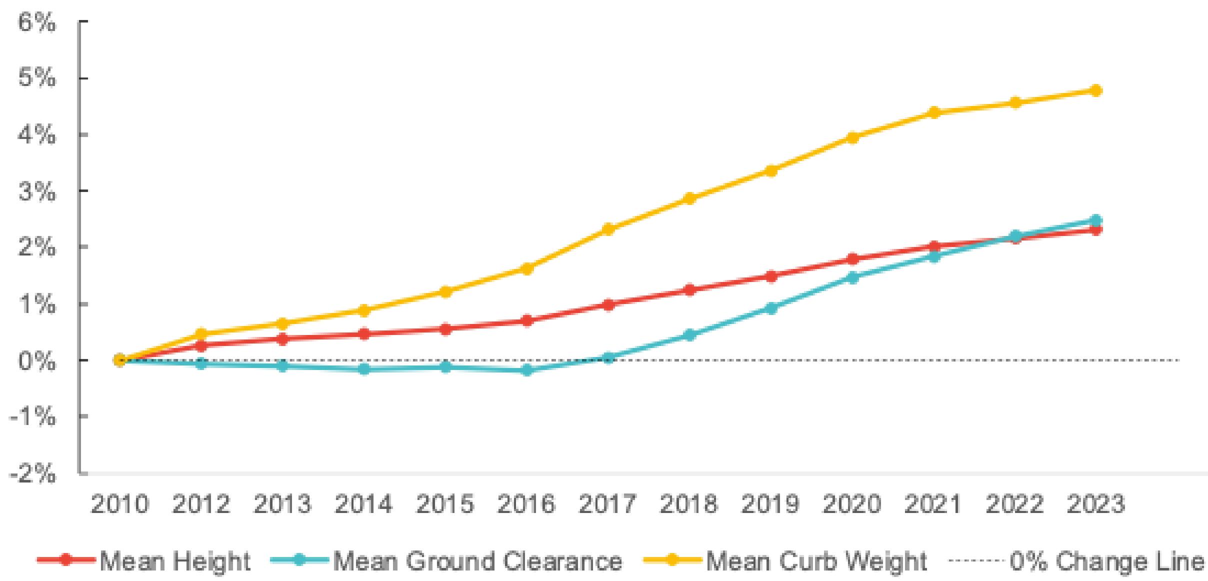

Figure 11. Change in Vehicle Size of the California Vehicle Fleet from 2010-2023.

In Figure 12, we examine how the California fleet has shifted over time broken down by vehicle type. Across the board, pickup trucks and cars have grown more over the past 14 years than SUVs. The average curb weight of pickup trucks registered in California has grown 6.8 percent from 2010 to 2023, with cars growing 3.0 percent in comparison. Similarly, pickups have grown just under 3 percent in height and ground clearance over the study period and cars have grown a more modest 1-2 percent.

Perhaps most notably, sport utility vehicles registered in California have decreased in size from 2010 to 2023; -1.7 percent in height; -2.4 percent in ground clearance, and -2.3 percent in curb weight. While it is not possible to conclusively determine why SUVs are deviating from the trend set by pickup trucks and cars, the most likely explanation is that the makeup of SUVs has been shifting over the period to include smaller SUVs. We observe this transition in the top 15 vehicles registered in California over the years (see Figure 8).

The popularity of large SUVs in 2010, like the Ford Expedition and Toyota 4Runner, gave way to smaller SUVs like the Honda CR-V and Toyota RAV4 in 2023. However, these popular smaller SUVs have themselves also increased in size over time, mainly with regard to curb weight. The curb weight of the Honda CR-V EX AWD trim, for example, increased 12.3% from 2000 to 2023 and the Toyota RAV4 base AWD model has increased roughly 19% in curb weight over the same period. The size difference between small and large SUVs is still quite present, though. A 2023 Toyota 4Runner is 6.4% taller, 26.7% heavier, and has 11.6% more ground clearance than a 2023 Toyota RAV4.

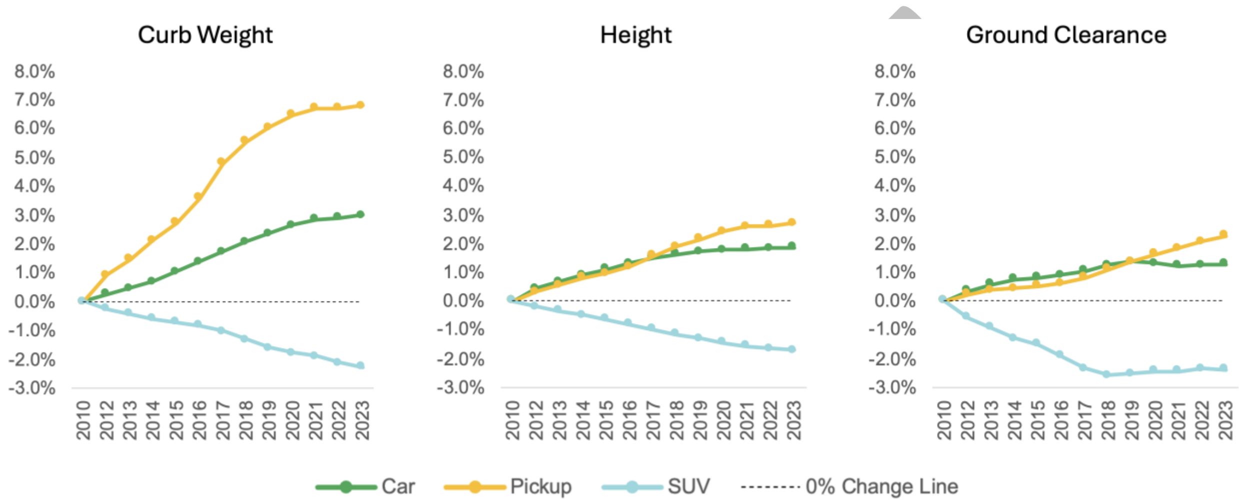

Figure 12. Change in Curb Weight, Height, and Ground Clearance of the California Vehicle Fleet from 2010-2023 by Vehicle Type.

This analysis suggests that it may be important to differentiate between large and small SUVs going forward. Historically, the easiest way to differential within the SUV category was "car SUVs" and "truck SUVs." These distinctions were developed because car SUVs were built on a car chassis that differed from truck SUVs built on truck chassis. As automobile manufacturers have moved away from manufacturing cars in general, the car SUV vs truck SUV distinction has become more challenging to implement.

Change in Vehicle Size Attributes by Vehicle Type and Urbanicity for the California Fleet

We also explored how curb weight, height, and ground clearance of the California vehicle fleet have shifted over time by urbanity. Each registered vehicle was assigned an urban-rural-suburban designation based on the county in which it was registered according to the California State Association of Counties County Caucuses list.[13] We observed an incremental relationship between urbanicity and the rate of vehicle growth across the board. Vehicles registered in rural counties are growing fastest with respect to height, ground clearance, and, most pronounced, curb weight. Vehicles in suburban counties were growing next fastest for all three vehicles attributes analyzed, followed by urban counties.

The observed differences in the transition in size of the vehicle fleet across these three attributes by urbanicity may have significance for improving road safety. In addition to differing with respect to population density, road density, road type, and other infrastructural factors, rural, suburban, and urban counties also differ with respect to the vehicles on the road. As noted above, rural counties have nearly twice the share of pickup truck registrations as urban counties do and a similar share of SUV registrations.

The differences observed here in the rate of change in curb weight may reflect the growing size of specific models of trucks and SUVs that are more popular in some counties than others. In concern with the registration analysis above, the differing rate of change in curb weight, height, and clearance in rural vs suburban vs urban counties suggests that the impacts of any policy or intervention focused on these attributes may affect residents differently across different county types.

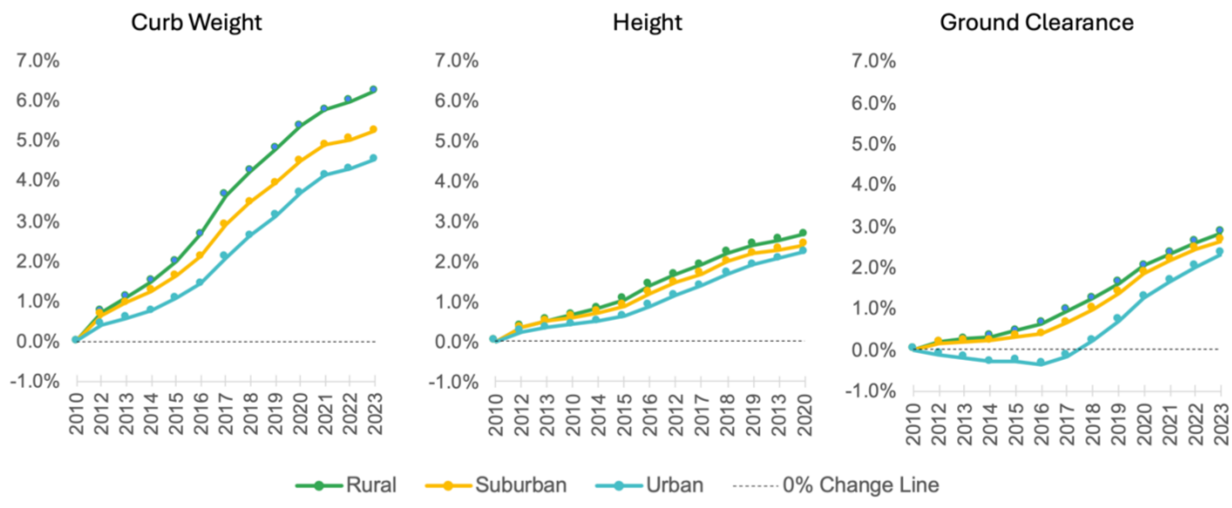

Figure 13. Change in Curb Weight, Height, and Ground Clearance of the California Vehicle Fleet from 2010-2023 by Urbanity, Registered Personal Vehicles.

Crash Safety Features

Vehicle safety technology has also become an increasingly important aspect of vehicle design and manufacturing. Referred to as advanced driver assistance systems (ADAS), these vehicle safety features can broadly be broken into two categories: 1) systems that alert a driver of a potentially dangerous situation; and, 2) systems that are capable of operating the vehicle (see Figure 14). Technologies in category one are generally designed to notify the driver so that the driver can take action and include systems like: forward and rear collision warning, lane departure warning, pedestrian detection warning, and blind spot warning. The second category of technologies is similar to the first, but includes the ability for the vehicle to take over to avoid a crash. These intervention technologies include: automatic emergency braking, pedestrian automatic emergency braking, adaptive cruise control, blind spot intervention, curve speed correction, and lane keeping assistance. None of these technologies is currently required by law to be standard on 2024 model year vehicles (though in practice a number are); however, earlier in 2024, NHTSA issued a final decision that automated emergency braking would be required to be standard on model year 2029 vehicles. However, it is not clear if the new federal administration will uphold the existing NHTSA final ruling. [22]

Advanced Driver Assistance Systems	
Alert Systems	**Operational Systems**
Forward Collision Warning	Automatic Emergency Braking
Rear Collision Warning	Intersection Automatic Emergency Braking
Lane Departure Warning	Lane Keeping Assistance
	Lane Centering Assistance
Pedestrian Detection Warning	Pedestrian Automatic Emergency Braking
Blind Spot Warning	Blind Spot Intervention
	Curve Speed Correction
	Adaptive Cruise Control
	Active Driving Assistance

Figure 14. Types of Advanced Driver Assistance Systems.

In a literature review of studies on the effectiveness of ADAS, Aleksa et al. (2024) identified five studies that found that ADAS related to warning and braking had the greatest potential to reduce road injuries and crashes.[23] Several studies have found that forward collision warning and automated emergency braking could prevent around 30 percent of passenger vehicle crashes. In another government-industry study focused on the U.S., vehicles with forward collision warning and automatic emergency braking were found to reduce front-to-rear crashes by half and vehicles with lane-keeping assistance have a reduced rate of single-vehicle crashes with injuries.[24–27] The implications for improved vulnerable road user safety, however, are less conclusive. The same U.S. study did not find a statistically significant improvement in pedestrian safety with pedestrian automatic emergency braking.[24] A different research study focused exclusively on the effectiveness of automatic emergency braking systems on pedestrian risk found a 25 to 27 percent reduction in pedestrian crash risk.[28] While there are several studies aimed at estimating how effective these technologies are at reducing road injury, there is a notable opportunity for additional research specifically focused on vulnerable road users.

Penetration of Advanced Driver Assistance Systems in the Vehicle Fleet

Due to data limitations and incomplete data in the NHTSA vPIC system, we were unable to estimate the penetration of crash safety features in the California vehicle fleet using the DMV vehicle registration data matched with vehicle attribute data.

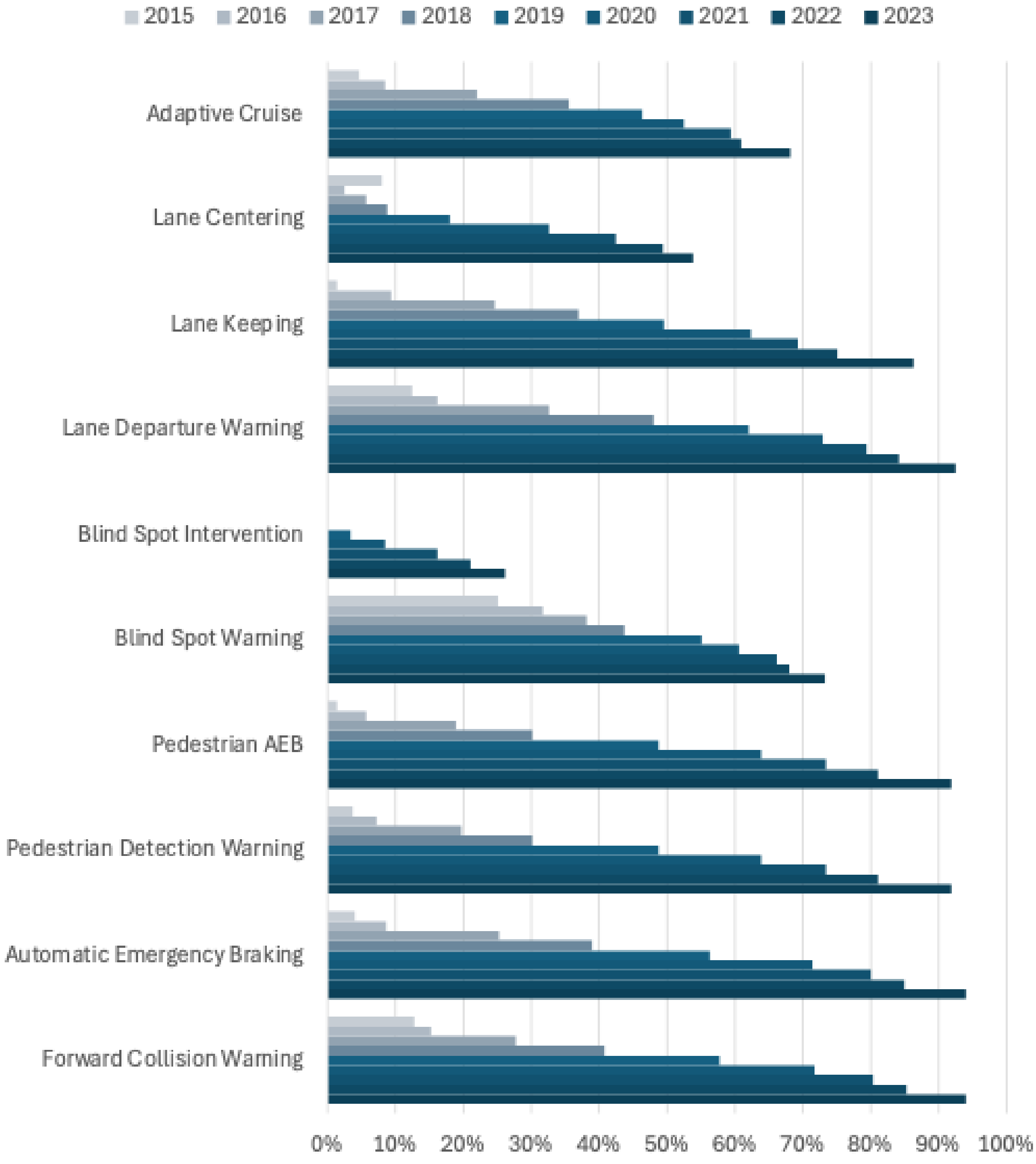

Figure 15. Penetration of advanced driver-assistance systems, 2015-2023. PARTS data collected and reported by MITRE.

As a proxy, we leverage data made available by the Partnership for Analytics Research in Traffic Safety (PARTS) to estimate penetration of these technologies in new model year vehicles sold in the United States. PARTS is a partnership between eight automobile manufacturers and NHTSA in which "participants voluntarily share applicable safety-related data for collaborative safety analysis."[29] The government-industry initiative is operated by a third-party, MITRE, that aggregates and reports on data collected from manufacturers on advanced driver assistance systems (ADAS). Collectively, data reported to PARTS from manufacturers include vehicles from all vehicle types and cover roughly 80 percent of vehicle market share.[30]

Over the better part of the past decade, there has been a dramatic increase in penetration rates for ADAS in new vehicle models (see Figure 15). Notably, over 90 percent of 2023 model year vehicles shipped with Forward Collision Warning, Automatic Emergency Braking, Pedestrian Detection Warning with Automatic Emergency Braking, and Lane Departure Warning. Blind spot intervention has the lowest penetration in new model year vehicles with only 26 percent of 2023 vehicles shipping with that system, though 73 percent had blind spot warning. It is encouraging that the systems found most likely to reduce crashes in the existing literature, forward collision warning and automatic emergency braking, are the most prevalent on new model year vehicles.

Several caveats are notable, however. Firstly, with regard to ADAS, technology penetration is important, but so is efficacy. Measuring continued improvement in the technology at preventing crashes and injuries is arguably more important going forward as penetration approaches 100 percent. The PARTS initiative is focused on studying the efficacy of these technologies going forward, however, initial results are mixed across the suite of ADAS.[29] Secondly, as noted earlier in the report, it takes the U.S. fleet roughly 12 years to turn over. This means that even if every single new model year vehicle shipped with all ADAS standard, it would be over a decade before all the vehicles on the road were operating with these systems. Finally, with the exception of pedestrian detection and pedestrian automatic emergency braking, most ADAS and associated efficacy studies are focused on vehicle-to-vehicle collisions. That is not to say these systems would not be helpful at reducing vulnerable road user injuries, but this has not been the focus of most academic research on these technologies. More research is needed to understand how effective these technologies are at reducing vulnerable road user injuries resulting from vehicle crashes.

3.3 Current California Passenger Vehicle Weight Classes and Fees

The California Department of Motor Vehicles (DMV) collects weight-related fees at vehicle registration that are applied in addition to other registration fees. Fee amounts are determined by the vehicle's classification as passenger or commercial, with fees based on the vehicle's unladen weight[2], number of axles, and fuel type.

Currently, fees are only applied to commercially registered vehicles with the exception of pickup trucks. Pickup trucks are treated as commercial vehicles for the purpose of a

[2] Unladen weight is defined as the total weight of the vehicle only and does not include fuel, passengers, cargo, spare wheel and/or tools (if applicable), or anything else. It is close to the definition of curb weight, which also excludes passengers and cargo, but includes fuel, spare tire, and anything else that comes standard on the vehicle.

weight-based fee and charged a fee based on their unladen weight according to the schedule below as long as they have a bed less than nine feet long, unladen weight of less than 8,001 pounds, and are rated to tow less than 11,500 pounds. Pickup trucks that do not meet these exceptions are treated as "motor trucks" and are assessed a fee based on the weight and towing capacity via a declaration of gross vehicle weight form (Reg-400) designed for larger commercial vehicles.

Commercial Motor Vehicles with Two Axels or Fewer	
Unladen Weight (lbs)	**Annual Supplemental Fee**
0 - 1,999	$8
2,000 - 2,999	$8
3,000 - 4,000	$24
4,001 - 5,000	$80
5,001 - 6,000	$154
6,001 - 7,000	$204
7,001 - 8,000	$257
8,001 - 9,000	$308
9,001 - 10,000	$360

Figure 16. California DMV Commercial Two-Axle Weight Fee Schedule.[31]

In addition, businesses may register two-axle passenger type vehicles as commercial vehicles. For these vehicles, a weight-based fee is applied based on the scale indicated in Figure 16. Electric vehicles are treated differently and subject to a separate fee table (see Figure 17).

While not directly relevant for the current approach to collecting weight-based fees, California does utilize the Federal Highway Administration's (FHWA) vehicle weight classes in other applications. For example, the California Energy Commission reports data on zero emissions vehicle registrations by these weight classes.[32] The FHWA vehicle weight classes are based on GVWR. Light-duty vehicles are broken up into two vehicle classes, Class 1 (6,000 lbs or less) and Class 2 (6,001 to 10,000 lbs), (see Figure 18). Notably, the current California weight-based commercial vehicle fees include the same break points (i.e. 6000 lbs and 10,000 lbs), making it possible to combine the DMV and Energy Commission vehicle classes if desired.

Commerical Electric Vehicles	
Unladen Weight (lbs)	**Annual Supplemental Fee**
0 - 5,999	$87
6,000 - 9,999	$266
10,000 or more	$358

Figure 17. California DMV Commercial Electric Vehicle Fee Schedule.[31]

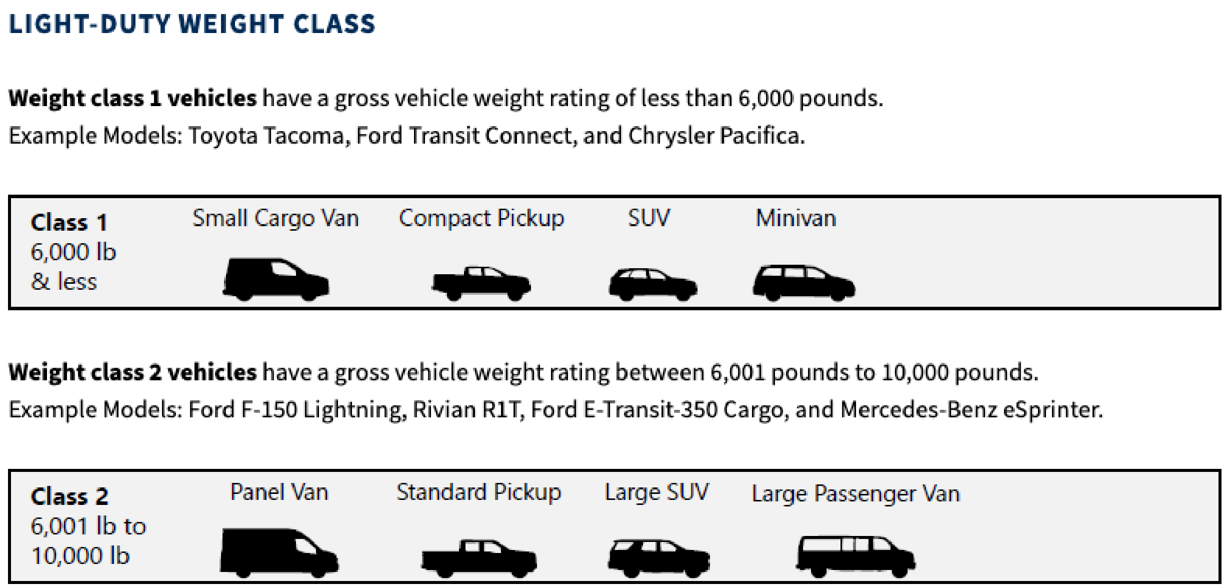

Figure 18. FHWA Light-Duty Vehicle Weight Classes, California Energy Commission.[33]

3.4 National Passenger Vehicle Weight Fees

Potential policies focused on the size and weight of vehicles registered in California may build upon existing fees and regulations already in place. To that end, we summarize in this section existing weight-related fees in California.

When someone registers their vehicle in the State of California, they are responsible for several fees, including: the registration fee, California Highway Patrol fee, vehicle license fee, transportation improvement fee, any applicable county/district fees, and numerous additional fees ranging from a fingerprint ID fee to an abandoned vehicle fee.[34] As these fees are dependent on the situation of the registering owner (e.g. in-state vs out of state, county of registration) and the registered vehicle (e.g. gas vs electric, vehicle cost), it is easiest to understand the fees in the context of a specific vehicle. To illustrate the fee structure, below we in figure 1, we provide the fee schedule for fees due at registration for a 2023 Ford F-150 XL (MSRP: $34,585) that is being registered for the first time by an in-state purchaser in Sacramento, CA. Together, these fees can be considered the fees paid upon registration of a vehicle in California, but it is notable that they include fees beyond the explicit “registration.” Fees are collected at the point of registration by the California Department of Motor Vehicles (DMV and then distributed based on the specific fee.

Fees due at Registration for a 2023 Ford F-150 Pickup XL	Fee
Current Registration	$ 65.00
Current California Highway Patrol	$ 30.00
Current Weight Fee	$ 80.00
Current Vehicle License Fee	$ 224.00
Current County Service Authority for Freeway Emergencies Fee	$ 1.00
Current Fingerprint ID Fee	$ 1.00
Current Smog High Polluter Repair Fee	$ 6.00
Original Smog Abatement	$ 6.00
Alt Fuel/Tech Smog Fee	$ 8.00
Current Air Quality Management District	$ 6.00
Alt Fuel/Tech Reg Fee	$ 3.00
Current Vehicle Theft/DUI 2	$ 2.00
Current Transportation Improvement Fee	$ 118.00
Reflectorized License Plate Fee	$ 1.00
Total (excluding sales taxes)	**$ 551.00**

Figure 19. Fees due at Registration for a Ford F-150 XL

Currently, weight-related fees at vehicle registration are applied in addition to other registration fees only for commercial vehicles. Fee amounts are determined by the vehicle's classification as commercial, with fees based on the vehicle's unladen weight, number of axles, and fuel type. Large pickup trucks are treated as commercial vehicles by California regulations and therefore subject to an additional weight-based fee.[31] Pickup trucks weighing more than 8,001 lbs. unladen and/or 11,499 lbs. gross vehicle weight rating (GVWR), which is the maximum operating weight of the vehicle including passengers and cargo, are subject to the Commercial Vehicle Registration Act (CVRA) fees described below. *(*Examples of pickup trucks that meet these criteria include the Chevy Silverado 3500 HD, Ford F-450 Super Duty, and GMC Hummer EV).

Commercial Motor Vehicles with Two Axels or Fewer	
Unladen Weight (lbs)	**Annual Supplemental Fee**
0 - 1,999	$8
2,000 - 2,999	$8
3,000 - 4,000	$24
4,001 - 5,000	$80
5,001 - 6,000	$154
6,001 - 7,000	$204
7,001 - 8,000	$257
8,001 - 9,000	$308
9,001 - 10,000	$360

Figure 20. California DMV Commercial Two-Axle Weight Fee Schedule.[31]

In addition, businesses may register two-axle passenger type vehicles as commercial vehicles. For these vehicles, a weight-based fee is applied based on the scale indicated in Figure 16. Electric vehicles are treated differently and subject to a separate fee table (see Figure 17).

While not directly relevant for the current approach to collecting weight-based fees, California does utilize the Federal Highway Administration's (FHWA) vehicle weight classes in other applications. For example, the California Energy Commission reports data on zero emissions vehicle registrations by these weight classes.[32] The FHWA vehicle weight classes are based on GVWR. Light-duty vehicles are broken up into two vehicle classes, Class 1 (6,000 lbs or less) and Class 2 (6,001 to 10,000 lbs), (see Figure 18). Notably, the current California weight-based commercial vehicle fees include the same break points (i.e. 6000 lbs and 10,000 lbs), making it possible to combine the DMV and Energy Commission vehicle classes if desired.

Commerical Electric Vehicles	
Unladen Weight (lbs)	**Annual Supplemental Fee**
0 - 5,999	$87
6,000 - 9,999	$266
10,000 or more	$358

Figure 21. California DMV Commercial Electric Vehicle Fee Schedule.[31]

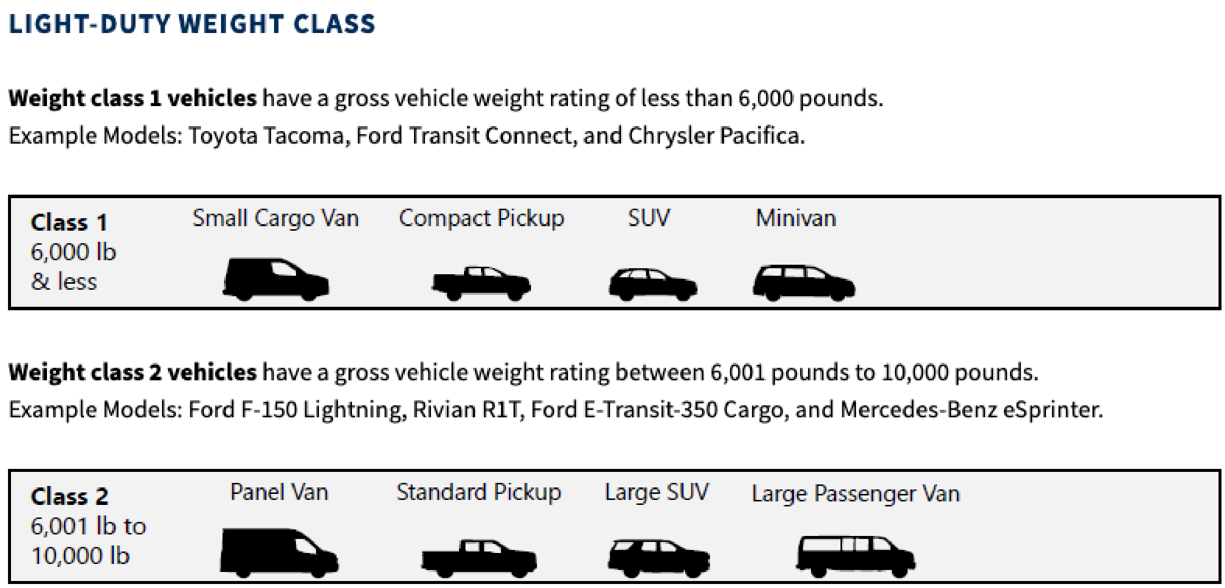

Figure 22. FHWA Light-Duty Vehicle Weight Classes, California Energy Commission.[33]

3.5 National Passenger Vehicle Weight Fees

Nationally, 25 states and the District of Columbia have some type of weight-based vehicle fee due at registration that applies to passenger vehicles, with considerable variation (see *Figure 23*). In most states, a passenger vehicle weight fee is applied as an additional fee that increases with defined weight classes, however, some states simply apply different base registration fees based on weight class. These classes vary by state. In some states, the weight classes follow the federally defined FHWA classes (see *Figure 18*). In other states, the weight classes are more refined. For example, the District of Columbia's fee structure includes three distinct weight classes for vehicles under 6,000 pounds.[35] Of the states that collect a weight-based fee, some do so in a conditional way, either applying it to electric vehicles (e.g. Michigan charges a different fee for electric vehicles under 8,000 pounds and those above, both tied to the gas tax). In California, while no passenger vehicle weight-based fee is levied, large passenger pickup trucks are treated as commercial vehicles if their unladed weight exceeds 8,000 pounds regardless of defined use vehicles. Notably, in Hawaii, the state weight tax is applied on a per-pound basis that increases with weight classes, effectively applying fees that linearly increase with weight.

Figure 23. States with Weight-based Fees for Passenger Vehicles, 2024.

To provide additional context on the scale and variation in passenger vehicle fees due at registration across the U.S., we calculated the effective total fees due at registration for the best-selling vehicle nationally in 2023: the Ford F-Series pick-up truck.[36] Specifically, we compare fees across states (see Figure 24) for the most affordable trim, the 2023 Ford F-150 Regular Cab XL pick-up (curb weight: 4,021 pounds; MSRP $34,585). The fees vary across states, ranging from $13.50 (Arizona) to $562 (New Hampshire) with an average fee of $110. California's total fees due at registration (for Sacramento, CA) of $551, which does include a specific weight-based add-on fee of $80 because the 4,021 pound F-150 XL is classified as a commercial vehicle under current California law. Hawaii, despite implementing a weight-based fee, is in the bottom quartile of states with a total fee due at registration of $66.

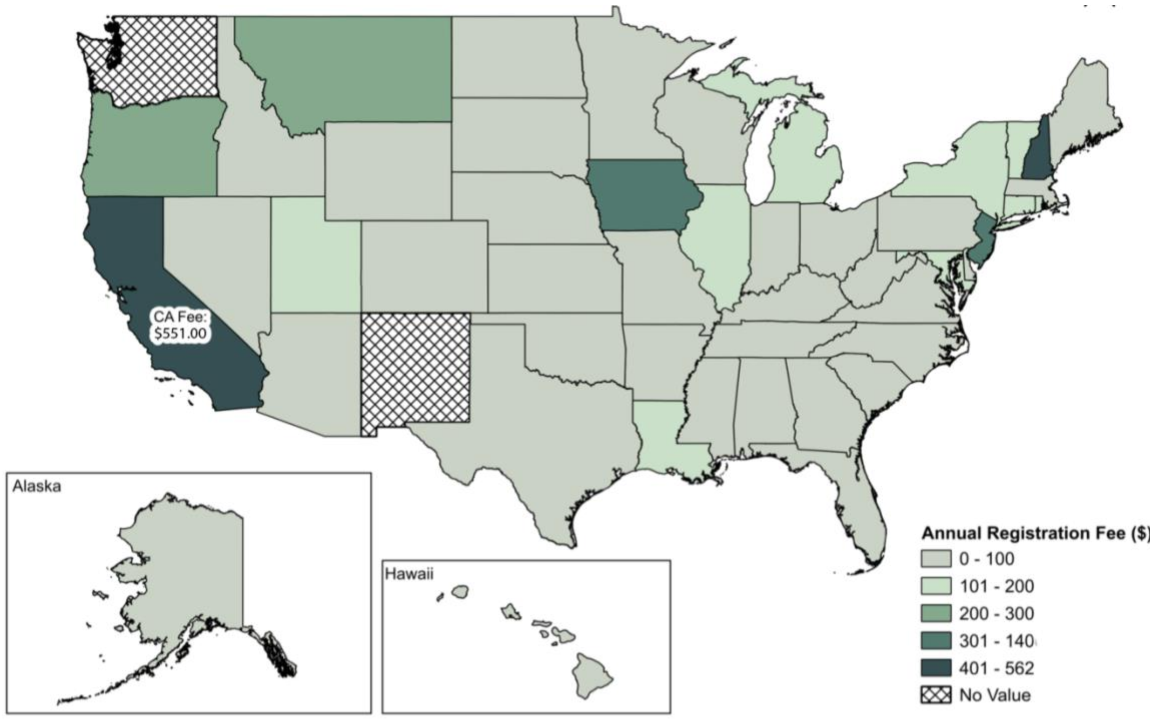

Figure 24. Estimated Vehicle Registration Fees by State for a 2023 Ford F-150 Regular Cab XL (MSRP $34,585).

We searched for height and footprint-based fees and did not find examples of any states implementing fees with these criteria.

References

1. Klier T, Linn J. New-vehicle characteristics and the cost of the Corporate Average Fuel Economy standard. *RAND J Econ*. 2012;43(1):186-213. doi:10.1111/j.1756-2171.2012.00162.x

2. Bento A, Gillingham K, Roth K. The Effect of Fuel Economy Standards on Vehicle Weight Dispersion and Accident Fatalities. Published online April 2017. doi:10.3386/w23340

3. Corporate Average Fuel Economy | NHTSA. Accessed September 27, 2024. https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy

4. US EPA O. Gas Guzzler Tax. February 7, 2017. Accessed September 27, 2024. https://www.epa.gov/fueleconomy/gas-guzzler-tax

5. Klier T, Linn J. The effect of vehicle fuel economy standards on technology adoption. *J Public Econ*. 2016;133:41-63. doi:10.1016/j.jpubeco.2015.11.002

6. Driving to 54.5 MPG: The History of Fuel Economy. April 20, 2011. Accessed September 27, 2024. http://pew.org/2ylt4mB

7. Trump administration rolls back Obama-era fuel efficiency standards. Accessed September 27, 2024. https://thehill.com/policy/energy-environment/490318-trump-administration-rolls-back-obama-era-fuel-efficiency-standards/

8. US EPA O. The EPA Automotive Trends Report. March 9, 2017. Accessed September 27, 2024. https://www.epa.gov/automotive-trends

9. Brown W. Warren Brown - The Station Wagon Stealthily Returns.http://www.washingtonpost.com/wp-dyn/content/article/2004/08/29/AR2005032405083.html. August 29, 2004. Accessed September 27, 2024.

10. Light Trucks in Auto Sales Data. *The New York Times*. October 15, 1984:58.

11. Teoalida. Year Make Model Trim Specs car database 1990-2025. The most updated car database. December 20, 2020. Accessed December 9, 2024. https://www.teoalida.com/cardatabase/year-make-model-trim-specs/

12. Welcome to VIN Decoding :: provided by vPIC. Accessed December 9, 2024. https://vpic.nhtsa.dot.gov/decoder/

13. California County Caucuses. California State Association of Counties. May 26, 2015. Accessed December 16, 2024. https://www.counties.org/pod/california-county-caucuses

14. S0101: AGE AND SEX - Census Bureau Table. Accessed December 9, 2024. https://data.census.gov/table/ACSST1Y2010.S0101?q=population%20&g=040XX00US06

15. Commercial Vehicle Registration. California DMV. Accessed December 16, 2024. https://www.dmv.ca.gov/portal/vehicle-registration/new-registration/commercial-vehicle-registration/

16. By. Vehicles with higher, more vertical front ends pose greater risk to pedestrians. IIHS-HLDI crash testing and highway safety. Accessed October 1, 2024. https://www.iihs.org/news/detail/vehicles-with-higher-more-vertical-front-ends-pose-greater-risk-to-pedestrians

17. Crocetta G, Piantini S, Pierini M, Simms C. The influence of vehicle front-end design on pedestrian ground impact. *Accid Anal Prev*. 2015;79:56-69. doi:10.1016/j.aap.2015.03.009

18. Edwards M, Leonard D. Effects of large vehicles on pedestrian and pedalcyclist injury severity. *J Safety Res*. 2022;82:275-282. doi:10.1016/j.jsr.2022.06.005

19. Anderson M, Auffhammer M. Pounds That Kill: The External Costs of Vehicle Weight. *Rev Econ Stud*. 2014;81(2):535-571.

20. Mayrose J, Jehle DVK. Vehicle Weight and Fatality Risk for Sport Utility Vehicle—versus—Passenger Car Crashes. *J Trauma Acute Care Surg*. 2002;53(4):751.

21. Tyndall J. Pedestrian deaths and large vehicles. *Econ Transp*. 2021;26-27:100219. doi:10.1016/j.ecotra.2021.100219

22. Feds Refuse to Hit the Brakes on Automated Emergency Braking. Accessed December 10, 2024. https://www.caranddriver.com/news/a63027394/feds-automated-emergency-braking/

23. Aleksa M, Schaub A, Erdelean I, Wittmann S, Soteropoulos A, Fürdös A. Impact analysis of Advanced Driver Assistance Systems (ADAS) regarding road safety – computing reduction potentials. *Eur Transp Res Rev*. 2024;16(1):39. doi:10.1186/s12544-024-00654-0

24. Real-world Effectiveness of Model Year 2015–2020 Advanced Driver Assistance Systems. Published online November 14, 2022. Accessed December 10, 2024. https://www.mitre.org/news-insights/publication/real-world-effectiveness-model-year-2015-2020-advanced-driver-assistance

25. Benson AJ, Tefft BC, Svancara AM, Horrey WJ. Potential Reductions in Crashes, Injuries, and Deaths from Large-Scale Deployment of Advanced Driver Assistance Systems. *Res Brief*. Published online 2018. Accessed December 10, 2024. https://trid.trb.org/View/1566022

26. Wang JS. Target Crash Population for Crash Avoidance Technologies in Passenger Vehicles. Published online March 2019. Accessed December 10, 2024. https://trid.trb.org/View/1602884

27. Impact analysis of Advanced Driver Assistance Systems (ADAS) regarding road safety – computing reduction potentials | European Transport Research Review. Accessed October 28, 2024. https://link.springer.com/article/10.1186/s12544-024-00654-0

28. Cicchino JB. Effects of automatic emergency braking systems on pedestrian crash risk. *Accid Anal Prev*. 2022;172:106686. doi:10.1016/j.aap.2022.106686

29. PARTS | Partnership for Analytics Research in Traffic Safety | NHTSA. Accessed December 10, 2024. https://www.nhtsa.gov/parts-partnership-for-analytics-research-in-traffic-safety

30. PARTS: Market Penetration of Advanced Driver Assistance Systems (ADAS). Published online September 30, 2024. Accessed December 10, 2024. https://www.mitre.org/news-insights/publication/parts-market-penetration-advanced-driver-assistance-systems-adas

31. Registration Fees. California DMV. Accessed December 19, 2024. https://www.dmv.ca.gov/portal/vehicle-registration/registration-fees/

32. Commission CE. Medium- and Heavy-Duty Zero-Emission Vehicles in California. current-date. Accessed October 7, 2024. https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics-collection/medium

33. Commission CE. Medium- and Heavy-Duty Zero-Emission Vehicles in California. current-date. Accessed December 19, 2024. https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics-collection/medium

34. Registration Fees. California DMV. Accessed March 26, 2025. https://www.dmv.ca.gov/portal/vehicle-registration/registration-fees/

35. § 50–1501.03. Fees classified and use of proceeds designated. | D.C. Law Library. Accessed October 8, 2024. https://code.dccouncil.us/us/dc/council/code/sections/50-1501.03

36. Wayland M. A compact crossover is coming for America's pickup trucks. Here are the top-selling cars of 2023. CNBC. January 6, 2024. Accessed October 8, 2024. https://www.cnbc.com/2024/01/06/top-10-best-selling-cars-in-the-us-in-2023.html