RESEARCH REPORT

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Vehicle Weight Safety Study Academic Report

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March 2026

UC Berkeley
Institute of Transportation Studies

DOI: 10.7922/G2S46Q9T

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
N/A	N/A	N/A

4. Title and Subtitle Vehicle Weight Safety Study Academic Report	**5. Report Date** March 2026 **6. Performing Organization Code** ITS Berkeley, ITS-Davis, ITS-Irvine
7. Author(s) Matthew Raifman, Ph.D., http://orcid.org/0000-0002-7141-0125 Julia Griswold, Ph.D., http://orcid.org/0000-0002-1125-3316 David Brownstone, Ph.D., http://orcid.org/0000-0001-9101-6494 John Harvey, Ph.D., https://orcid.org/0000-0002-8924-6212 Amalia Stahl, M.A., Jon Atkins, B.A., https://orcid.org/0009-0008-4748-8142 Celia Johnson, B.A., https://orcid.org/0000-0002-9659-1890 Michael Anderson, Ph.D., https://orcid.org/0000-0002-4079-1965 Federico Vaco, Ph.D., https://orcid.org/0000-0002-8652-3755	**8. Performing Organization Report No.** N/A
9. Performing Organization Name and Address Institute of Transportation Studies, Berkeley 109 McLaughlin Hall, MC1720 Berkeley, CA 94720-1720 Institute of Transportation Studies, Davis 1605 Tilia Street Davis, CA 95616 Institute of Transportation Studies, Irvine 4000 Anteater Instruction and Research Building Irvine, CA 92697	**10. Work Unit No.** N/A **11. Contract or Grant No.** CTC-C-25-008
12. Sponsoring Agency Name and Address The University of California Institute of Transportation Studies www.ucits.org	**13. Type of Report and Period Covered** N/A **14. Sponsoring Agency Code** UC ITS

15. Supplementary Notes
DOI: - The UC ITS librarian Kendra Levine will fill out this section. Please leave blank

16. Abstract
The Vehicle Weight Safety Study provides supporting analysis for the California Transportation Commission's study on the relationship between vehicle weight and road user injury and roadway degradation required by Assembly Bill (AB) 251, which was signed by the Governor in October 2023. To inform the work of the CTC, this report summarizes trends of road user injuries and fatalities in California and potential factors contributing to these trends (Chapter 2); summarizes trends in vehicle weight, size, and height for registered vehicles in California (Chapter 3); documents the landscape of policy solutions focused on vehicle size that might address California's road user injuries and fatality challenge (Chapter 4); analyzes the impact of potential weight-based fees on consumer vehicle purchasing behavior (Chapter 5); and, analyzes the relationship between shifts in passenger vehicle weight and degradation of road infrastructure (Chapter 6).

17. Key Words	18. Distribution Statement
TBD – The UC ITS librarian Kendra Levine will fill out this section. Please leave blank	No restrictions.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	116	N/A

Form Dot F 1700.7 (8-72) Reproduction of completed page authorized

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Acknowledgments

We are grateful to Professors Michael Anderson and Federico Vaca for their guidance and comments in support of Chapters 2-4. We would like to thank the California Department of Motor Vehicles for providing registration data in support of Chapter 3 and Professor Anderson for providing supplemental data to complement analysis classifying vehicles by identification number. For Chapter 5, David Bunch (UC Davis ITS) ran the simulations reported. We are indebted to Aniss Bahreinian and Jesse Gage (California Energy Commission) for providing custom data from multiple sources and their review. Jiawei Chen, Cassie Zhang, and Farzana Khatoun (UCI) provided research support and their review. Ron Lawson and Taylor Krieger (JD Power) provided vehicle weight and price data. None of these people are responsible for any errors or omissions.

Disclaimer

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Executive Summary

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In recent decades, the United States has experienced a troubling divergence from international road safety trends (Yellman, 2022). While peer nations have seen steady declines in traffic fatalities, the U.S. has seen a dramatic increase, particularly over the last 15 years. In particular, the share of fatalities and serious injuries born by those outside of vehicles (e.g., pedestrians and cyclists) has increased over the same period (*Dangerous by Design*, 2024). Concurrently, vehicles for sale in the U.S. have increased in weight and size. In 2023, the California State Legislature passed Assembly Bill 251, which mandated a comprehensive study on the impacts of increasing vehicle weight on road safety for vulnerable road users and infrastructure (CalMatters, 2024). The bill assigned the California Transportation Commission with the responsibility of delivering findings to the Legislature, informed in part by convening a Task Force and commissioning an academic report. This report, the Vehicle Weight Safety Study Academic Report, summarizes trends of road user injuries and fatalities in California and potential factors contributing to these trends, with a focus on vehicle weight, vulnerable road users, road degradation, consumer behavior, and the landscape of potential policy solutions.

Vehicle Size and Road Safety

This report begins by establishing the context of the current national road safety crisis in *Chapter 2 Trends in California Road User Injuries and Fatalities*. After hitting a historic low in 2011, national traffic fatalities rose to over 42,000 by 2022 (NHTSA, 2023b, 2025a; U.S. Department of Transportation, 2024c). This trend stands in stark contrast to other high-income nations; compared to Organization for Economic Co-operation and Development (OECD) peers, the U.S. experiences approximately 25,000 excess deaths annually (Leonhardt, 2023).

A potential driver of this trend is the changing composition of the American vehicle fleet. Since the mid-1980s, consumer preference has shifted decisively from passenger cars (e.g. sedans, coupes, and hatchbacks) to light trucks (e.g. SUVs, pickups, and vans). By 2022, SUVs and pickups accounted for 71% of new vehicle sales (US EPA, 2024). Concurrently, these vehicles have grown physically larger and heavier; the average pickup truck increased in weight by 46% between 1987 and 2022, from 3,526 pounds to 5,281 pounds (Kahane, 2012, US EPA, 2024).

The safety implications of this shift are rooted in physics and design:

- **Kinetic Energy:** Heavier vehicles impart significantly more force during a collision. Studies indicate that a 1,000-pound increase in vehicle weight increases the probability of fatality for the occupants of a struck vehicle by 40–60% (Anderson & Auffhammer, 2014a; The Economist, 2024).

- **Vehicle Design:** The higher front-end profiles and hood heights of modern trucks and SUVs strike pedestrians higher on the body, causing more severe injuries to the torso and head rather than the legs. Furthermore, these designs create larger blind zones, reducing driver visibility of pedestrians and children immediately in front of the vehicle (Adiel Kaplan et al., 2022).

While Advanced Driver Assistance Systems (ADAS) offer potential mitigation, their penetration into the vehicle fleet on the road will take at least a decade, and initial results on their efficacy are mixed.

Trends in California Road User Injuries and Fatalities

An analysis of California Statewide Integrated Traffic Records System (SWITRS) data from 1997 to 2023, presented in *Chapter 3 Trends in California Road User Injuries and Fatalities*, confirms that national trends are mirrored—and in some cases exacerbated—within the state. After a period of stability, California traffic fatalities surged 66% from 2010 to 2022, with serious injuries rising by 72%.

Key findings:

- **Traffic fatalities** are *the* top cause of death for Californians aged 5 to 24, and a top cause of death and life-years lost for most age groups.
- **Pedestrian and Bicyclist Risk:** Pedestrian fatalities doubled between 2010 and 2022, and bicyclist fatalities reached a 25-year high (199 deaths and 1,257 serious injuries).
- **Passenger cars are more commonly involved in pedestrian fatal or serious injury crashes** regardless of urbanity, most likely due to their popularity over the study period.
- However, the **share of pedestrian crashes involving an SUV is growing faster** than all other vehicle types, suggesting that SUVs may pass passenger cars as the most common vehicle to strike and seriously injure a pedestrian in the near future.
- **Vulnerable road user crashes occurring in disadvantaged areas** on a per capita basis is nearly two-times as high compared to non-disadvantaged areas across all vehicle types.
- In California, **speed was the primary crash factor in 32 percent of fatalities** in 2022, slightly higher than for the nation (29 percent), but we did not find evidence that speed and vehicle type were correlated.
- When a **young (under 15 years old) pedestrian or cyclist was struck and seriously injured**, the striking vehicle was more often an SUV than other vehicle types. We did not see a similar trend for adults aged 65 or older.

In general, the data suggests that the safety gains made in previous decades are being eroded in California with severe consequences for the most vulnerable residents. While there are some indications in the population-level data that the shift to larger vehicles is accelerating road safety losses, there is not a strong correlation apparent yet in the population level analysis. This finding does not mean that there is no relationship between the transition to larger vehicles and increasing fatalities and serious injuries. Empirical evidence from national studies and the basic principles of kinetic energy transfer suggest a relationship does exist. Rather, in

California, a potential relationship between the transition to larger vehicles and increased road injuries may be masked by the by the fact that sedans were still the most commonly registered vehicle during the study period.

Trends in Vehicle Weight, Size, and Height

Chapter 4 Trends in Vehicle Weight, Size, and Height provides an overview of national vehicle sales data before going deeper into the evolution of the California vehicle fleet, a more precise method of measuring the shift in vehicles on the road. Using registration data from the California Department of Motor Vehicles joined with vehicle specification databases, the chapter documents a measurable shift toward larger vehicles across the state. Key findings include:

- Over the 2010–2023 period, the **SUV share of registered vehicles in California has climbed quickly** from around 20% to nearly 35%, while the passenger car share has declined.
- **Vehicle are getting larger** as the average curb weight, height, and ground clearance of vehicles registered in California increased over the 2010–2023 period.
- The vehicle type distribution of vehicles in urban and rural areas differed, with pickups more popular in rural counties and cars more popular in urban ones. In 2023, however, **SUVs were the most popular registered vehicle type in both urban and rural counties**.
- A **vehicle manufactured in 2023 was much more likely to have advanced driver assistance systems** (such as forward collision warning and automatic emergency braking) than a vehicle sold in 2015.

California's registered vehicle fleet is getting heavier, taller, and higher. The fleet is shifting towards larger vehicle types (i.e., SUVs and pickup trucks) as well. These larger vehicles are more dangerous to other road users, including those in smaller vehicles and vulnerable road users, as they transfer more energy in a crash, have larger blind spots, and have higher front ends.

Landscape of Policy Solutions

To address these challenges, this report surveys the policy landscape in *Chapter 5 Landscape of Policy Solutions*, categorizing potential interventions into fee-based, regulatory, and built-environment solutions. Due to federal preemption of regulations regarding vehicle design, the policies available to improve road user safety through shifts in the vehicle fleet are severely limited. As such, federal action would be needed to mandate safer designs of vehicles. While the state could potentially implement weight-based fees due at registration and weight-based sales taxes, it is unclear if these policies would shift behavior (see *Chapter* 6 Weight Fees and Consumer Behavior). Around half of U.S. states have some weight-based registration fee currently in place. Linking proceeds from a weight-based fee to safety infrastructure investments would enhance the safety impacts of any weight-based revenue-generating policy by also improving the built environment. For most safety countermeasures, vehicle weight is a factor and the efficacy of infrastructure improvements on increasing safety may shift with a larger vehicle fleet, requiring further analysis. We also consider the equity implications of various policy interventions, including but not limited to: the implications of a weight-based fee on different professions; those living in different areas of the state; and the differing equity impacts of regulation vs. fee vs. built environment solutions.

Weight Fees and Consumer Behavior

To better understand the potential impacts of a weight-based fee on consumer behavior, *Chapter* Chapter 5 models how consumer behavior might shift with the imposition of weight-based fees and a weight-based sales tax using California Energy Commission (CEC) models. The analysis simulated the introduction of both one-time purchase fees and recurring annual registration fees based on vehicle weight. Key findings include:

- **A high weight-based new purchase fee would shift demand.** A $5 per pound fee imposed on newly purchased vehicles exceeding 3,800 lbs would apply to roughly 60% of new car buyers and shift the weight distribution lower along with a shift away from pickup trucks and SUVs. However, a $5 per pound fee on a 4,000 pickup truck would be $20,000 and is highly unlikely to be implemented due to its outsized financial burden for Californians.
- **A weight-based fee policy more in line with other states would be unlikely to shift demand.** A $0.10 per pound annual registration fee would result in a mean annual fee of $77 and maximum fee of $390, which is generally in line with other states imposing weight-based fees. The fee would cause nearly no shift in the distribution of vehicle weight, though it might decrease new large SUV purchases by 4% and pickup trucks by 3%.
- **Fees would generate substantial revenue that could be reinvested in road safety.** While the $0.10 per pound fee would not substantially shift consumer behavior, it is estimated to generate $1.2 billion per year in 2040 if applied only to 2024 vehicles and newer. These resources could be used to improve road safety through infrastructure improvements and other investments, creating a virtuous cycle whereby fees shift purchasing behavior towards safer form-factor vehicles and fee proceeds improve safety through changes to the built environment.

Vehicle Weight and Infrastructure Degradation

Finally, in *Chapter* Chapter 6 we explore the potential road degradation impact of a heavier vehicle fleet. We find that road damage is overwhelmingly driven by heavy commercial trucks and buses, not passenger cars, SUVs, trucks, and vans. Even the heaviest electric passenger vehicles or large personal pickups cause a negligible fraction of the damage caused by a fully loaded commercial freight truck. To put it in perspective, it takes approximately 1,255 passes of a heavy electric pickup truck to cause the same damage as one pass of one axel of a heavy duty truck loaded to the legal limit. We conclude that concerns about heavier passenger vehicles (EVs or SUVs) significantly degrading road pavement are largely unfounded from a structural engineering perspective.

Conclusion

The Vehicle Weight Safety Study Academic Report finds that road fatalities and severe injuries are increasing in the state of California, particularly for pedestrians. We also find that the weight, height, and ground clearance of the registered California vehicle fleet is growing, with a rapid shift occurring away from the passenger cars and towards SUVs. Evidence collected during the study suggests several reasons why the growing vehicle fleet weight and height might be at least a partial cause of the rise in traffic injuries, including increased kinetic energy transfer, higher impacts (particularly an issue for vulnerable road users), and reduced visibility. Preliminary studies do suggest a relationship between larger vehicles with higher front ends and increased risk to smaller vehicles and vulnerable road users.

Our analysis did not find a clear correlation between larger vehicles and increased vulnerable road user injury in California; however, we believe this is most likely due to the lack of controls for confounding and the continued dominance of the passenger car in California registration data during the study period. The lack of an empirical relationship in our analysis should not be interpreted as conclusive evidence of a lack of an association between larger vehicles and increased vulnerable road user injuries. It most likely means that it is too early to see the effect in population-level data.

We found that there are limited levers for the State of California to pull to shape the design and composition of the vehicle fleet due to federal preemption of vehicle design regulations. While the state could implement weight-based fees due annually at registration or one-time at vehicle sale, our consumer behavior analysis suggest that these fees would need to be extremely high to shape consumer decision-making towards smaller and lighter vehicle types. The imposition of a vehicle weight-fee would, however, generate considerable revenue that could be invested into safety improvement to the built environment and is worth consideration on those grounds. Finally, we find that the increased weight of passenger vehicles would have trivial impact on road degradation, particularly when compared to the damage done by commercial trucks.

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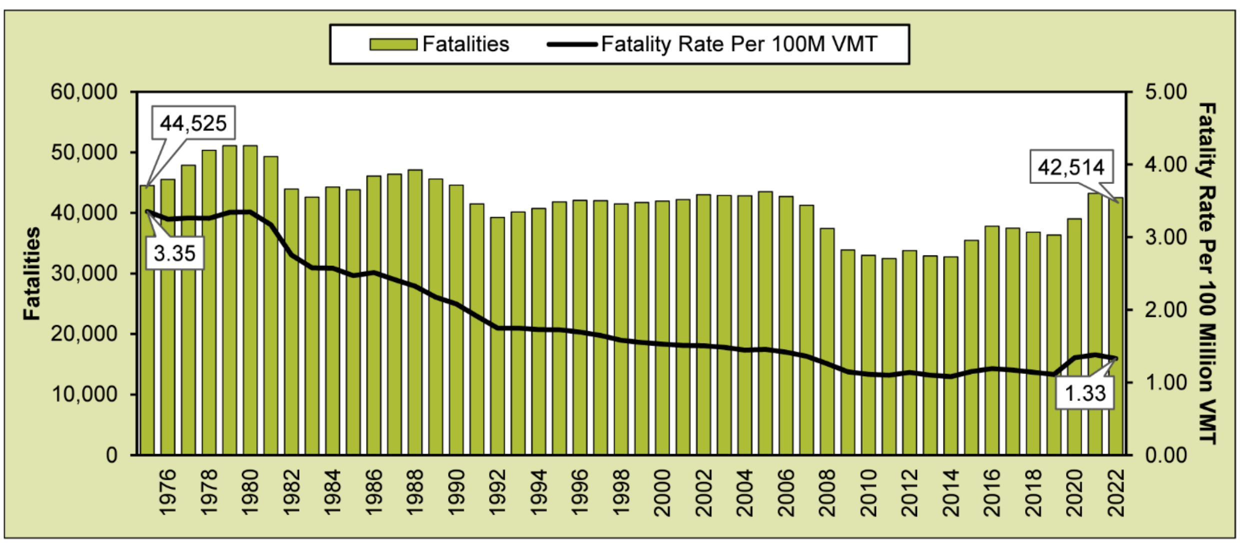
Chapter 1. Introduction

By: Matthew Raifman

1.1 Growth of Traffic Fatalities

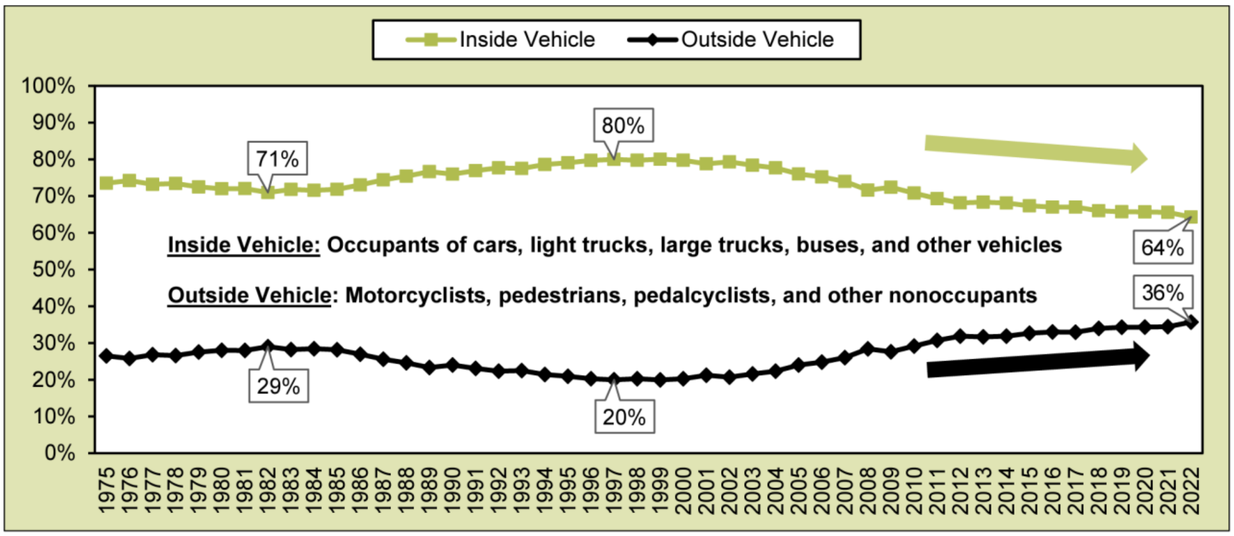
In the United States, traffic fatalities have been increasing over the past 15 years. After reaching a peak in the 1980s, they fell consistently into the early 2000s (U.S. Department of Transportation, 2024c). The Centers for Disease Control and Prevention even deemed the reduction in traffic fatalities from 1960s to 2000 one of America's 20th Century Public Health Achievements (CDC, 1999). From 2011 to 2022, however, annual fatalities on our nation's roads grew dramatically from 29,867—the lowest recorded level—to 42,514 deaths.(NHTSA, 2023b, 2025a; U.S. Department of Transportation, 2024c) These same trends are apparent even when adjusting for vehicle miles traveled. After a period of more than 30 years of decline in the rate of fatalities per vehicle mile traveled, deaths per 100 million vehicle miles traveled flatlined in 2009 and began rising during the past decade (see Figure 1). This trend is at odds with other well-developed nations. Compared to other high-income Organization for Economic Co-operation and Development (OECD) countries, there are approximately 25,000 excess deaths each year in the United States (Leonhardt, 2023).



Sources: FARS 1975-2021 Final File, 2022 ARF; 1975-2022 VMT – FHWA's Annual Highway Statistics

Figure 1. National fatalities and fatality rate per mile traveled (National Center for Statistics and Analysis, 2024)

While traffic fatalities fell during the 1970-1990 period, particularly the rate per vehicle mile traveled, the burden of unsafe roads shifted to those outside the vehicle. The 1966 National Traffic and Motor Vehicle Safety Act and its operationalization through Federal Motor Vehicle Safety Standards (FMVSS) and the creation of the National Highway Traffic Safety Administration's (NHTSA) New Car Assessment Program in the 1970s all aligned with consumer demand for larger vehicles that were safer for occupants (O'Neill, 2009). The result was the initiation of a trend in the late 1980s that continues through to this day: every year, the roads are becoming relatively less safe for those outside the vehicle compared to those within.



Source: FARS 1975-2021 Final File, 2022 ARF

Figure 2. Share of national traffic fatalities that were occupants of a vehicle compared to fatalities outside the vehicle (National Center for Statistics and Analysis, 2024)

Vulnerable road users, such as pedestrians, cyclists, and motorcyclists, make up an increasingly large share of traffic fatalities every year. The share of fatalities borne by those outside the vehicle has been growing since the mid-1990s, increasing from 20% in 1997 to 35% in 2022 (see Figure 2). In 2022, 7,522 pedestrians were killed by motor vehicles across the country, a level not seen since the early 1980s (Cova, 2024). Over just the 2019-2020 period, pedestrian fatalities increased nearly 20% (GHSA, 2023).

In California (see Trends in California Road User Injuries and Fatalities), we are experiencing a similar trend. After dropping to a historic low of 2,739 in 2010, traffic fatalities in California increased 66% to 4,537 in 2022. Over the same period, serious injuries increased even more (72%) from 10,423 to 17,916. A similar story regarding vulnerable road users is also playing out in California; pedestrian fatalities have doubled from 2010-2022 and bicyclist fatalities have increased 81% to the highest level (199 deaths and 1,257 serious injuries) in more than 25 years.

1.2 Growth in Vehicle Size

Over the same period, the vehicles on our roads have increased in footprint and weight (US EPA, 2024). The vehicle fleet is beginning to shift in two ways. One, beginning in the mid-1980s and continuing to present, all vehicle types from passenger cars to SUVs started getting heavier, especially pickup trucks and truck SUVs

(SUVs built on a truck chassis). From 1987-2022, the average weight of passenger cars and pickup trucks increased 19% and 46%, respectively (see Figure 3) (Kahane, 2012).

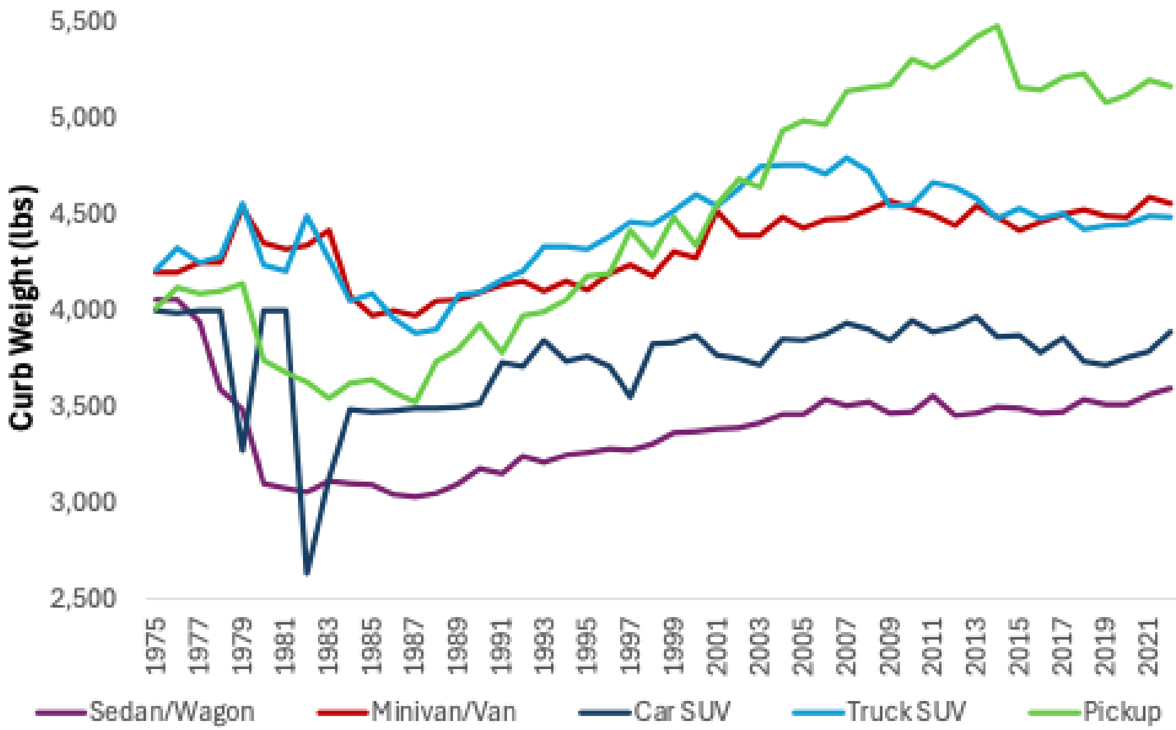


Figure 3. Average Curb Weight of U.S. Vehicle Sales by Vehicle Type (USEPA Data)

Two, vehicle manufactures transitioned to focusing on heavier vehicle form factors, namely SUVs and pickup trucks. Until 2014, sedans and wagons made up the largest share of vehicles sold every year. In 2015, the share of new model year vehicles for sale that were passenger cars dropped below 50% for the last time (US EPA, 2024). As of 2022, passenger cars now account for only 27% of new vehicles sales (see Figure 4). Conversely, SUVs and pickup trucks have grown in share to now represent the largest share of vehicles produced (combined share of 71% in 2022) (US EPA, 2024). American manufacturers Ford, Chevrolet, and Dodge/Chrysler have all announced over the past decade that they will stop manufacturing sedans (Nick Bunkley, 2018; Zipper, 2024).

Americans are purchasing more SUVs and pickup trucks, *and* the vehicles of today are much heavier. The combined effect of these trends is that vehicles sold now are heavier and larger than they were in past decades, with serious implications for road safety.

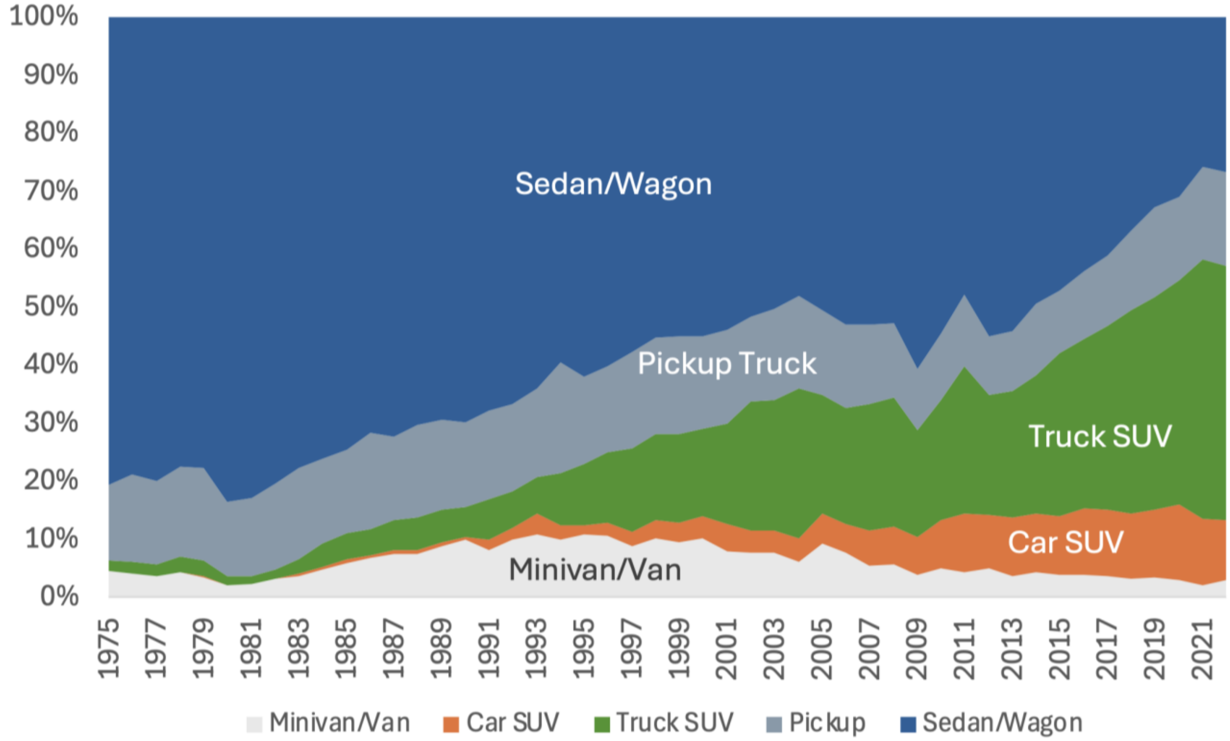


Figure 4. Production share of new vehicles for sale in America by vehicle type (USEPA, 2024)

1.3 Composition of Vehicles on the Road Lag New Vehicle Sales

While the majority of new vehicles sold in the U.S. are SUVs and pickup trucks, that does not immediately equate to a larger share of vehicles on the road. Americans tend to hold on to their vehicles for around 12 years on average, meaning that any transition in the form factor of vehicles sold (whether from sedans to trucks or from the internal combustion engine to electric) takes decades to fully transition through the whole fleet (Reuters, 2024). Even if every single vehicle sold in the U.S. in 2025 were an SUV or pickup truck, it would likely take at least 15 years for the full on-road fleet to turn over (Plumer et al., 2021). Further, some opt to purchase used vehicles which delays fleet-level transitions further.

California appears to have resisted the transition to larger form-factor vehicles more than the nation on average. California's more nascent transition to light-duty trucks, vans, and SUVs may create a longer policy window to limit the growth of the vehicle fleet compared to other states, as the vehicle fleet is comparatively less truck centric. Using data from the Federal Highway Administration (Federal Highway Administration, 2024b), we analyzed vehicle registrations in California compared to the nation at large, comparing the share of registered vehicles that were automobiles vs. light trucks (defined by FHWA as: pickup trucks, vans, sport utilities, and other light truck vehicles less than 10,000 pounds). Until 2019, the share of vehicles that were light trucks vs. automobiles was relatively equal in California, whereas light trucks were already the dominant vehicle type in the U.S. as early as 2012. (Note: FHWA data for this comparison combines private and commercial vehicles together, including taxi cabs, and is therefore not comparable to the analysis of new model year data discussed above). It is not clear why the vehicle fleet looks different in California; however, California is not immune to the large vehicle transition. Over the past few years, California's fleet has been transitioning to larger vehicles and away from automobiles at roughly the same pace as the nation (see Figure 5).

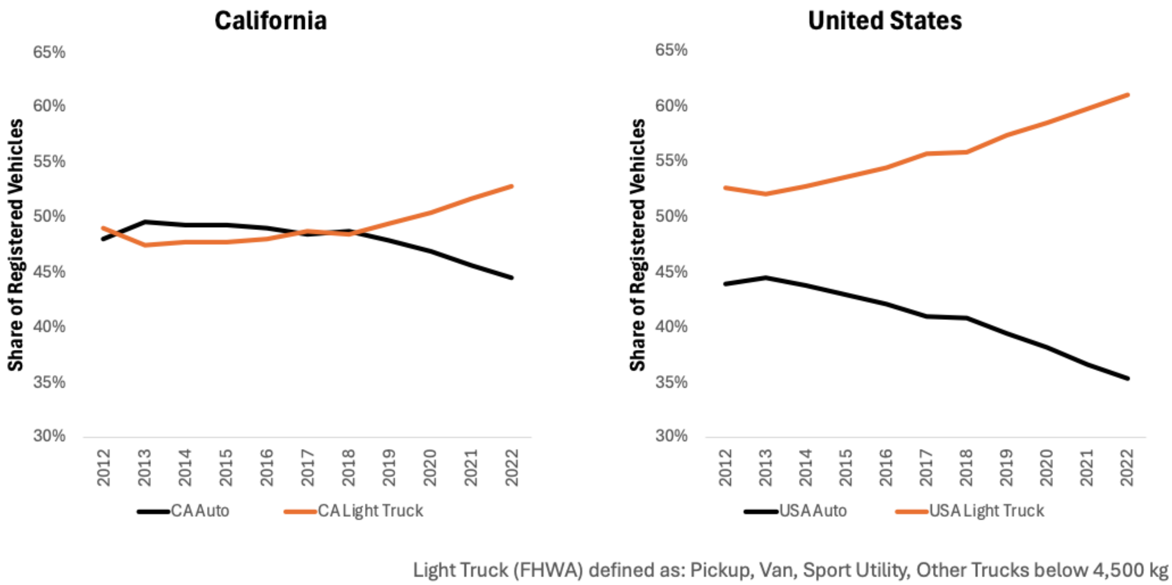


Figure 5. Share of registrations by vehicle type, California compared to the national average (Federal Highway Administration, 2024b)

The turnover lag has implications for population-level trend analysis of road safety. Passenger cars represented most vehicles sold nationally as recently as 2014, and most of those model year 2014 vehicles are still on the road today. Over time, as the vehicle fleet transitions, we expect the implications of the transition from passenger cars to larger SUVs and trucks to become more apparent in population-level road safety data.

1.4 Larger vehicles present a road safety challenge

The transition to heavier vehicles presents a road safety challenge. The simple, mathematical relationship between mass, speed, and kinetic energy implies larger vehicles will inflict greater force on the other party in a crash, all things equal. Empirical analysis of crashes, where confounding variables can be adjusted to allow researchers to isolate the effects of changes in weight on risk of injury, also find a strong and clear relationship between weight and risk of injury, particularly for vulnerable road users.

1.4.1 Kinetic Energy

The relationship between vehicle weight and severity of injury in a crash is particularly well established. From a theoretical perspective, kinetic energy transferred between two parties during a crash is a function of mass and velocity. Comparatively, vehicle velocity is substantially more important than vehicle mass. All things equal, though, increased weight translates into increased kinetic energy. For two-vehicle crashes, the transition to larger vehicles is concerning because the weight difference between large- and small-platform vehicles translates into a difference in force applied in a crash. That difference in force is more likely to inflict harm on occupants of the smaller vehicles, as the larger vehicle transfers more kinetic energy. All things equal, as the difference in weight between vehicles increases, the potential for harm in a crash increases.

Kinetic energy is defined as:

$$E = \frac{1}{2}mv^2$$

where E is the kinetic energy of the vehicle at impact, m is the mass of the vehicle, and v is the impact speed of the vehicle.

In a crash with a vulnerable road user, a larger vehicle is more likely to inflict catastrophic harm because the differential in weight is even more pronounced. The kinetic energy from a moving vehicle is transferred entirely to the vulnerable person in a crash without any intermediary structure to dissipate the force.(Niebuhr et al., 2016; Tyndall, 2021a, 2024a)

1.4.2 Empirical Evidence of the Relationship between Vehicle Weight and Risk of Injury

Empirical evidence supports the association between increasing vehicle weight and increasing risk of severe injury. By focusing on crashes and controlling for known confounders, these studies can isolate the impacts of vehicle type on the risk of injury and fatality using statistical methods. Several studies of two-vehicle crashes have found that for every 1,000-pound increase in one vehicle's weight, the risk of fatality for occupants of the other vehicle increases between 40 and 60 percent. This finding holds true even when adjusting for the weight of the other vehicle and the vehicle type (e.g., passenger car or light truck) of each vehicle (Anderson & Auffhammer, 2014a; The Economist, 2024).

Federal regulations and vehicle testing, most notably the New Car Assessment Program score, play a key role in focusing automobile safety concerns on a vehicle's occupants instead of the safety of those outside a vehicle. Many of the same attributes that make a vehicle safer for its own occupants—most notably weight and size—make the vehicle more dangerous for others (J. A. Thomas & Walton, 2008). Multiple studies have shown that the negative social impacts on road safety outweigh the safety benefits for occupants of larger vehicles.

A recent analysis of vehicle-to-vehicle crashes by *The Economist* found that for every life saved for occupants of the heaviest light-duty trucks, over a dozen would be expected to die in smaller vehicles (The Economist, 2024). Another study found for every life saved among occupants who switched to a light truck or SUV from a passenger car, an estimated 4.3 fatalities occurred among other drivers, pedestrians, and bicyclists (White, 2004). More modest changes in vehicles can still have notable impacts on overall safety. One study, for example, found that a uniform 20 percent reduction in vehicle weight across the fleet would reduce annual fatalities by 0.8 percent (367 fatalities).[17]

Efforts to quantify the impacts of this perceived safety for size are notable. One study into the economic costs of the so called “arms race” to ever larger vehicles found the value of crash externalities for light-duty trucks to exceed $3,203 (2020 USD) over the lifetime of the vehicle (Li, 2012). Researchers found that for every 1 million light-duty trucks that replace cars, an estimated 34 to 93 additional car occupants, pedestrians, bicyclists, and motorcyclists are killed annually, at a value of hundreds of millions of dollars per year (White, 2004). Another study found that every one percentage point increase in light-duty truck share is associated with a 0.34 percent increase in fatalities per year, 80 percent of which occur among other vehicle occupants or pedestrians (Anderson, 2008a). In 2024, NHTSA proposed rules that would establish a Federal Motor Vehicle Safety Standard requiring that passenger vehicles are designed to reduce deaths and injuries of those outside the vehicle, but it is unclear how this issue will be treated by a new federal administration (NHTSA, 2024c). Similar rules have been in place in Europe for more than a decade.

1.4.3 Empirical Evidence of the Relationship between Vehicle Design and Risk of Injury

The impact of larger vehicles on road safety is not just a function of vehicle weight, but also of design. Specifically, vehicle front-end design can play an important role in the risk of injury and death, as impact points determine where kinetic energy is transferred in a crash. In a recent study of 121 pedestrian crashes, researchers from Insurance Institute for Highway Safety (IIHS) found that vehicles with a higher hood leading-edge were associated with crashes with higher pedestrian injury severity, as these vehicles were more likely to inflict severe injury on a pedestrian’s torso and hip in a crash and throw the pedestrian forward (Monfort et al., 2024a). In another study, researchers found corroborating evidence that vehicles with tall or medium-height front ends had elevated risk of pedestrian fatality compared to lower front ends (Hu et al., 2024).

Given the transition from passenger cars to SUVs—and that they appear to be substitutes for each other—recent research has begun to examine the specific impact of SUVs on road safety. One study found that replacing the growth in SUVs with cars would have avoided over 1,000 pedestrian deaths (Tyndall, 2021a). Children are also at higher risk of death when hit by an SUV compared to a passenger car. Compared to a passenger car, SUVs are eight times more likely to kill a child in a crash (Edwards & Leonard, 2022a), and they are more likely to cause higher velocity head-to-ground injuries when hitting children (Crocetta et al., 2015). Even when an SUV is the same weight as a passenger car, occupants of the passenger car were almost twice as likely to die in the crash (Mayrose & Jehle, 2002a). Comparing vehicle-to-vehicle crashes, one study found that occupants of passenger cars colliding with SUVs were almost three times as likely to die than the occupants of the SUV. These findings suggest that both vehicle weight and geometry make larger vehicles less safe, particularly for vulnerable road users (Monfort et al., 2024b).

1.4.4 Potential to Observe Population-level Trends

There is reason to believe that we might be able to observe the effects of increasing vehicle weight and size in population-level traffic fatality trend data even if the full effect of transitioning to larger form factors (i.e., SUVs and pickup trucks) is not yet apparent, particularly because vehicles began increasing in weight in the mid-1980s before the car-to-SUV transition began in force. As noted above (see Figure 2), from 1997 onward, the share of traffic fatalities borne by those outside the vehicle began to increase, approximately lagged one decade behind the transition to heavier vehicle weight for new models. Given that SUV and truck sales began to ramp up in the 1990s, it is possible that the road safety impacts of this transition are already apparent in traffic fatalities and injury data today but may be masked by the continued – though waning – dominance of passenger vehicles particularly in California.

1.5 Are vehicle safety features enough?

Vehicle safety has also become an increasingly important aspect of vehicle design and manufacturing. As such, vehicle manufacturers increasingly design for the safety of vehicle occupants, leading to further increases in vehicle size and weight (Anderson, 2008b; Anderson & Auffhammer, 2014a). This shift is also reflected by consumer preferences toward larger vehicles, partially due to higher perceived safety (Anderson & Auffhammer, 2014a).

Improvements in vehicle safety technology such as lane departure alerts, forward collision warnings, blind spot detection, and automatic emergency braking have the potential to improve safety for vehicle occupants and those outside a vehicle. One study found that vehicles with advanced driver assistance systems (ADASs) were less likely to be involved in head-on and rear-end crashes (Schoner et al., 2024). Some studies have gone further to estimate the number of crashes that could have been avoided if all vehicles had advanced driver assistance system (Aleksa et al., 2024). However, as these systems are primarily designed to avoid on-road, vehicle to vehicle crashes, they are at best unlikely to reduce the disparities observed between vehicle occupants and vulnerable road users, and may actually increase disparities in risk. Some technological improvements to vehicles like automatic emergency braking, which have been shown to significantly reduce the risk of crash at speeds under 35 miles per hour, will likely mitigate some risk to pedestrians (Haus et al., 2019). Notably, a new Federal Motor Vehicle Safety Standard (FMVSS) was implemented in 2024 that requires all automakers to include automatic emergency braking in their vehicles by 2029 (NHTSA, 2024b).

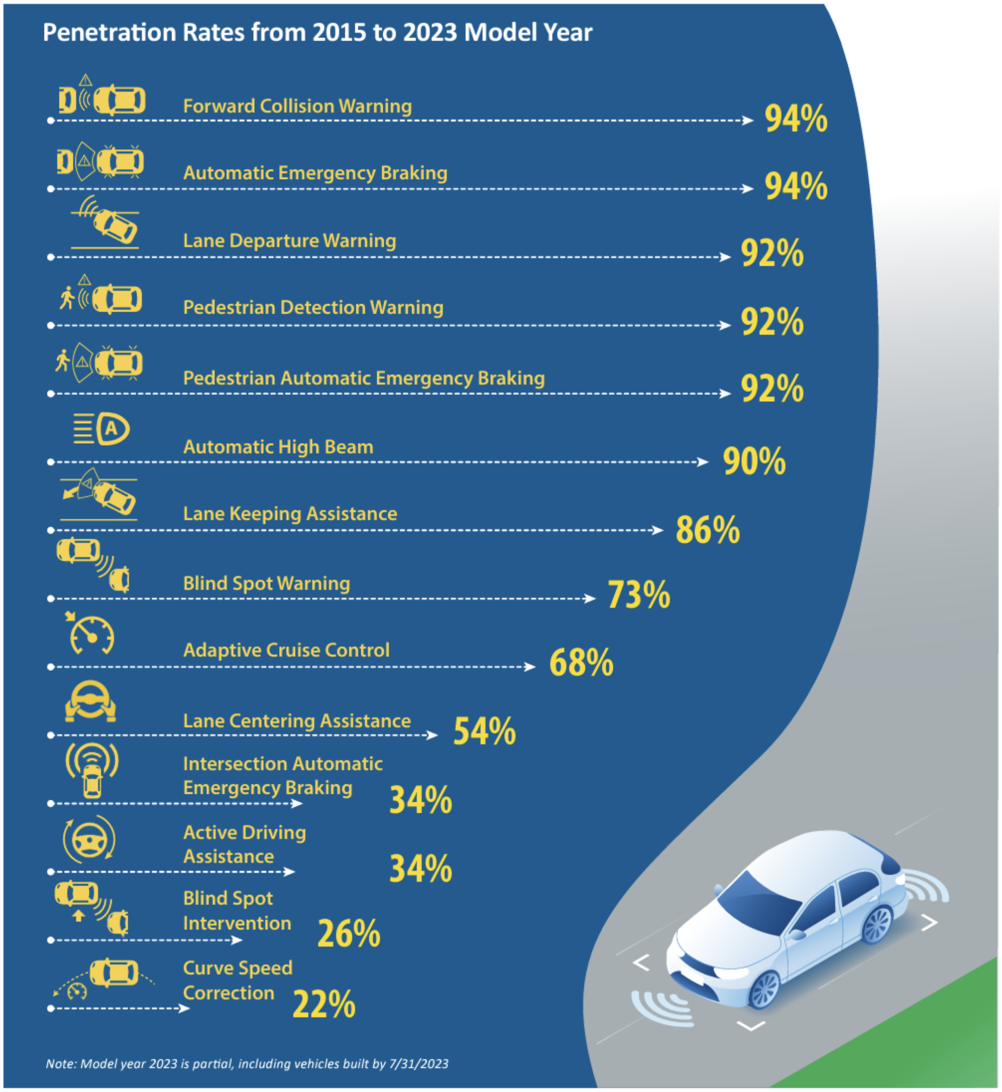


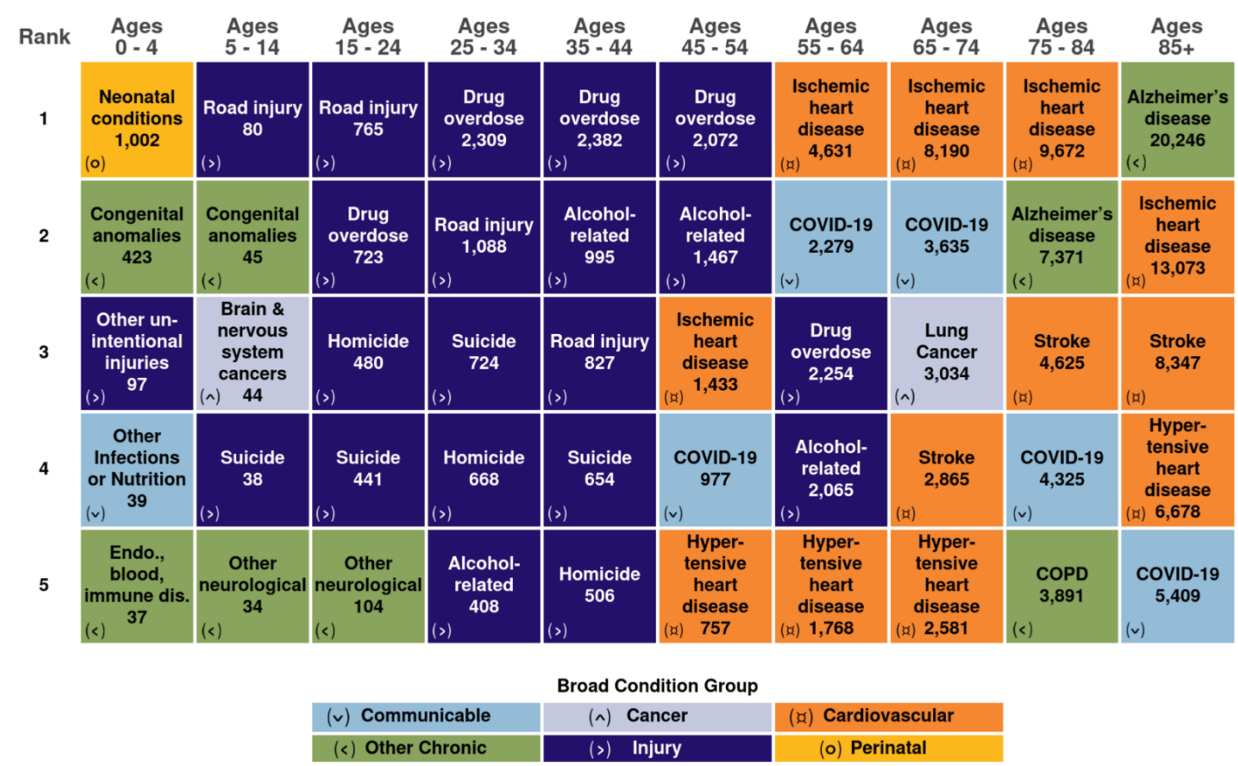
Figure 6. Penetration of advanced driver-assistance systems (MITRE)

Over the past decade, there has been a dramatic increase in penetration rates for ADAS in new vehicle models (see Figure 44). Notably, 92 percent of new model year vehicles ship with pedestrian detection and pedestrian automatic emergency braking technology. These systems may reduce the likelihood of a crash and, possibly, the lower the speed of a vehicle in the event of a crash. However, they do not appear to have meaningfully impacted population-level impacts yet. The uptick in traffic fatalities and serious injuries over the past decade occurred during the same period when ADASs became increasingly common as standard features in new model years. The same lags discussed earlier apply to penetration of these new technologies across the vehicle fleet, suggesting that it may be years before enough vehicles are on the road for ADAS to have an observable impact on road safety trends.

Chapter 2. Trends in California Road User Injuries and Fatalities

By: Matthew Raifman, Amalia Stahl, Celia Johnson, Michael Anderson, Federico Vaca, and Julia Griswold

Traffic fatalities and serious injuries are a major public health issue in California. As is the case across the nation, traffic fatalities are *the* top cause of death for Californians aged 5 to 24, and a top cause of death and life-years lost for most age groups (see Figure 7) (California Department of Public Health, Office of Policy and Planning, 2024; Gostin, 2018). Troublingly, the roads are becoming even less safe for the most vulnerable users, pedestrians and bicyclists. This is not just an issue for road safety, but also for the state's goals of mitigating greenhouse gas emissions, improving local air quality, and increasing physical activity. While walking and cycling are far better options for human and environmental health, they are more dangerous transport modes per mile traveled than light-duty vehicles are (Raifman & Choma, 2022).



Leading Causes of Death across the Life Course, 2022

Rank	Ages 0 - 4	Ages 5 - 14	Ages 15 - 24	Ages 25 - 34	Ages 35 - 44	Ages 45 - 54	Ages 55 - 64	Ages 65 - 74	Ages 75 - 84	Ages 85+
1	Neonatal conditions 1,002 (o)	Road injury 80 (›)	Road injury 765 (›)	Drug overdose 2,309 (›)	Drug overdose 2,382 (›)	Drug overdose 2,072 (›)	Ischemic heart disease 4,631 (¤)	Ischemic heart disease 8,190 (¤)	Ischemic heart disease 9,672 (¤)	Alzheimer's disease 20,246 (‹)
2	Congenital anomalies 423 (‹)	Congenital anomalies 45 (‹)	Drug overdose 723 (›)	Road injury 1,088 (›)	Alcohol-related 995 (›)	Alcohol-related 1,467 (›)	COVID-19 2,279 (⌄)	COVID-19 3,635 (⌄)	Alzheimer's disease 7,371 (‹)	Ischemic heart disease 13,073 (¤)
3	Other un-intentional injuries 97 (›)	Brain & nervous system cancers 44 (^)	Homicide 480 (›)	Suicide 724 (›)	Road injury 827 (›)	Ischemic heart disease 1,433 (¤)	Drug overdose 2,254 (›)	Lung Cancer 3,034 (^)	Stroke 4,625 (¤)	Stroke 8,347 (¤)
4	Other Infections or Nutrition 39 (⌄)	Suicide 38 (›)	Suicide 441 (›)	Homicide 668 (›)	Suicide 654 (›)	COVID-19 977 (⌄)	Alcohol-related 2,065 (›)	Stroke 2,865 (¤)	COVID-19 4,325 (⌄)	Hyper-tensive heart disease 6,678 (¤)
5	Endo., blood, immune dis. 37 (‹)	Other neurological 34 (‹)	Other neurological 104 (‹)	Alcohol-related 408 (›)	Homicide 506 (›)	Hyper-tensive heart disease 757 (¤)	Hyper-tensive heart disease 1,768 (¤)	Hyper-tensive heart disease 2,581 (¤)	COPD 3,891 (‹)	COVID-19 5,409 (⌄)

Broad Condition Group

(⌄) Communicable	(^) Cancer	(¤) Cardiovascular
(‹) Other Chronic	(›) Injury	(o) Perinatal

Figure 7. Leading causes of death, 2022 (California Department of Public Health, Office of Policy and Planning, 2024)

To better convey the magnitude and trends of the road safety epidemic in California over the past 25 years, we analyzed the full period of traffic fatality and serious injury data from the California Statewide Integrated Traffic Records System (SWITRS) from 1997 to 2023. (Note: Data from 2023 is provisional, still subject to change at the time of writing this report.) Given the focus of this report on the impact of larger vehicles on road safety, we report trends and descriptive analyses broken down by vehicle type and for vulnerable road user victims. As scoped for this report, our analysis is descriptive and derived from population-level crash data. Where possible, we cite supporting academic literature that addresses causality to support the findings. While we provide contextual interpretation of the results, our analysis is fundamentally not causal and should not be interpreted as such. On the other hand, the findings describe the state of road safety on California's roads, particularly as it relates to crashes involving larger vehicles and those resulting in pedestrian or bicyclist victims. We believe there is both inherent value in understanding these trends, and in using the observed trends to inform follow-up research that may isolate the effects through causal analysis.

2.1 California Crash Data

This report uses data from SWITRS as its primary data source for crashes in California. U.C. Berkeley SafeTREC geocodes all injury crashes in SWITRS on a quarterly basis to improve location accuracy from approximately 50 percent to 97 percent. Injuries are coded into four possible categories including: 1) fatal injury; 2) suspected serious injury; 3) suspected minor injury; and, 4) possible injury. Suspected serious injuries are generally defined as injuries that are severe enough that they could have resulted in death in the absence of treatment (including severe lacerations, significant blood loss, crush injuries, paralysis or spinal injury, significant burns, and other specifications) (California Highway Patrol, 2017). For our analysis, we analyze the two most serious levels of injury—fatal injury and serious injury—as both are indications of crashes that could have resulted in loss of life.

In SWITRS, each crash also contains limited information on the parties involved, including the vehicle type, if applicable. For our analysis on vehicle type, we consider only the period from 2010 onward after determining that missingness for the vehicle type variable exceeded 5% prior to this period. We define large vehicles as those classified as: pickup trucks, sport utility vehicles (SUVs), and vans. For analysis in Chapter 2.1, we consider all fatalities and serious injuries that occurred in California. For analysis in Chapter 2.2, we consider only two-party crashes that resulted in a vulnerable road user fatality or serious injury. We limit our analysis to two-parties for Chapter 2.2 because it was not possible to determine which vehicular party stuck the pedestrians or bicyclist in a multi-party crash.

Supporting demographic and equity data was collected from the USDOT Equitable Transportation Community (ETC) Explorer (U.S. Department of Transportation, 2024a). The ETC explorer uses 2020 census tract data to identify communities that are disadvantaged using five different components, including: transportation insecurity, health vulnerability, hazard vulnerability, social vulnerability, and overall environmental burden. For this analysis, the data was limited to the state of California and used in the urban-rural analysis and the analysis of disadvantage and vehicle type (see Chapter 2.3).

2.2 Trend in Traffic Fatalities and Serious Injuries in California

California's roads are getting less safe. Around 4,500 Californians died in 2022 on our roads, an increase of almost 25 percent compared to 1997. Comparatively, just under 18,000 people were seriously injured in 2022, a 40 percent increase compared to 1997. While the size and weight of the vehicles on the road have increased steadily over the 1997 to 2023 period, the trend in fatalities and serious injuries is more clearly connected to intermediary economic shocks than to vehicle size and weight. We discuss the observed trends and their possible explanations below and then examine the relationship between vehicle type and crashes in California by several factors.

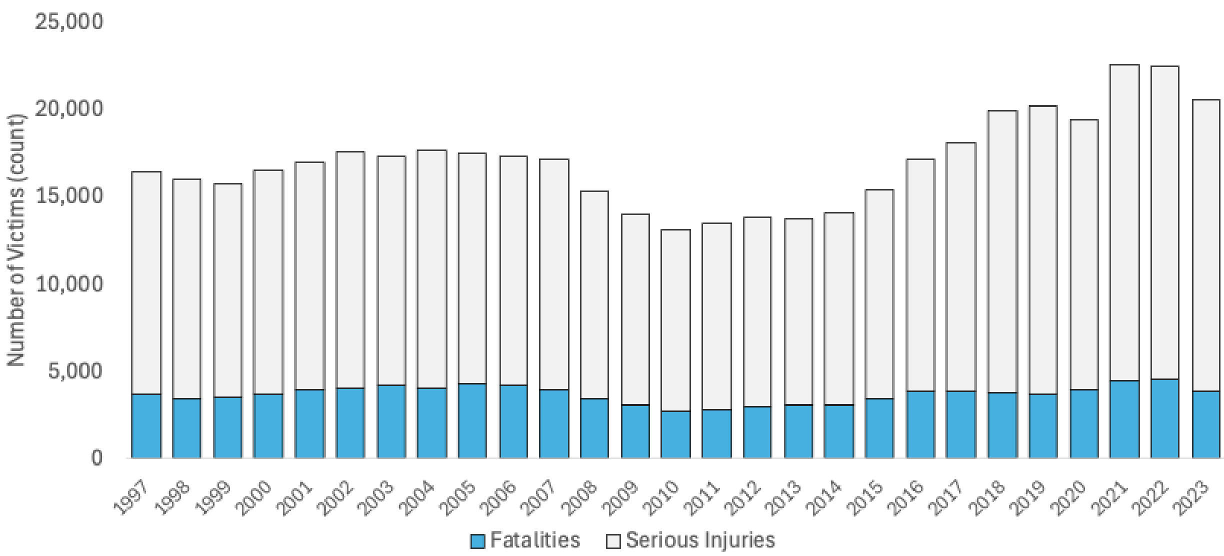


Figure 8. California fatalities and serious injuries, 1997-2023

Figure 8 shows the number of total fatalities and serious injuries in California by year from 1997 to 2023. Over the past 25 years, the number of fatalities and serious injuries (FSI) has shifted dramatically in apparent response to national and global events, with particular sensitivity to economic shocks. Four distinct periods emerge with different trend characteristics: 1997 to 2007; 2008-2014; 2015-2020; and, 2021 to 2022.

2.2.1 The Stable Decade: 1997-2007

From 1997 to 2007, total fatalities and serious injuries hovered around 16,000 in California. During this period the number of fatalities slowly crept up, but fatalities and serious injuries were relatively stable. Over the past 25-year period, this first decade was the most stable and consistent.

2.2.2 The Great Recession and its Aftereffect: 2008-2014

In 2008, both fatalities and serious injuries began a brief but rapid decline. Over the three years from the beginning of 2008 to the end of 2010, overall fatalities decreased 44% and serious injuries decreased 30%. This period of decline coincidences with the Great Recession (St. Louis Federal Reserve, 2024). Analysis of national fatality data from this time suggests a relationship between unemployment rate and fatalities, even after adjusting for known confounders. One hypothesis for the traffic fatality-economy relationship is that decreased commercial activity during recessions is reflected in fewer large commercial vehicles on the roads (He, 2016). One study examining the relationship between unemployment rate and traffic fatalities found that the relationship is strongest for large trucks weighing more than 10,000 pounds (He, 2016). During periods of recession, vehicle miles traveled tends to decrease for passenger vehicles too. With fewer vehicles on the road, and fewer miles logged, one would expect fewer crashes and fewer fatal and serious injuries (Caltrans, 2024).

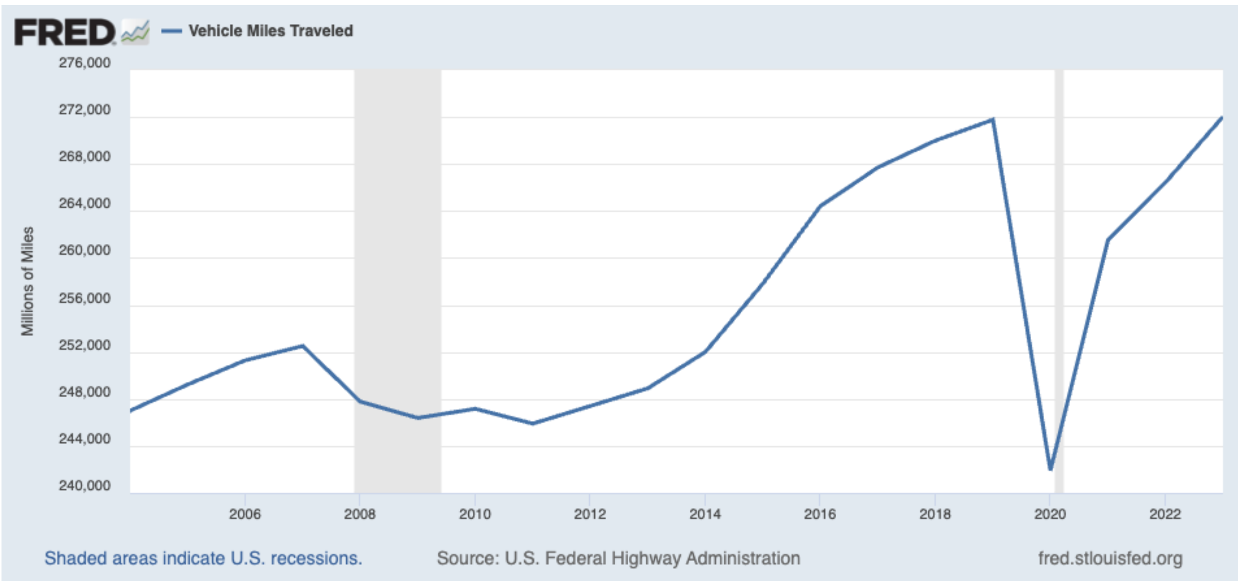


Figure 9. Vehicle miles traveled and U.S. recessions (St. Louis Federal Reserve, 2024)

The relationship between economic and transportation activity and road safety is also bidirectional, giving more strength to the correlation. As the U.S. economy came out of recession in late 2010, transportation activity began to increase and, slowly, so did traffic fatalities and serious injuries in California and across the nation (see

Figure 9). Transportation activity (as measured by vehicle miles traveled) continued to increase until the COVID-19 pandemic hit in March 2020.

2.2.3 Decoupling of the Trend for Vulnerable Road Users

Despite some gains in road safety for vulnerable road users in 2008-2010 with lower transportation activity, the improvements were not as significant as they were for vehicle occupants. In California, fatalities decreased 15 percent and serious injuries 7 percent for pedestrians, as compared to 44 percent and 30 percent for all road users. For bicyclists, fatalities decreased 29 percent, but serious injuries increased by 7 percent.

Similar disparities between differing road users are apparent from 2010 to 2013. While in aggregate, it appears that fatalities and serious injuries were relatively flat during the Great Recession period (see Figure 10), a clear shift was beginning for vulnerable road users. During the 2010 to 2013 period, pedestrian fatalities increased 20 percent and bicyclist fatalities 49 percent compared to only 13 percent for all road users (see Figure 11). This divergence is apparent in both figures, which convey that the share of total fatalities that were vulnerable road users began increasing during the Great Recession period from 2008 onward.

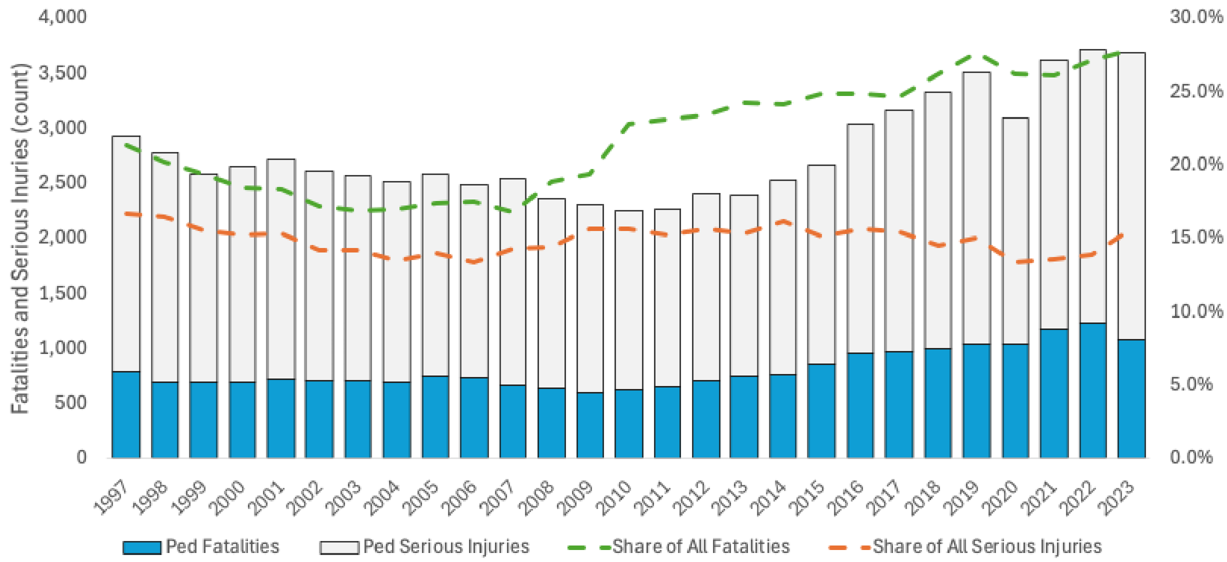


Figure 10. California fatalities and serious injuries for pedestrians, 1997-2023

It is unclear why there is dip in traffic fatalities and serious injuries during the Great Recession and period immediately afterwards. One hypothesis is that during recessions, people are more likely to walk and bike. Cars are more expensive than walking, cycling, and transit, and car use and car ownership decreases during economic recessions (Thakuriah & Keita, 2014). Analysis comparing 2009 (in the heart of the Great Recession) to 2001 suggests that there were measurable increases in vulnerable road user activity during the period, primarily for walking, which saw increases in number of trips, frequency duration, and distance (Pucher et al., 2011). Bicycling activity increased more modestly. It is challenging to understand the magnitude of changes in activity during this period, however, as data collection on vulnerable road user activity is inconsistent and periodic. While alcohol-involved and speed-involved crashes resulting in fatalities increased during this period, the observed changes are only directionally correlated and do not explain the trends observed.

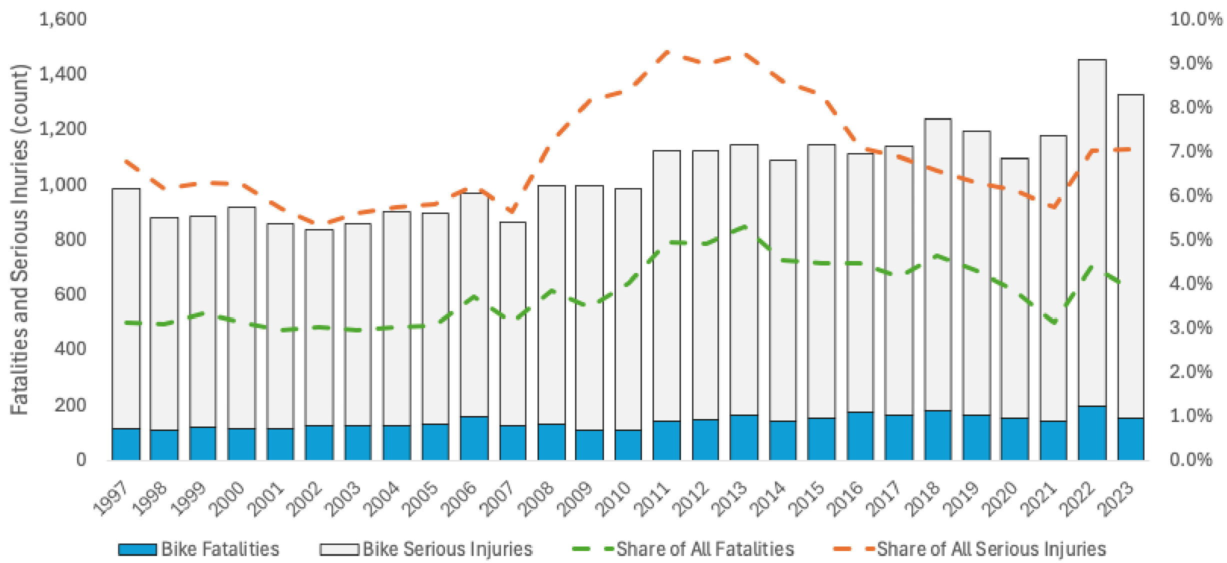


Figure 11. California fatalities and serious injuries for bicyclists, 1997-2023

2.2.4 Economic Recovery: 2015-2020

Fatalities and serious injuries were relatively stable at a depressed level until 2015 when the road safety gains reversed and traffic fatalities increased rapidly. During the 2015 to early 2020 period, total fatalities increased 28 percent and serious injuries increased 40 percent in California. This was a period of economic growth and recovery, and increased vehicle miles traveled (Sarah Bohn and Jenny Duan, 2024). Increases in pedestrian fatalities and injuries were directionally consistent with economic growth, but cyclist fatalities and serious injuries increased more modestly.

2.2.5 Coronavirus: 2020-2022

Finally, over the 2020-2022 period fatalities and serious injuries increased dramatically in California and across the country. In 2020, reduced transportation activity during the coronavirus lockdown corresponded initially with a reduction in traffic fatalities and serious injuries in California compared to 2019. In early 2021, there was also a brief economic recession that further depressed activity. However, in 2021, the established relationship between economic and transportation activity and road safety decoupled and we saw the largest year-to-year increase in traffic fatalities and injuries in recent history from 2020 to 2021. This is consistent with national findings as well (Meyer, 2020). While research into the COVID-bump in traffic fatalities is still underway, preliminary findings in the academic literature and from NHTSA suggest that a combination of factors were at play, including: selection bias into who was traveling during this time (Islam et al., 2023), reduced enforcement (Demir & Cassino, 2024), reduced congestion allowing for greater speed (Hughes et al., 2023; Shahlaee et al., 2022), and more risky driving behavior (Adanu et al., 2021). Preliminary 2023 data suggests that traffic fatalities and serious injuries may be trending downwards compared to the 2022 high in

California, a trend that is mirrored nationally (NHTSA, 2023a). Finally, over the 2020-2022 period fatalities and serious injuries increased dramatically in California and across the country.

2.2.6 Macro or Micro Trends?

There is a strong theoretical and empirical basis establishing a positive association between the number of large vehicles on the roadway and traffic fatalities. In aggregate, from 1997 to 2023 the roads have become less safe, particularly for vulnerable road users. During this same period, and going back to the 1980s, the United States vehicle fleet has been shifting to heavier and larger-form vehicles. Evidence from empirical studies of crashes suggest that weight and form-factor are key aspects in the severity of injury in crashes. However, in our trend analysis of traffic fatalities over this period, we do not find evidence of a clear, uniform, macro trend in traffic fatalities and serious injuries over the past 25 years. Rather, we observe distinct directional shifts (micro trends) in fatalities and serious injuries that are temporally co-existent with either economic shocks or the global pandemic. Most likely we do not observe a correlation between the transition to larger vehicles and declining road safety because: 1) the impact of large shocks occurring during the period mask any observable trend (even when adjusting for miles-traveled); and, 2) there are possibly not enough large vehicles on the road yet to observe a shift in population-level data.

In the following chapters, we explore further the potential relationship between larger vehicles and road safety with a deeper dive into vehicle type and vulnerable road users.

2.3 Vulnerable Road User Crashes in Urban/Rural Areas by Vehicle Type

In 2022, 92 percent of all fatal pedestrian crashes in California occurred in urban areas.(SafeTREC, 2024) While this can in part be explained by the fact that approximately 94 percent of California's population lives in urban areas, there are unique roadway and road type characteristics that contribute to different types of crashes in urban areas versus rural ones. As a result, we have conducted additional analysis on how vulnerable road users and the vehicles that strike them differ by urban-rural classification.

To determine whether an area was considered urban or rural in California, we used the USDOT Equitable Transportation Community (ETC) Explorer (U.S. Department of Transportation, 2024b). For this analysis, we specifically used the binary urban-rural flag created for each census tract in California and the population variable to calculate per capita rates. We used crash data exclusively from SWITRS spanning the 2018 to 2022 period and kept only crashes that resulted in one pedestrian or bicyclist fatality or serious injury. We then combined the data and crashes by urban and rural classification and vehicle type. For this analysis, we limited vehicle types to large vehicles (defined as: SUVs, pickup trucks and panel trucks, and vans) and passenger cars.

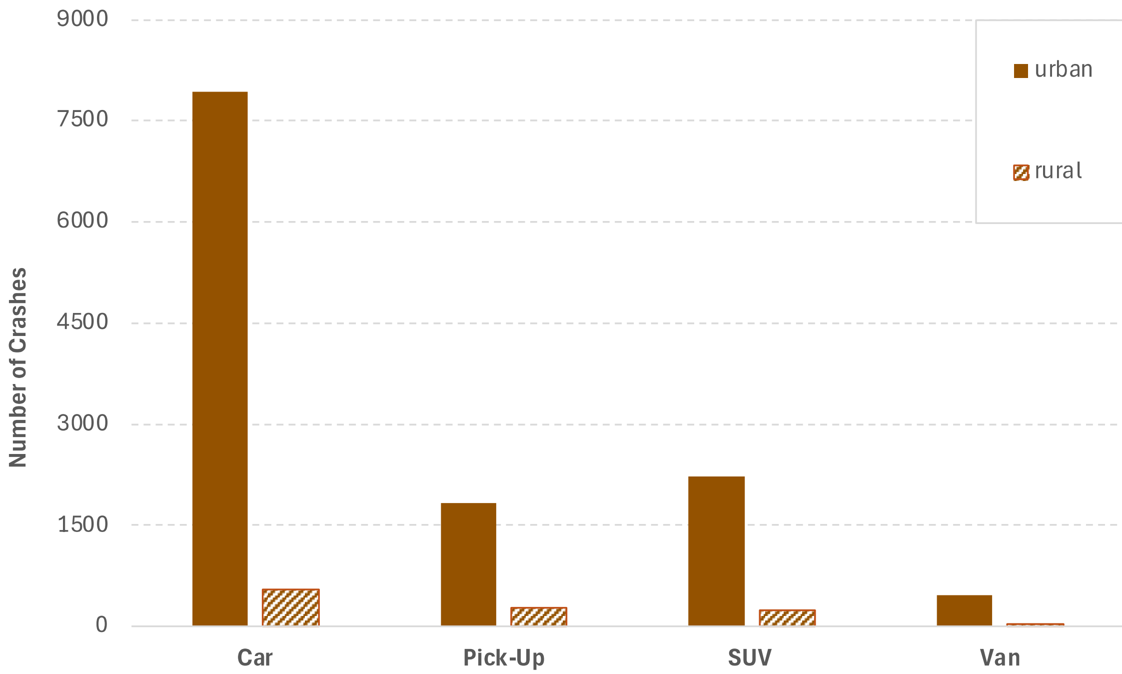


Figure 12. Number of pedestrian fatality or serious injury crashes by vehicle type and urban-rural classification

Across all vehicle types, pedestrian fatal or serious injury (FSI) crashes in urban areas far outnumbered those in rural areas (see Figure 12). Pedestrian FSI crashes occurring in urban areas involving cars accounted for the largest number of crashes, at 7,929, followed by SUVs (2,222), pickups (1,838), and vans (474).

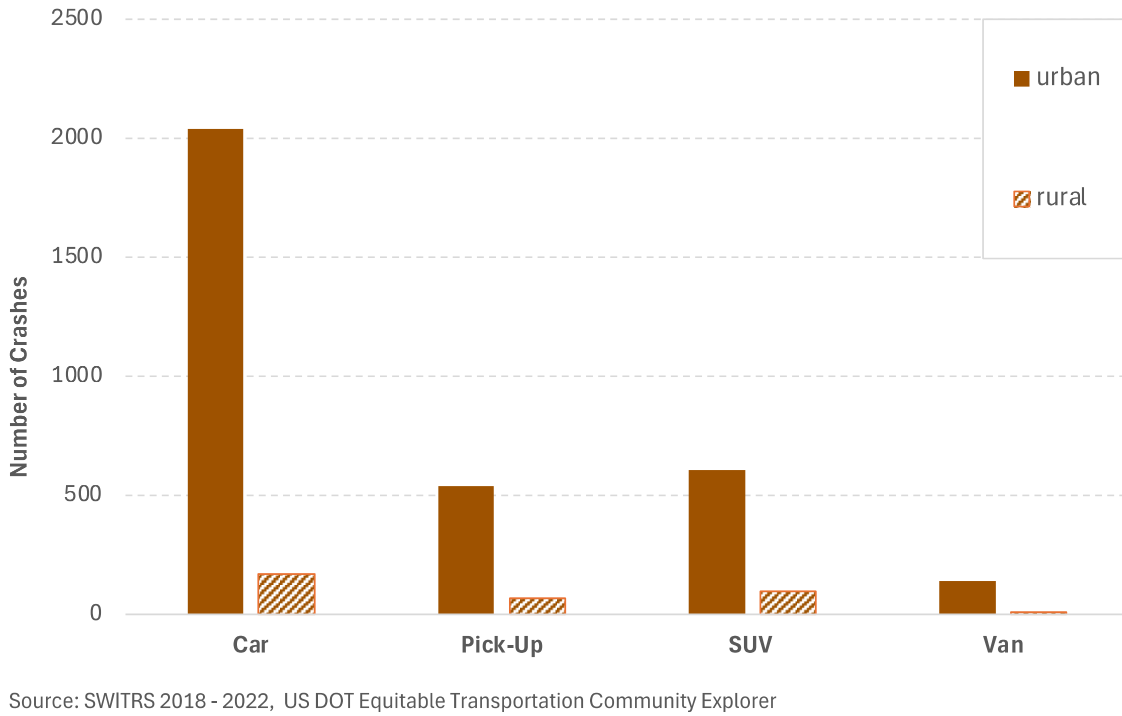


Figure 13. Number of bicyclist fatality or serious injury crashes by vehicle type and urban-rural classification

The trend was the same for bicyclist FSI crashes (see Figure 13). Car-involved vehicle crashes in urban areas made up the top category.

Given that 94 percent of California's population lives in urban areas, we would expect the number of crashes to be substantially greater in these areas. To better understand how urban-rural crashes may differ with respect to vehicle type, we adjusted for population differences in California by calculating pedestrian and bicyclist FSI crashes per capita by urban-rural and vehicle type (see Tables 1 and 2).

Table 1. Pedestrian fatal and serious injury crashes per capita (adjusted by 100,000 population), urban-rural by vehicle type (2018 – 2022)

Vehicle Type	Urban	Rural
Car	22.09	15.99
SUV	6.19	6.95
Pickup	5.12	8.28
Van	1.32	1.22

Table 2. Bicyclist fatal and serious injury crashes per capita (adjusted by 100,000 population), urban-rural by vehicle type (2018 – 2022)

Vehicle Type	Urban	Rural
Car	6.43	4.81
SUV	1.68	1.97
Pickup	1.49	2.72
Van	0.38	0.29

On an adjusted per capita basis, pedestrian FSI crashes involving a car in urban areas remain at the top with 22.09 FSI crashes per 100,000 population. For urban crashes, this is followed by SUVs, pickups, and vans, respectively. This indicates that when there is a pedestrian fatality or serious injury crash in either an urban or rural area, even after adjusting for population differences, passenger cars are much more likely to be the vehicle involved than other vehicle types (see Table 1). This is likely driven by several factors, including: 1) more passenger cars on the road compared to other vehicle types, 2) a greater likelihood of vulnerable road user and vehicle interactions in urban areas due to a higher proportion of California residents residing in urban areas than rural areas.

We also examined the differences in urban-rural FSI crashes by vehicle type. Here we see substantial differences across vehicle types. First, we examined pedestrian FSI crashes. For sedans, pedestrian FSI crashes were nearly 40% more common per capita in urban areas compared to rural areas. Conversely, pedestrian FSI crashes were around 10% and 40% less likely to occur in urban areas per capita than rural areas for SUVs and pickup trucks. We see the same relative differences between urban-rural and vehicle type for bicyclist FSI crashes (see Table 2).

These findings show that across all vehicle types, the absolute number of vulnerable road user fatalities and serious injury crashes is greater in urban areas than rural ones. However, when adjusting for population differences, we see that SUVs and pickup truck FSI crashes are skewed slightly towards rural areas and car FSI crashes are heavily skewed towards urban areas. This finding is generally consistent with our analysis of vehicle registrations by body class, which found that sedans are more common in urban areas than other body classes, and pickups are more commonly registered in rural areas than urban areas.

2.4 Crashes in Disadvantaged Areas by Vehicle Type

Disadvantaged communities in the United States are disproportionally affected by traffic fatalities (Federal Highway Administration, 2024a). Systemic disparities and inequalities, including historical underinvestment in roadway design and safety systems, have led to disadvantaged communities being disproportionally represented in fatal traffic crashes, specifically vulnerable road users. This chapter explores potential relationships between vehicle type and pedestrian and bicyclist deaths in disadvantaged census tracts across California.

We defined disadvantaged census tracts based on the binary disadvantaged flag in the ETC Explorer (U.S. Department of Transportation, 2024b). A community is designated as disadvantaged if its 'final index score' falls above the 65th percentile when compared to other census tracts. The final index score is calculated based on five subcomponents scores that include variables related to transportation insecurity, health, hazard and social vulnerability, and overall environmental burden (See Methods section for more information, U.S. Department of Transportation, 2024a).

A similar analysis was performed for the disadvantaged communities as for the urban-rural analysis in section 2.2 with crash data from SWITRS restricted to the 2018 to 2022 period and the Justice 40 population variable used to calculate per capita rates. Vehicle type was limited to large vehicles and passenger cars as in section 2.2.

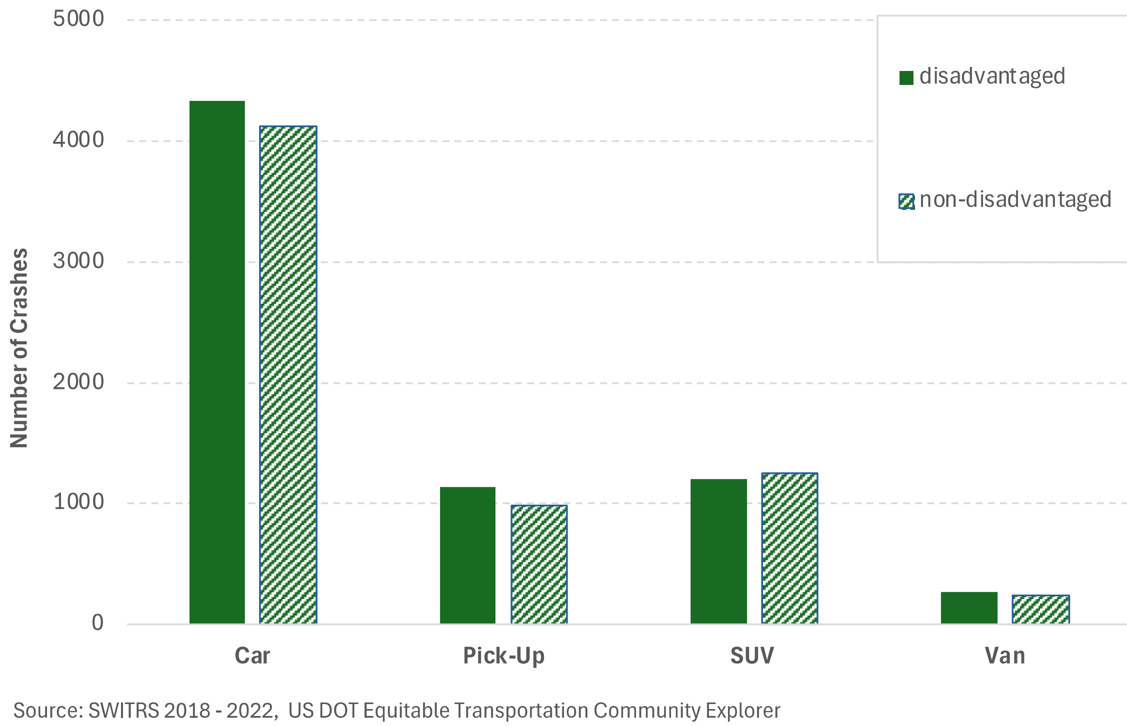


Figure 14. Number of pedestrian fatality or serious injury crashes by vehicle type and disadvantaged community classification, 2018 – 2022

Across all vehicle types, the number of pedestrian FSI crashes in disadvantaged and non-disadvantaged areas was almost equal, with slightly more car, pickup, and van related crashes occurring in disadvantaged census tracts and slightly more SUV related crashes occurring in non-disadvantaged ones.

However, given that only about one-third of California's population lives in a census tract that is designated as disadvantaged, the proportion of pedestrian crashes occurring in disadvantaged areas on a per capita basis is much higher in those areas across all vehicle types when compared to non-disadvantaged areas.

Table 3. Pedestrian fatal and serious injury crashes per capita (adjusted per 100,000 population) in disadvantaged and non-disadvantaged areas by vehicle type (2018 – 2022)

Vehicle Type	Disadvantaged	Non-Disadvantaged
Car	31.68	16.08
SUV	8.82	4.87
Pick Up	5.12	3.82
Van	1.32	0.93

Pedestrian FSI crashes per capita (adjusted per 100,000 population) occurring in disadvantaged areas that involved cars had the highest per capita rate across all vehicle types followed by SUVs, pickups, and vans. In fact, there were almost twice as many sedan-involved pedestrian FSI crashes per capita in disadvantaged areas compared to non-disadvantaged areas. When looking at all vehicles types, pickups had the highest disadvantaged to non-disadvantaged ratio of 2.18:1, while SUV had the lowest with 1.81:1. While higher rates in disadvantaged areas may be attributed to factors related to historic underinvestment in traffic safety, the difference in rates between SUVs and pickups may be due to specific types of vehicles present in disadvantaged communities versus non-disadvantaged ones and the types of crashes occurring in these areas.

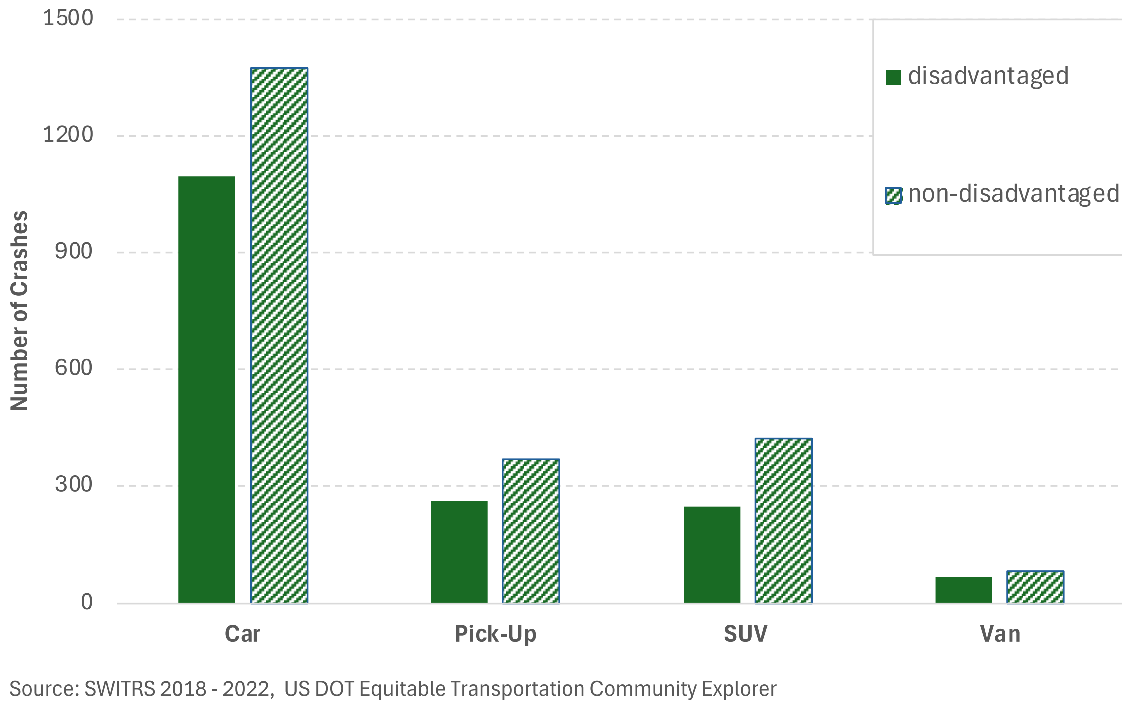


Figure 15. Number of bicyclist fatality or serious injury crashes by vehicle type and disadvantaged community classification, 2018 – 2022

The trend for bicyclist FSI crashes in disadvantaged and non-disadvantaged census tracts was different than that of pedestrians. Non-disadvantaged communities experienced more bicyclist FSI crashes across all vehicle types, with car-involved crashes making up the largest group, followed by SUVs, pickups, and vans.

Table 4. Bicyclist Fatal and Serious Injury Crashes Per Capita (Adjusted per 100,000 Population) in Disadvantaged and Non-Disadvantaged Areas by Vehicle Type (2018 – 2022)

Vehicle Type	Disadvantaged	Non-Disadvantaged
Car	8.02	5.35
SUV	1.82	1.64
Pickup	1.91	1.43
Van	0.49	0.32

On a per capita basis, trends were similar to that of pedestrian FSI crashes in disadvantaged areas, with bicyclist crashes involving cars making up the first group, followed by pickups, SUVs and vans. This trend was the same in non-disadvantaged areas. When comparing bicyclist FSI crashes in disadvantaged and non-disadvantaged areas, vans have the highest disadvantaged to non-disadvantaged crashes per capita ratio with a value of 1.55:1. They were closely followed by car-involved crashes that had a 1.5:1 ratio, pickups (1.33:1) and SUVs (1.11:1).

Disadvantaged communities experienced higher pedestrian FSI crashes on both a count and per capita basis. For per capita rates, pedestrian FSI crashes occur at approximately twice the rate in disadvantaged areas than they do in non-disadvantaged ones. For bicyclists, more crashes occurred in non-disadvantaged areas, but on a per capita basis bicyclist crashes still occurred at approximately 1.5 times the rate in disadvantaged communities and they did in non-disadvantaged ones.

2.5 Vulnerable Road User Crashes and Vehicle Type

Given that vulnerable road users are potentially at increased risk of injury in a collision with a larger vehicle due to both the weight differential and vehicle design, we explored whether a shift over time is detectable in the vehicle type striking pedestrians and bicyclists. We collected data from SWITRS on all crashes that resulted in at least one pedestrian or bicyclist fatality or serious injury over the 2010 to 2022 period. (We exclude data prior to 2010 as the vehicle variable in SWITRS was missing in more than five percent of records.) We limited our analysis to crashes with only two parties (a vulnerable road user and a vehicle), as it was unclear which vehicle struck the vulnerable road user in multi-party crashes. (This excluded less than 10 percent of pedestrian-involved crashes and less than 3 percent of bicyclist-involved crashes.) In each crash, we determined what vehicle was involved using CHP vehicle codes.

2.5.1 Crashes resulting in a pedestrian fatality or serious injury by vehicle type

The number of pedestrian FSI crashes involving both large vehicles and passenger cars increased substantially from 2010 to 2022. There were 1,723 pedestrian FSI crashes involving a passenger car, up 83 percent from 2010, and 1,079 crashes involving a large vehicle, up 68 percent compared to 2010 (see Figure 16). The proportion of pedestrian FSI crashes that involved a passenger car vs. a large vehicle over the 2010 to 2022 period shifted from 1.43 to 1.56 car crashes to every 1 large-vehicle crash.

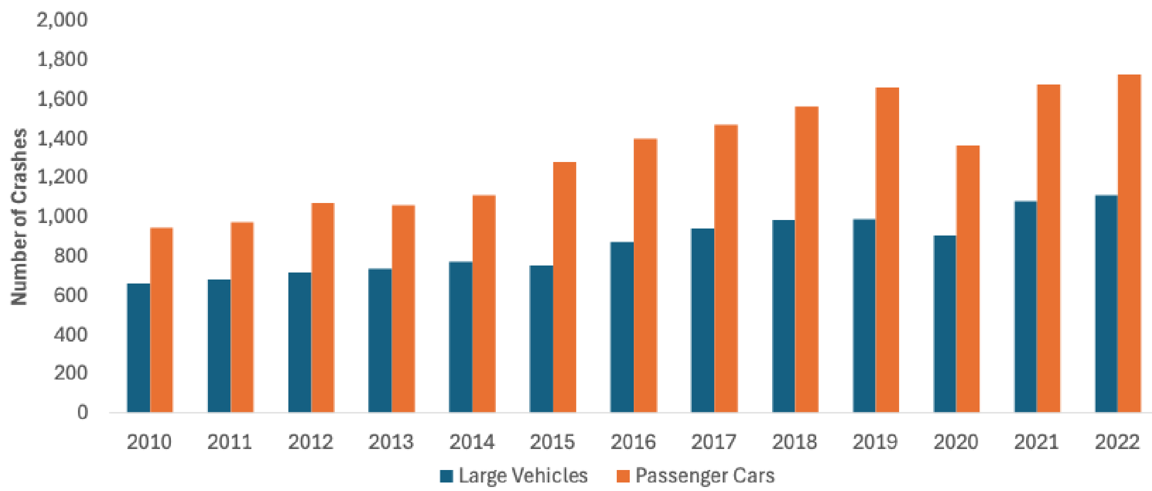


Figure 16. Number of pedestrian fatality or serious injury crashes by vehicle type, 2010 - 2022

To better understand the trend in large-vehicle crashes, we disaggregated the large vehicle data and calculated how the number of pedestrian FSI crashes changed over time by vehicle type, indexed to 2010 (see Figure 17). We found that the rate of change in the number crashes was different for each large vehicle type. Notably, SUV crashes resulting in a pedestrian FSI are growing at the fastest rate of all vehicle types, including passenger cars. Compared to 2010, there are twice as many (197 percent) SUV-involved pedestrian FSI crashes. During the same period, car-involved pedestrian crashes grew 1.8 times (184 percent), pickup-involved crashes grew 1.6 times (158 percent), and van-involved crashes decreased by 10 percent (90 percent).

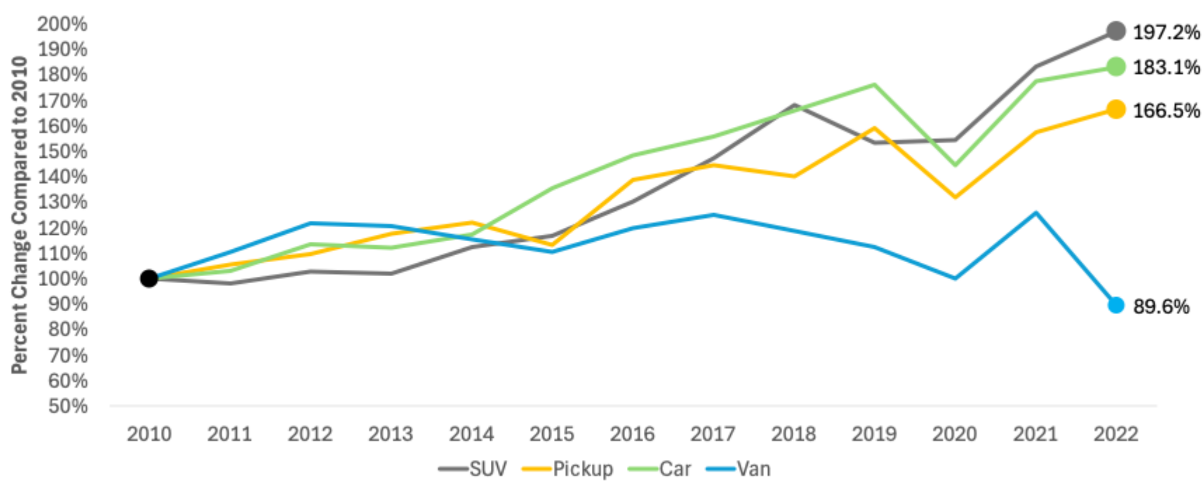


Figure 17. Disaggregated change in number of pedestrian fatality or serious injury crashes by vehicle type compared to an index year of 2010, 2010 - 2022

2.5.2 Crashes resulting in a bicyclist fatality or serious injury by vehicle type

Bicycle FS crashes with large vehicles and passenger cars also increased substantially from 2010 to 2022: an increase from 343 to 589 passenger car crashes (72 percent) and an increase from 228 to 345 large-vehicle crashes (51 percent). Again, we observe that the number of passenger car crashes resulting in a bicyclist fatality or serious injury is growing faster than crashes involving large vehicles (see Figure 18). Notably, the number of crashes is growing for all vehicle types over the 2010-2022 period. Pedestrian and bicyclist crash trends do differ over the 2019 to 2022 period, with the number of passenger car-related crashes shifting more dramatically compared to large-vehicle crashes. In addition, bicyclist crashes decreased in 2020 and 2021, whereas pedestrian crashes decreased only in 2020. For bicyclist FSI crashes in particular, the number of large-vehicle crashes showed less variability than passenger car crashes during this period.

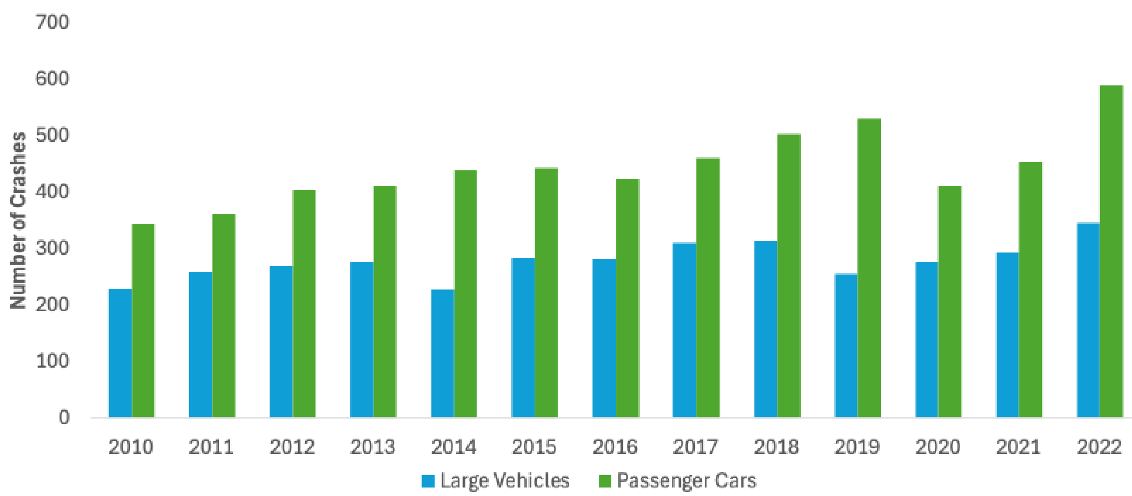


Figure 18. Number of bicyclist fatality or serious injury crashes by vehicle type, 2010 - 2022

We disaggregated vehicle type and compared how the number of bicyclist crashes shifted over the 2010 to 2022 period by vehicle type. A similar pattern was observed for bicyclist crashes as for pedestrian crashes, with SUV-involved crashes growing at the fastest rate of all vehicle types (tied with cars) (see Figure 19).

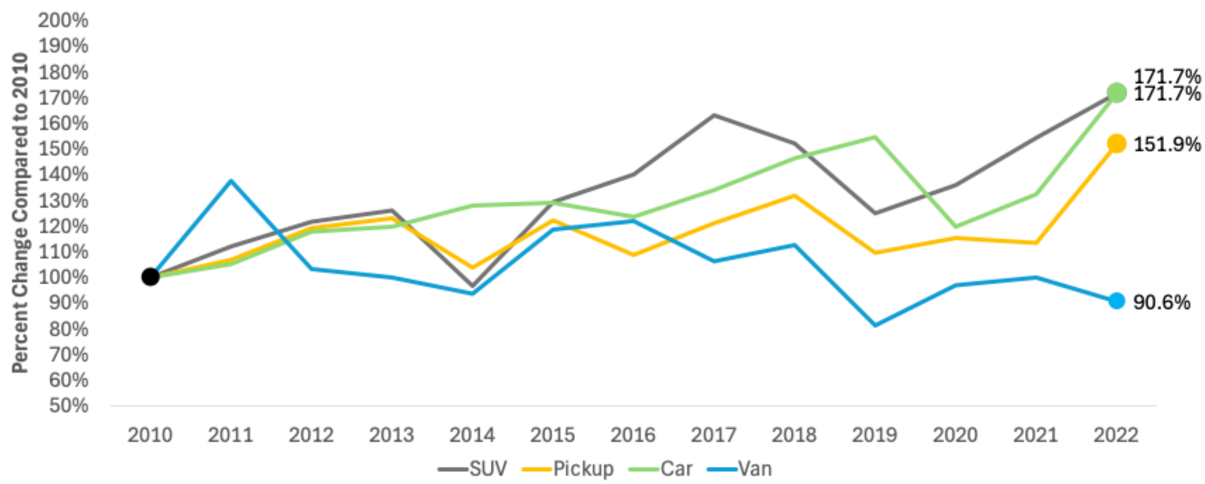


Figure 19. Disaggregated change in number of bicyclist fatalities or serious injuries by vehicle type indexed to 2010, 2010 - 2022

This analysis showing that pedestrian FSI crashes with SUVs are increasing at a faster rate than pedestrian FSI crashes with other vehicle types may indicate that the former will eventually outnumber the latter. We see similar results with bicyclist crashes. When it comes to changes in the number of vulnerable road user crashes over time, all large vehicles are not the same. The number of vulnerable road user crashes involving a SUVs is growing faster than the number involving vans or pickup trucks and, in the case of pedestrian crashes, faster than passenger cars as well. When it comes to absolute number of crashes, however, for both pedestrians and bicyclist crashes, passenger cars are still the primary vehicle involved. The number of vulnerable road user crashes involving a van has decreased; this occurred during a time when van registrations also decreased.

There is reason to believe that SUV-share of vulnerable road user FSI crashes will continue to increase. SUVs are on pace to continue to replace passenger cars in the vehicle fleet. Pickup trucks and SUVs are potentially more harmful in a crash to vulnerable road users due to their form factor and weight, making such crashes more likely to result in a fatality or severe injury (Mayrose & Jehle, 2002a; White, 2004).

2.6 Crash Type and Vehicle Type

To better understand if there is evidence that the type of crash differs by vehicle type for vulnerable road users, we analyzed the type of crash recorded for fatal and serious injuries in California involving a vehicle and bicyclist over the 2010 to 2023 period. Figure 20shows the results of this analysis, averaged over a five-year period (2018 to 2022) to minimize year-to-year variance. (Note: this analysis is only possible for bicyclists as the crash type variable in SWITRS includes a separate “pedestrian-vehicle” value that is used for all pedestrian crashes.)

Firstly, regardless of vehicle type, the dominant crash type resulting in a bicyclist fatality or serious injury is a broadside crash, accounting for over 40% of fatal or serious injury crashes regardless of vehicle type involved.

Broadside crashes typically occur at intersections when either the vehicle or cyclist is turning, or when both are going straight at perpendicular trajectories, resulting in a T-bone type crash. Rear-end, sideswipe (when the bicyclist and vehicle collide on their side, traveling in either direction), and head-on crashes were the next most common with the order depending on the vehicle type.

Secondly, we observe differences in the share of fatal or serious injuries by crash type for each vehicle type. Notably, broadside FSI crashes were more common for pickup trucks and SUVs than cars, and sideswipe FSI crashes were substantially more common for pickups than for SUVs and cars. These findings corroborate the analysis in the empirical literature that large vehicles are more likely to hit vulnerable road users when turning at intersections (broadside) and when the vulnerable road user is next to the road edge (sideswipe) (Hu & Cicchino, 2022). In general, these findings are aligned with the theory that vulnerable road users are more difficult to see for drivers of large vehicles vs. cars, due to larger blind spots (Epstein et al., 2016; The Canadian Association of Road Safety Professionals (CARSP), 2024). Conversely, we see that cars are more likely to have rear end or head-on FSI crashes with bicyclists, both of which are less likely to be affected by visibility issues. Broadside impacts are also more likely to be affected by the blunt, higher front ends of the larger vehicles, which increase the likelihood of knocking down the rider and running them over (IIHS, 2023a).

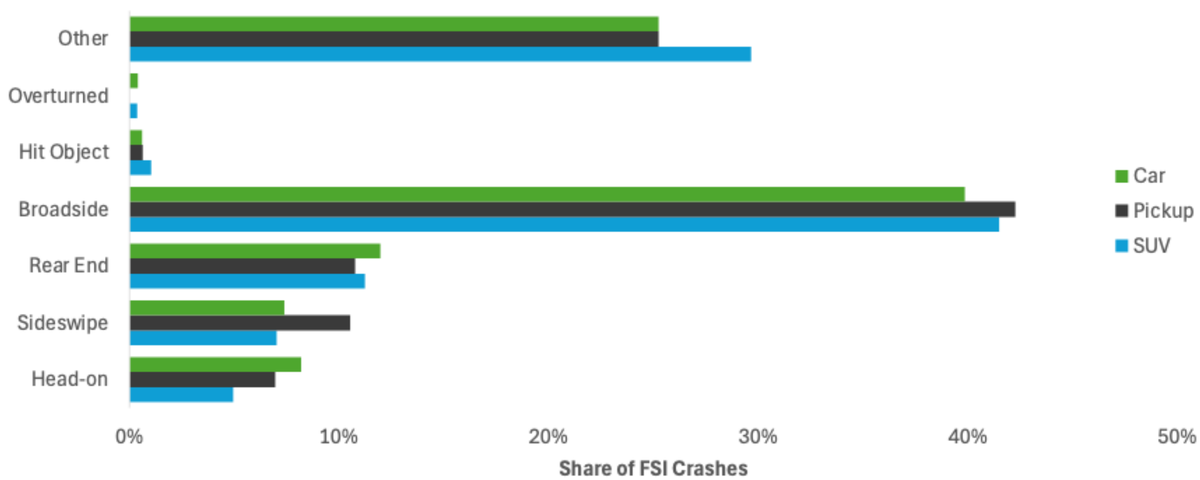


Figure 20. Share of bicyclist fatal and serious injury crashes by type of crash and vehicle type, 2018 - 2022

We also examined whether the share of bicyclist FSI crashes has shifted over time by vehicle type (see Figure 21 and Figure 22). While the year-to-year data exhibit considerable statistical noise, there are clear upward trends in the share of FSI crashes that were rear-end and head-on type. These trends were observed for all vehicle types. However, during this period, crashes coded as “other” also declined, which could point to the possibility that the increases observed are due to improved classification of crash type in the crash reports over time. That said, not all crash types increased over this period, for example broadside crashes stayed relatively constant at around 40 percent for all vehicle types, so the changes observed may not be entirely explained by improved classification from “other” to more explicit crash types.

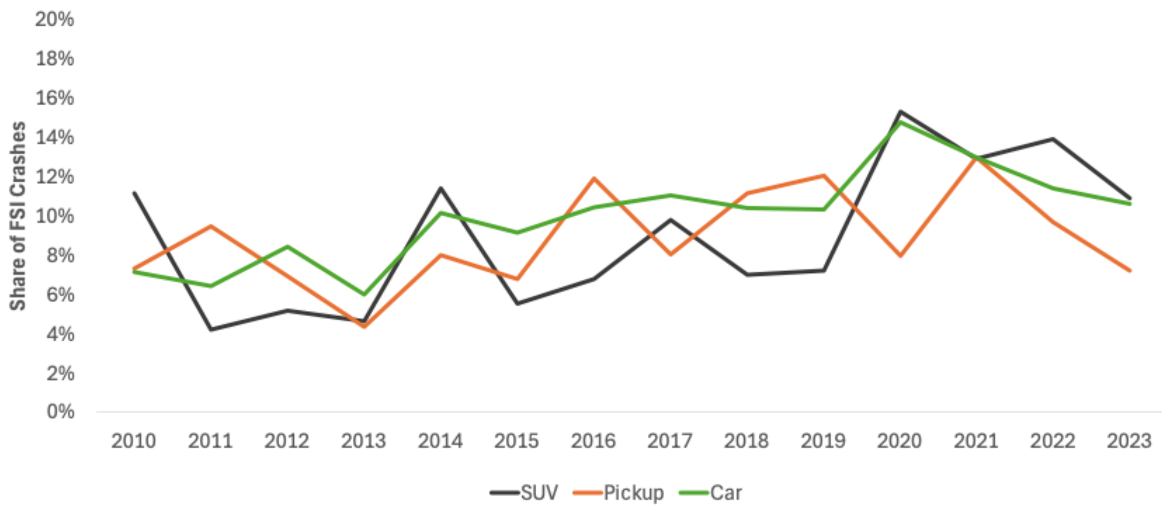


Figure 21. Share of pedestrian fatal and serious injury rear end crashes by vehicle type, 2010 - 2022

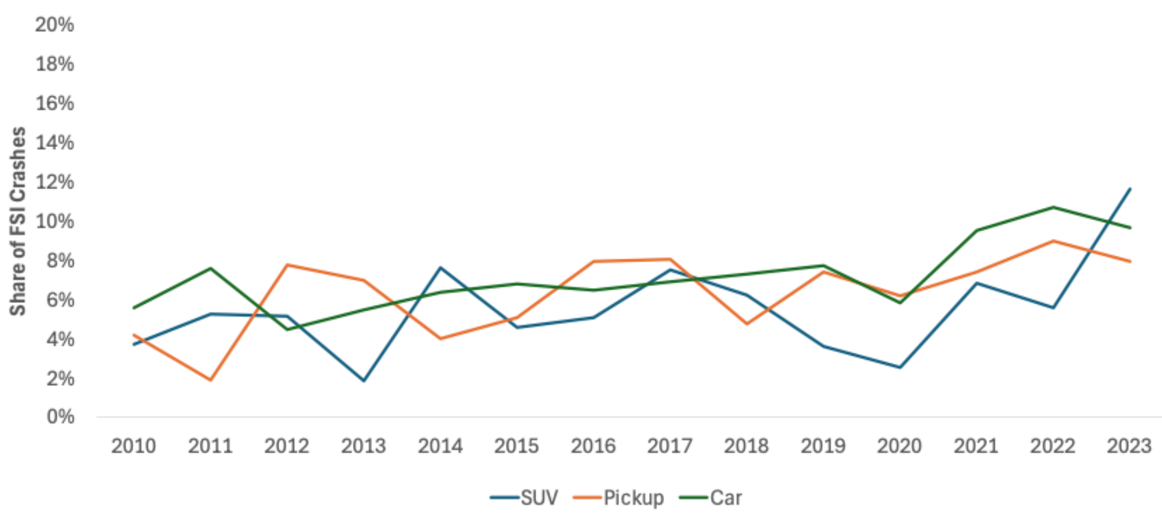


Figure 22. Share of bicyclist fatal and serious injury head-on crashes by vehicle type, 2010 - 2022

2.7 Pedestrian Action Prior to Crash and Vehicle Type

We find some differences in the types of pedestrian crashes by vehicle type. For pedestrian crashes only, data is collected in crash reports that can shed light on where the victim was immediately preceding the crash. We examined these data for over 10,000 crashes that resulted in a pedestrian fatality or serious injury between 2018 and 2022. For all vehicle types, the largest share (around 40 percent) of FSI crashes involved a pedestrian that was not in a crosswalk. Pedestrian FSI crashes with large vehicles—namely, pickup trucks (29 percent) and SUVs (27 percent)—were more likely than those with cars (23 percent) to involve pedestrians that were in the road (i.e., not in a crosswalk). This may be due to the rural vs. urban context of these crashes.

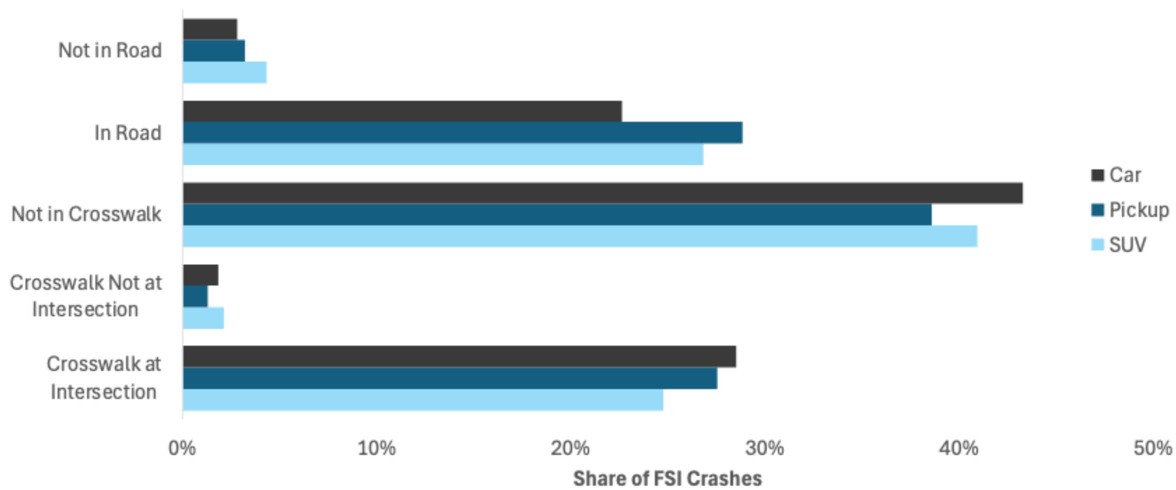


Figure 23. Pedestrian action preceding crash by vehicle type, 2018 - 2022

The share of on-road pedestrian fatalities and serious injuries has been increasing for all vehicle types over the past decade. Pedestrian fatalities and serious injury crashes involving SUVs and pickup trucks have consistently been more likely to occur on the road. This may be explained by differential activity by vehicle type in urban areas, as it is likely that on-road crashes are more common in non-urban areas where pickups and SUVs are comparably more common. However, it is notable that the share of on-road pedestrian crashes for passenger cars has also increased from 18% in 2010 to 23% in 2023.

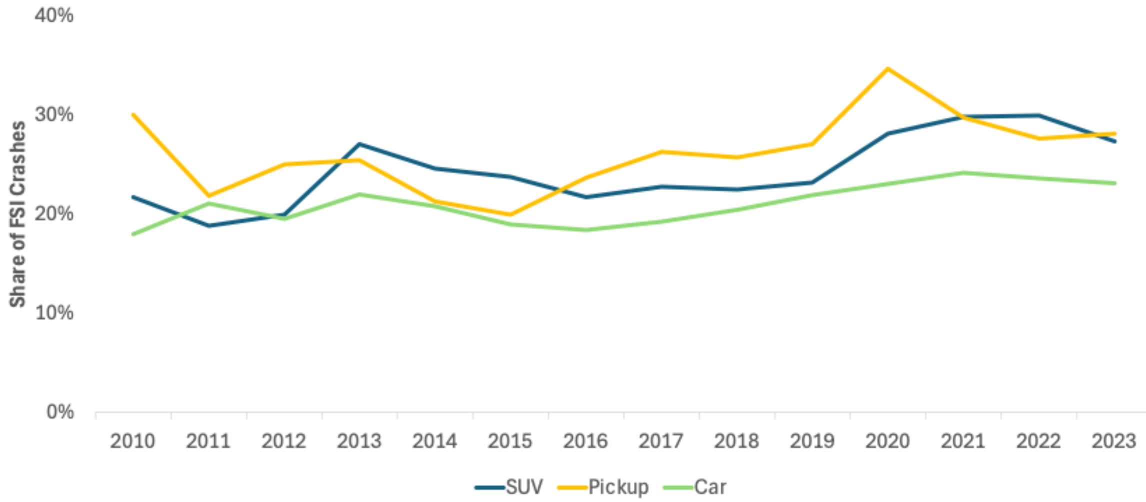


Figure 24. Share of pedestrian FSI crashes with pedestrian in road, 2018 - 2023

2.8 Unsafe Speed and Vehicle Type

In California, speed was the primary crash factor in 32 percent of fatalities in 2022, slightly higher than for the nation (29 percent) (NHTSA, 2023a). Speed-related crashes that resulted in a fatality or serious injury tended to be rear end collisions (36 percent), with a smaller share made up of hit object crashes (22.1 percent). To explore if unsafe speed is a more common factor for certain vehicle types, we calculated the share of pedestrian and bicyclist FSI crashes with unsafe speed as a factor by vehicle type.

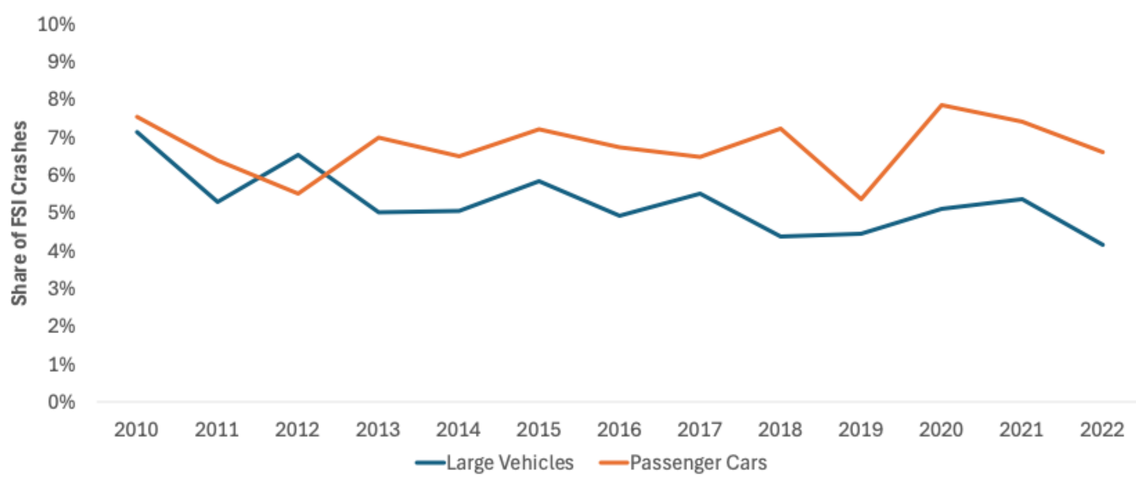


Figure 25. Share of pedestrian FSI crashes with unsafe speed by vehicle type, 2010 - 2022

For pedestrian FSI crashes, unsafe speed was a more common factor for passenger cars compared to large vehicles (see Figure 25). It is not clear from this analysis why this is the case. The share of pedestrian FSI crashes has also been relatively constant over the past decade, slightly increasing for passenger cars and decreasing for large vehicles. Conversely, for bicyclist FSI crashes, the share where unsafe speed was the primary factor has been both increasing over the past decade and relatively similar for large vehicle and passenger cars (see Figure 26).

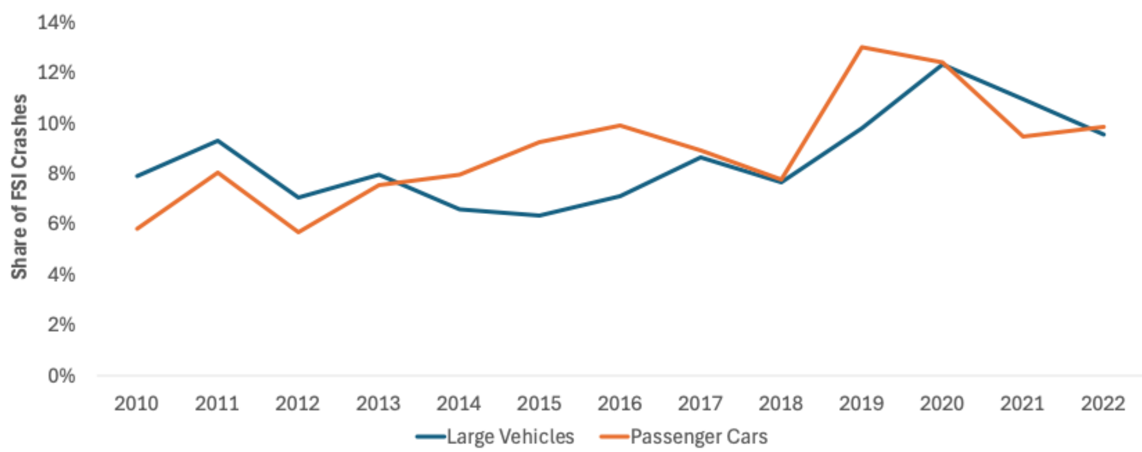


Figure 26. Share of Bicyclist FSI Crashes with Unsafe Speed by Vehicle Type, 2010 – 2022

2.9 Age and Vehicle Type

Empirical research has shown the larger vehicles with higher and more blunt front ends are more likely to seriously injure pedestrians and cyclists in a crash (Edwards & Leonard, 2022a; Epstein et al., 2016; IIHS, 2023a; Tyndall, 2021a, 2024a). Our trend analysis suggests that there is already evidence in California that the share of pedestrian FSI crashes is growing fastest for SUVs compared to other vehicle types. Due to reduced visibility from larger blind spots, SUVs and pickup trucks may be more likely to strike small children.(Adiel Kaplan, Jean Lee, Joe Enoch and Vicky Nguyen, 2022; *The Hidden Danger of Big Pickup Trucks*, 2024).

To investigate the possible relationship between age, crashes, and vehicle type, we examined all two-party crashes that resulted in a pedestrian or bicyclist FSI by vehicle type. We determined how many FSI crashes resulted in a vulnerable road user who was aged 14 years or younger and, separately, aged 65 years or older. We then calculated the share of crashes for each vehicle type that fell into each age group, averaging over a five-year period (2018 to 2022) due to year-to-year variation. We answer the question: of the crashes when an SUV, pickup truck, or car hit a vulnerable road user, what is the share that was a child aged 14 and under or an adult aged 65 and older.

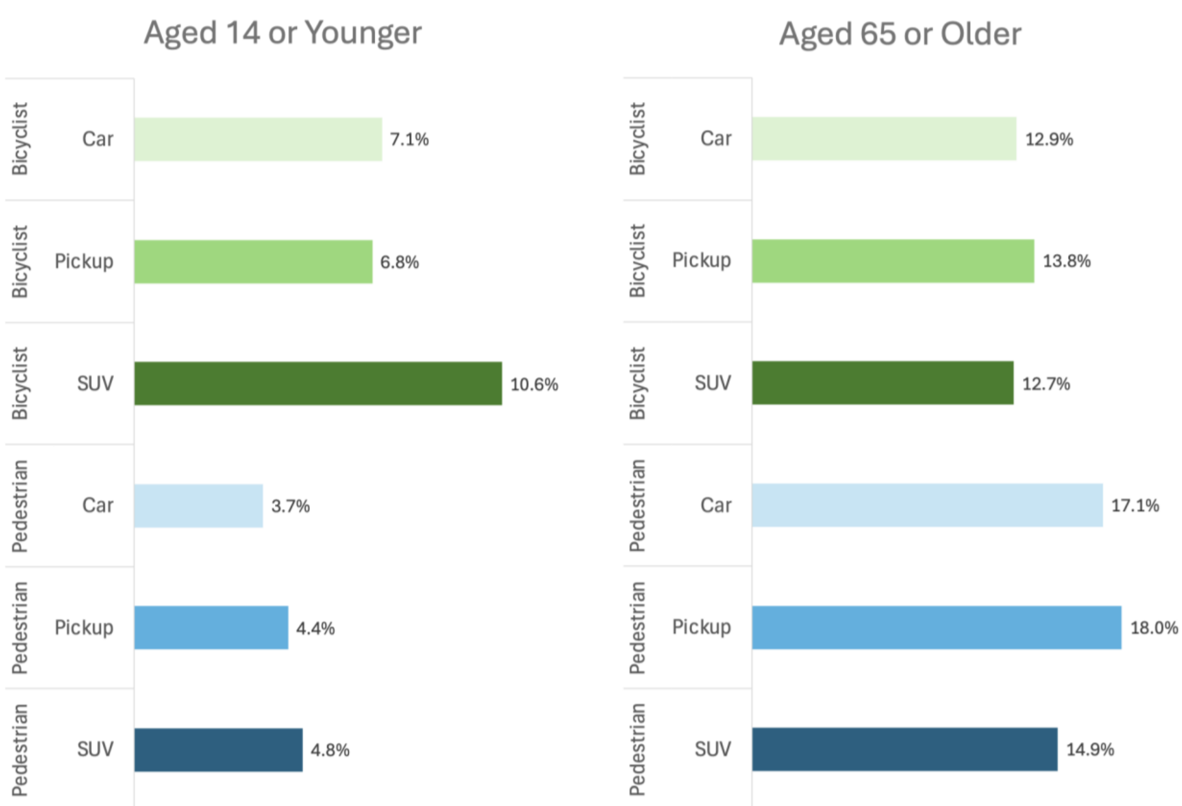


Figure 27. Share of fatal or serious injury vehicle type crashes that had a vulnerable road user victim aged 14 or younger and aged 65 or older, 2018-2022

A higher share of SUV and pickup FSI crashes than car FSI crashes involved victims aged 14 or younger (see Figure 27). Similarly, a higher share of SUV FSI crashes than pickup and car FSI crashes involved a victim aged 14 or younger.

Examining the 65 and older data, the share of pickup truck FSI crashes that involve an older vulnerable road user is higher than other vehicle types for both bicyclist FSI crashes and pedestrian FSI crashes. However, the differences between vehicle types is smaller for the older than for the younger age group. We conclude that based on trends observed in California, we do not see a consistent relationship between vehicle type and share of FSI crashes that involve older adults.

These results suggest that large vehicles may be disproportionately injuring younger people compared to cars; however, due to data availability it is not possible to adjust for differences in miles-traveled by vehicle type and location. In the case of younger victims, we might expect the share of car crashes involving a younger pedestrian or bicyclist to be higher than other vehicle types due to the higher representation of cars in urban areas where younger pedestrian and bicyclists are more common. However, we do not observe this in the crash data. This suggests that the observed values for larger vehicles are due to factors other than activity, potentially vehicle weight and visibly. We consider this to be area where further study is needed.

2.10 Sex and Vehicle Type

Over 70 percent of total traffic fatalities in the United States were male in 2023 (NHTSA, 2021). An even higher share of motorcycle fatalities (92%) and bicyclist fatalities (88%) were male in 2023; 71% of pedestrian fatalities in the U.S. were male (IIHS, 2025). Disparities in traffic fatalities by sex is an ongoing area of study, but several studies have attributed the differences—at least in part—to male risk seeking behavior and greater discounting of future concerns (Freeman et al., 2017; Gulliver & Begg, 2007). In the same crash scenario, however, women are more likely to be fatally or seriously injured due to crash dynamics, how vehicles are designed, and the ability of different body sizes to survive a crash (Abrams & Bass, 2024). Recognizing the importance of sex as a factor in traffic fatalities, we have expanded our analysis on vehicle type to include sex in order to highlight any potential relationship between vehicle type and sex.

For this analysis, we consider crashes where at least one male or female pedestrian (or bicyclist) was fatally or seriously injured in the crash. Additionally, we collapsed SUV, pickups, and vans into one large vehicle category for this analysis because of the small number of counts when splitting pedestrian and bicyclist crashes by vehicle type and sex.

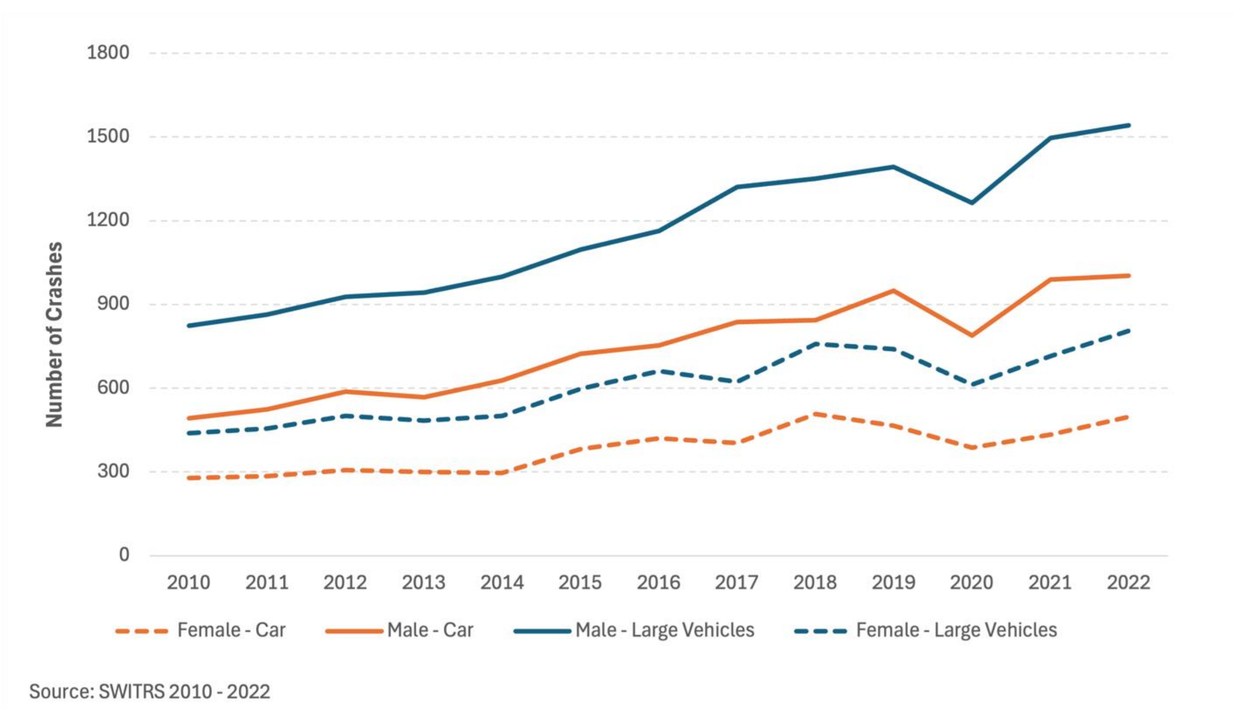
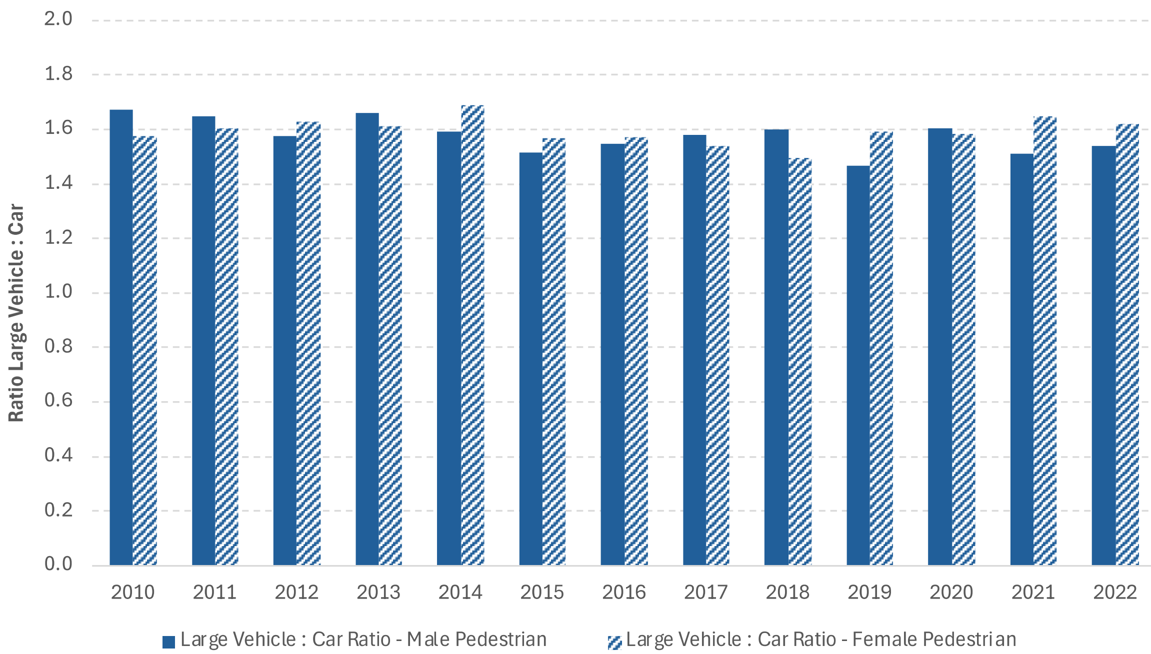


Figure 28. Share of fatal or serious injury pedestrian crashes by vehicle type and sex

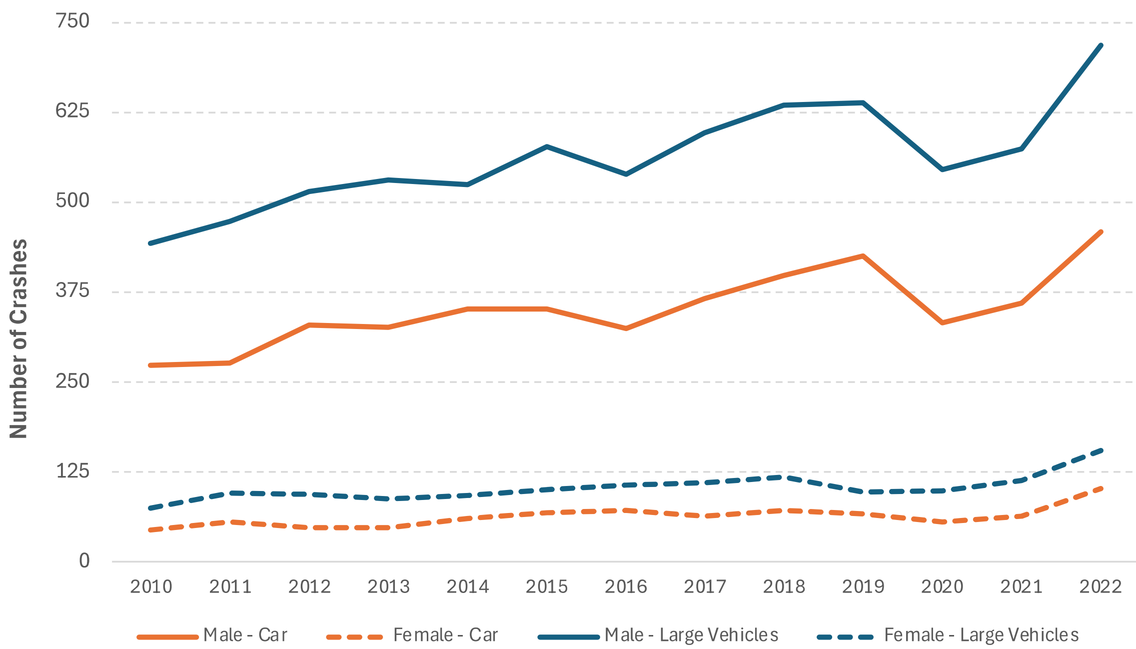
Across all vehicle types, both male and female pedestrian FSI crashes increased from 2010 to 2023, with a slight dip occurring in 2020 (see Figure 28). This dip is likely due to the effects of the COVID-19 pandemic and should be interpreted with caution. Male pedestrian FSI crashes involving large vehicles were the largest group followed by car crashes also involving male pedestrians. Female pedestrian FSI crashes involving large vehicles significantly outnumbered those involving cars from 2010 to 2023.



Source: SWITRS 2010 - 2022

Figure 29. Ratio of large vehicle to car crashes fatal or serious injury pedestrian crashes by sex

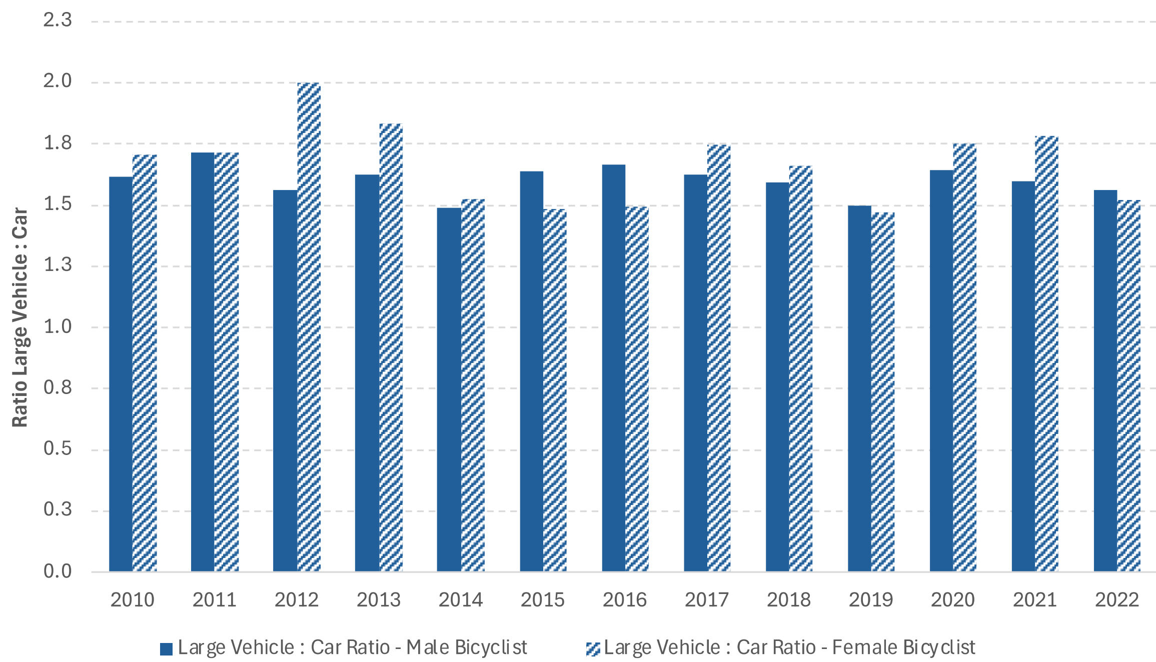
To analyze the gap between large vehicle and car crashes in male pedestrian FSI crashes (see Figure 29), we considered the large vehicle to car ratio over time. In these crashes, large vehicles outnumbered cars involved crashes somewhat consistently over time with an average ratio of 1.6:1. In female pedestrian FSI crashes, the ratio of large vehicles to cars was almost the same.



Source: SWITRS 2010 - 2022

Figure 30. Share of fatal or serious injury bicyclist crashes by vehicle type and sex

Bicyclist FSI crashes broken down by sex along a similar trend as pedestrian FSI crashes, with the exception of a dip in male involved pedestrian FSI crashes involving cars and large vehicles in 2016 (see Figure 30).



Source: SWITRS 2010 - 2022

Figure 31. Ratio of large vehicle to car crashes in fatal or serious injury bicyclist crashes by sex

Overall, the number of male pedestrians or bicyclists involved in car or large vehicle FSI crashes is much higher than those involving women, consistent with national statistics noted above that highlight disparities in traffic fatalities by sex. This trend has held true over the 12-year period, with both groups experiencing significant increases.

2.11 Challenges to Analysis and Opportunities

This analysis has potential limitations. Due to the scope and timeline, only descriptive analysis was conducted, meaning that no causal relationships were identified, and other factors may have a played a role in explaining some of the trends highlighted. Additional challenges occurred in relation to the crash data used. These included inconsistent vehicle type coding in SWITRS over time. This resulted in the exclusion of certain vehicles and our analysis period starting in 2010 for breakdowns by vehicle type. Additional challenges include the granularity of SWITRS reporting, specifically: the lack of victim race and ethnicity data and no estimated speed for cars at the time of impact. As a result, the race and ethnicity of victims is excluded from this report and speeding was only determined based on the primary crash factor violation (the law code that was violated and was the primary cause of the crash) associated with the crash instead of an estimated speed. The organizational structure of SWITRS also made it difficult to determine which vehicle struck the pedestrian or bicyclist. As a result, most analyses throughout the report are limited to two party crashes, meaning one party was the vulnerable road user and the other the motor vehicle.

Chapter 3. Trends in Vehicle Weight, Size, and Height

By: Matthew Raifman, Jon Atkins, Celia Johnson, Michael Anderson, and Julia Griswold

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. The history of fuel economy regulation and its impact on vehicle size provides a context on the evolution of larger vehicles in the U.S. and suggests that regulatory signals and vehicle taxes—even when indirectly related to weight—impact vehicle design and consumer preferences (see Figure 32).

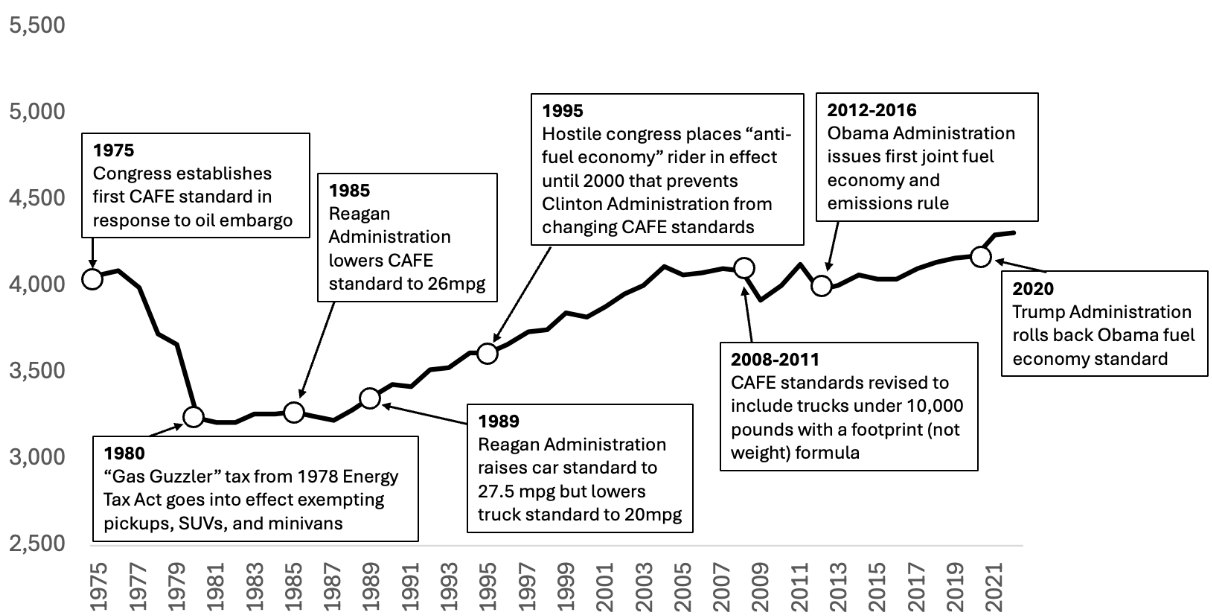


Figure 32.Average Curb Weight of U.S. Vehicle Sales by Model Year (Data: USEPA)

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

[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.

initially responded with reductions in weight and power, resulting in an approximately 25 percent decrease in average vehicle curb weight over five years (Bento et al., 2017; Klier & Linn, 2012). 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 different treatment of vehicle types 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 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 15.8 mpg for 4WD trucks and 17.2 mpg for 2WD trucks—similar to the 19.0 mpg standard for passenger vehicles (NHTSA, 2024a). By 1985, however, the standard was much less strict for trucks (19.5 combined 4WD and 2WD) than for passenger vehicles (27.5 mpg).

The Gas Guzzler Tax, implemented in 1980, further instituted different treatment of passenger vehicles than of 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 (US EPA, 2017). 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" (US EPA, 2017). 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 (Klier & Linn, 2016). 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 (Pew Charitable Trusts, 2011). 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 (Beitsch, 2020).

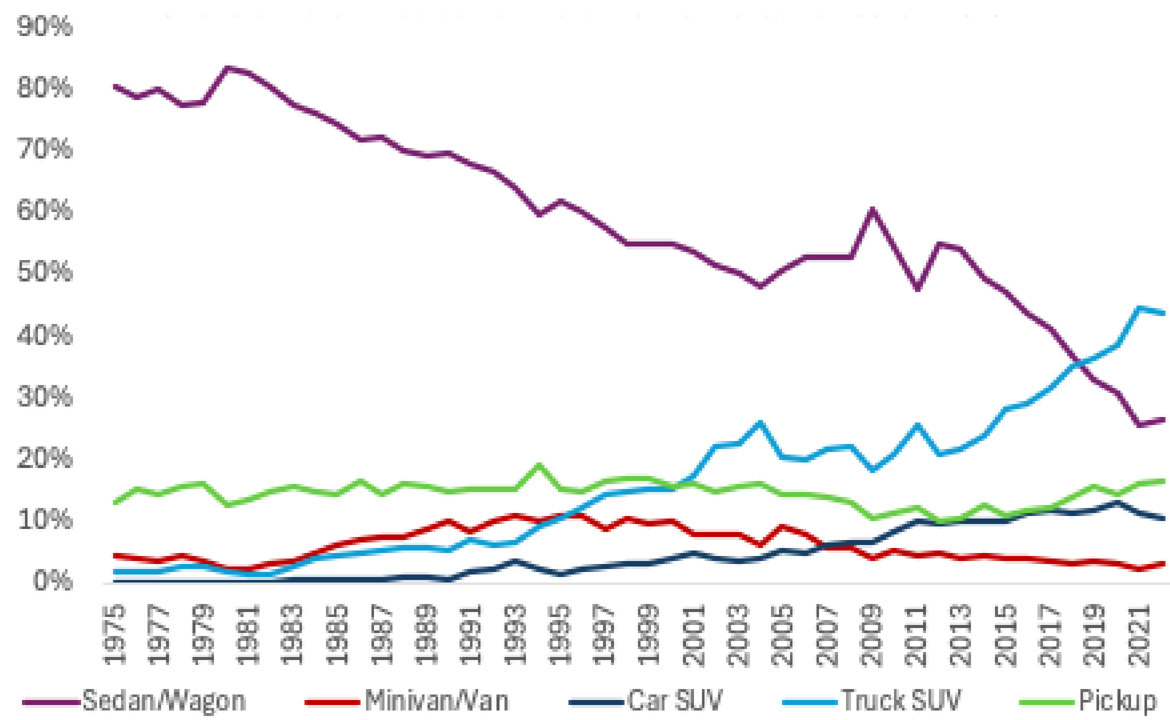


Figure 33. Share of total production volume delivered for sale in the U.S (Data: USEPA)

The composition of the American vehicle fleet also shifted towards larger vehicles over the past 50 years (Figure 33). 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) (US EPA, 2024). 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 (Brown, 2004). 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”(“Light Trucks in Auto Sales Data,” 1984). These vehicles were larger, safer for their occupants, and more comfortable to travel in than traditional passenger vehicles. 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).

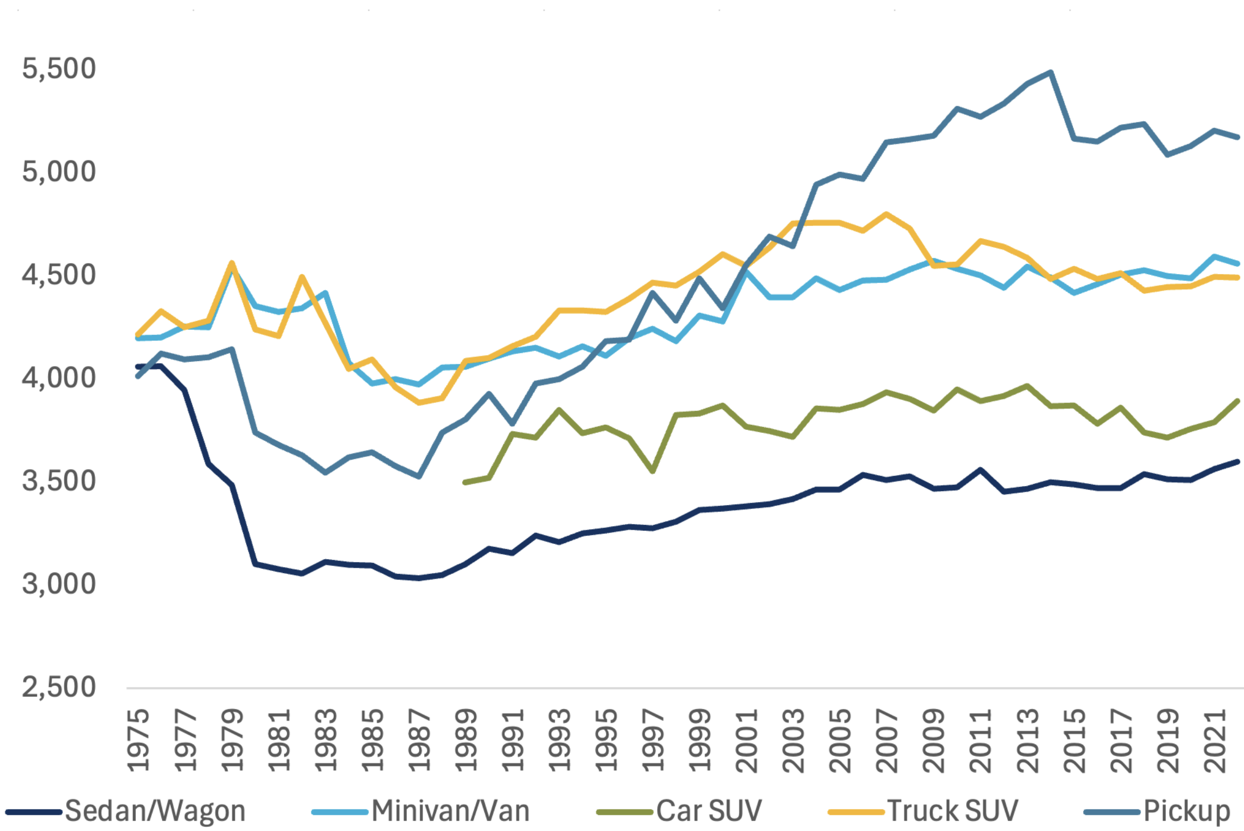


Figure 34. Average Curb Weight of U.S. Vehicle Sales by Vehicle Type (Data: USEPA)

Not only did the American fleet transition to larger vehicles, but these vehicle classes grew in size over the past 35 years (see Figure 34). 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 the U.S., 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 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.

3.2.1 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 (Teoalida, 2020) 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 (NHTSA, 2024d) 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 (*California County Caucuses*, 2015). We then used the county registration field available in the registration data provided by the 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 analyzed the entire California registered fleet across the 2010 to 2023 time period.

3.2.2 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 (U.S. Census, 2024). 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 35. 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 primarily consisted 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 the 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"(*Commercial Vehicle Registration*, 2024).

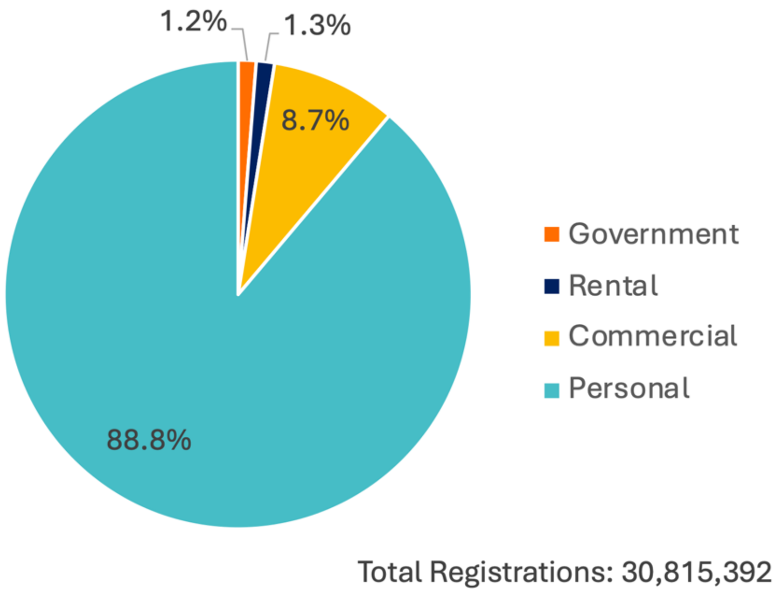


Figure 36. Distribution of California Vehicle Registrations by Ownership Type, 2023

3.2.3 Vehicles Registrations by Year by Vehicle Type

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

In Figure 37, 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 SUVs has increased concurrently, from 19.6 percent in 2010 to 32.5 percent in 2023. The pickup truck share has grown more modestly from 14.5 percent in 2010 to 14.9 percent in 2023, while the 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.

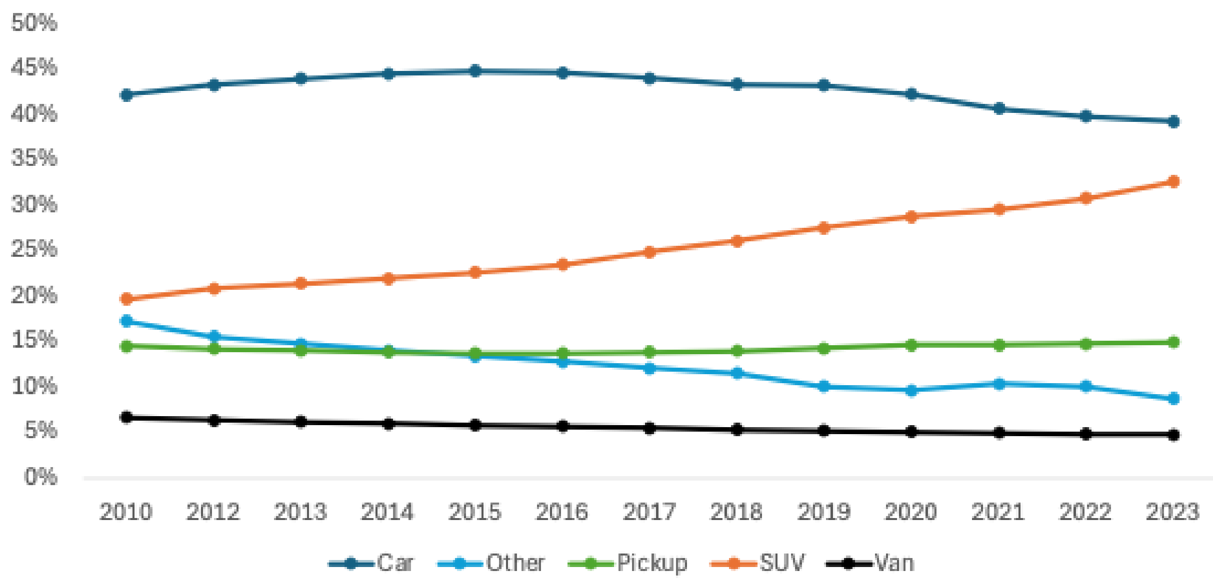


Figure 37. California Vehicle Registrations by Year and Vehicle Type

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

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 popular 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).

3.2.4 Vehicles Registrations by Urbanicity and by Vehicle Type

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 39).

Pickup trucks account for approximately twice the share of vehicle registrations in rural counties than in 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.

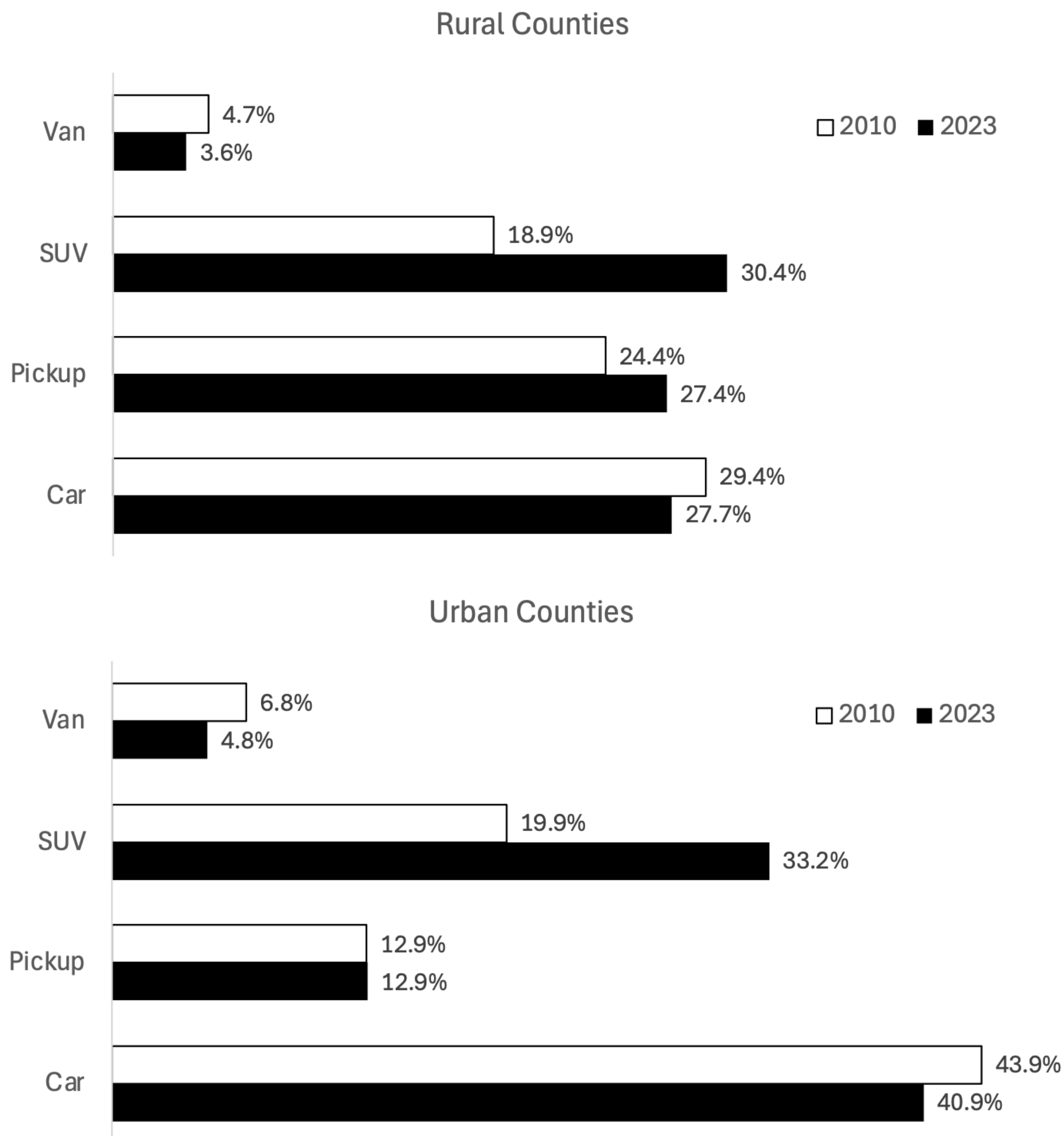


Figure 39. Distribution of Registered Vehicle Types by Urbanicity of County and Year

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 urban and rural registrations that are cars has declined by roughly three percentage points from 2010 to 2023. Similarly, urban and rural counties have also seen a dramatic shift in SUV registrations.

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 by roughly 50 percent in both county types—to 30.4 percent of 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 shown in Figure 39, 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.

3.2.5 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 40). 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 than pickups, SUVs are 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.

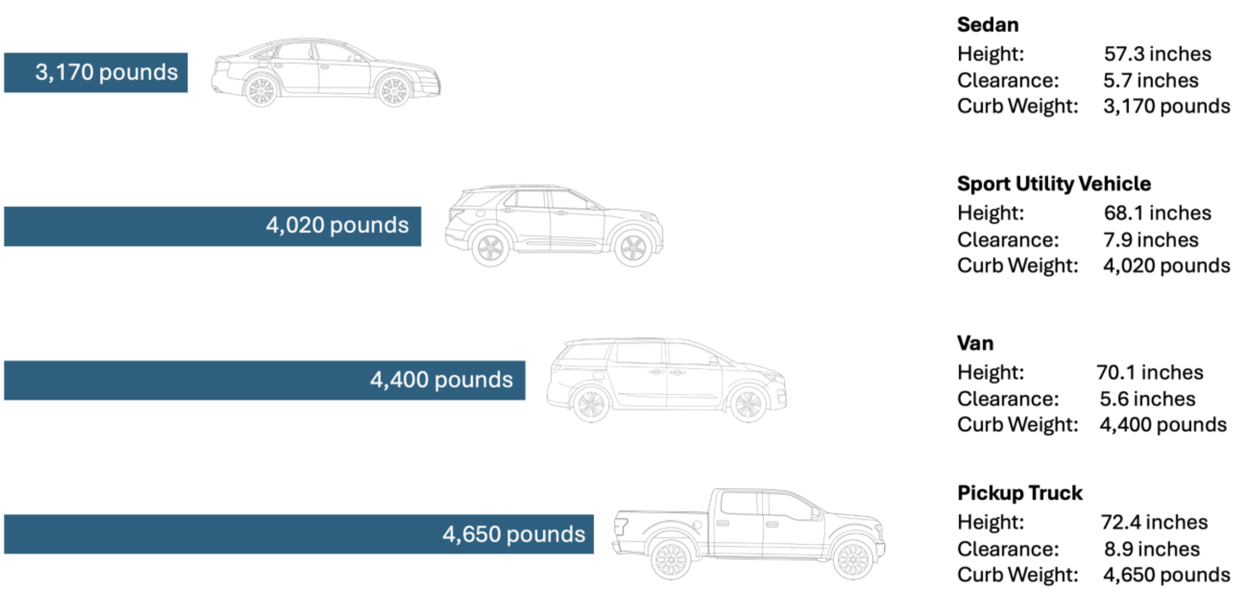


Figure 40. Average height, ground clearance, and curb weight by vehicle type in 2023 for the California vehicle fleet

These vehicle attributes matter for road safety. 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 (Crocetta et al., 2015; Edwards & Leonard, 2022b; IIHS, 2023b). 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 (Anderson & Auffhammer, 2014b). Heavier vehicles are also more likely to injure vulnerable road users in a crash (Bento et al., 2017; Mayrose & Jehle, 2002b; Tyndall, 2021a).

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. 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 41).

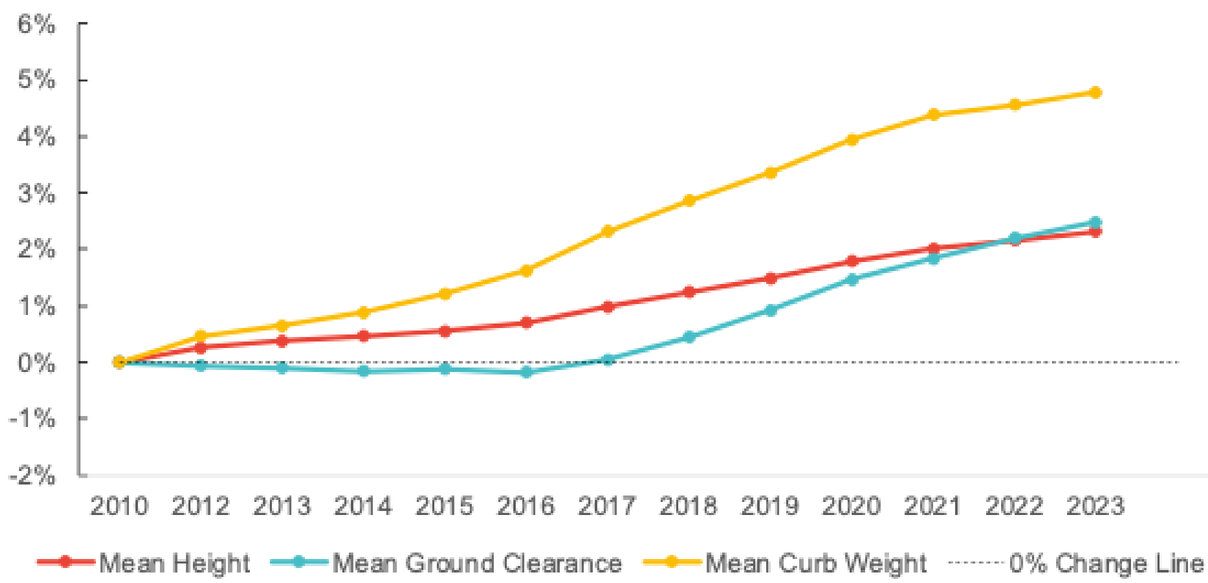


Figure 41. Change in Vehicle Size of the California Vehicle Fleet from 2010-2023

In Figure 42, 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, SUVs 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 38).

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 also increased in size over time, mainly in terms of curb weight. The curb weight of the Honda CR-V EX AWD trim, for example, increased 12.3 percent from 2000 to 2023 and the Toyota RAV4 base AWD model has increased roughly 19 percent in curb weight over the same period. The size difference between small and large SUVs is still present, though. A 2023 Toyota 4Runner is 6.4 percent taller, 26.7 percent heavier, and has 11.6 percent more ground clearance than a 2023 Toyota RAV4.

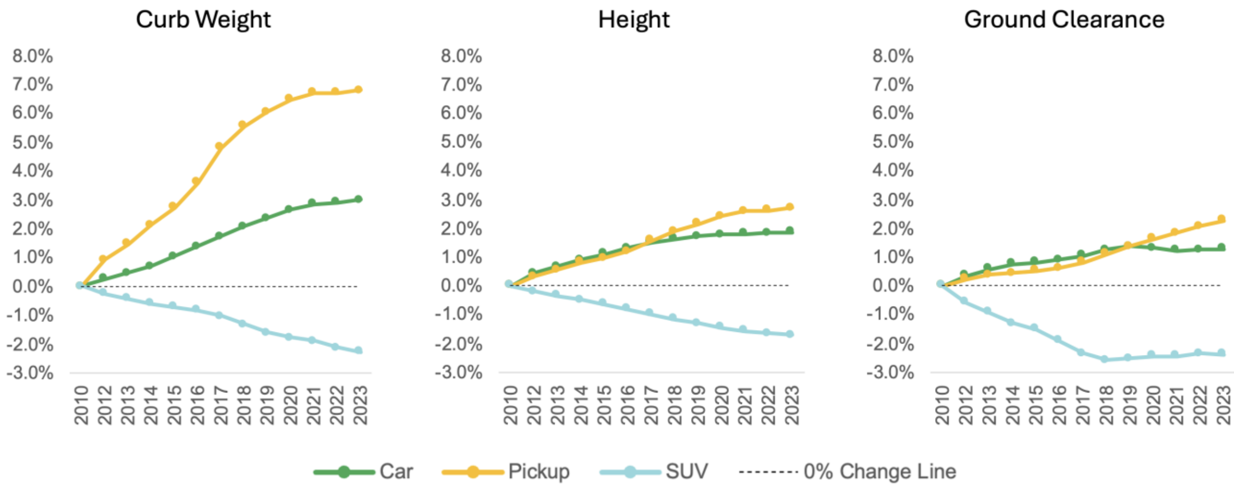


Figure 42. Change in Curb Weight, Height, and Ground Clearance of the California Vehicle Fleet from 2010-2023 by Vehicle Type

This analysis suggests that it may be important to differentiate between large and small SUVs going forward. Historically, the easiest way to differentiate 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.

3.2.6 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 in urban, suburban, and rural areas. Each registered vehicle was assigned one of these area designations based on the county in which it was registered according to the California State Association of Counties County Caucuses list (*California County Caucuses*, 2015).

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. 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.

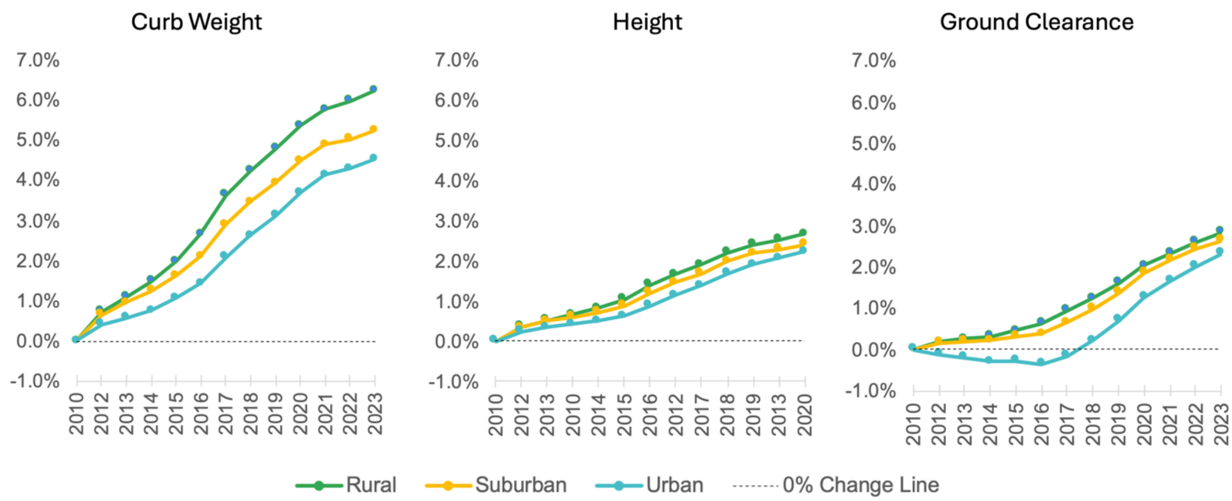


Figure 43. Change in Curb Weight, Height, and Ground Clearance of the California Vehicle Fleet from 2010-2023 by Urbanity, Registered Personal Vehicles

3.3 Crash Safety Features

3.3.1 Advanced Driver Assistance Systems

Vehicle safety technology has also become an increasingly important aspect of vehicle design and manufacturing. Referred to as advanced driver assistance systems (ADAS), technological 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 Table 5. Types of Advanced Driver Assistance Systems). Technologies in category one are generally designed to notify the driver so that the driver can take action and include systems such as: 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 on model year 2029 vehicles. However, it is not clear whether the new federal administration will uphold the existing NHTSA final ruling (Blanco, 2024).

Table 5. Types of Advanced Driver Assistance Systems

Alert Systems	Operational Systems
Forward Collision Warning	Automatic Emergency Braking
Rear Collision Warning	Intersection Automatic Emergency Braking

Alert Systems	Operational Systems
Lane Departure Warning	Lane Keeping Assistance
	Lane Centering Assistance
Pedestrian Detection Warning	Pedestrian Automatic Emergency Braking
Blind Spot Warning	Blink Spot Intervention
	Curve Speed Correction
	Adaptive Cruise Control
	Active Driving Assistance

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 (Aleksa et al., 2024). 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 collaboration 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 (Aleksa et al., 2024; Benson et al., 2018; MITRE, 2022; Wang, 2019). 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 (MITRE, 2022). A different study that focused exclusively on the effectiveness of automatic emergency braking systems on pedestrian risk found a 25 to 27 percent reduction in pedestrian crash risk (Cicchino, 2022). 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.

3.3.2 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.

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"(Partnership for Analytics Research in Traffic Safety, 2024a). 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 (Partnership for Analytics Research in Traffic Safety, 2024b).

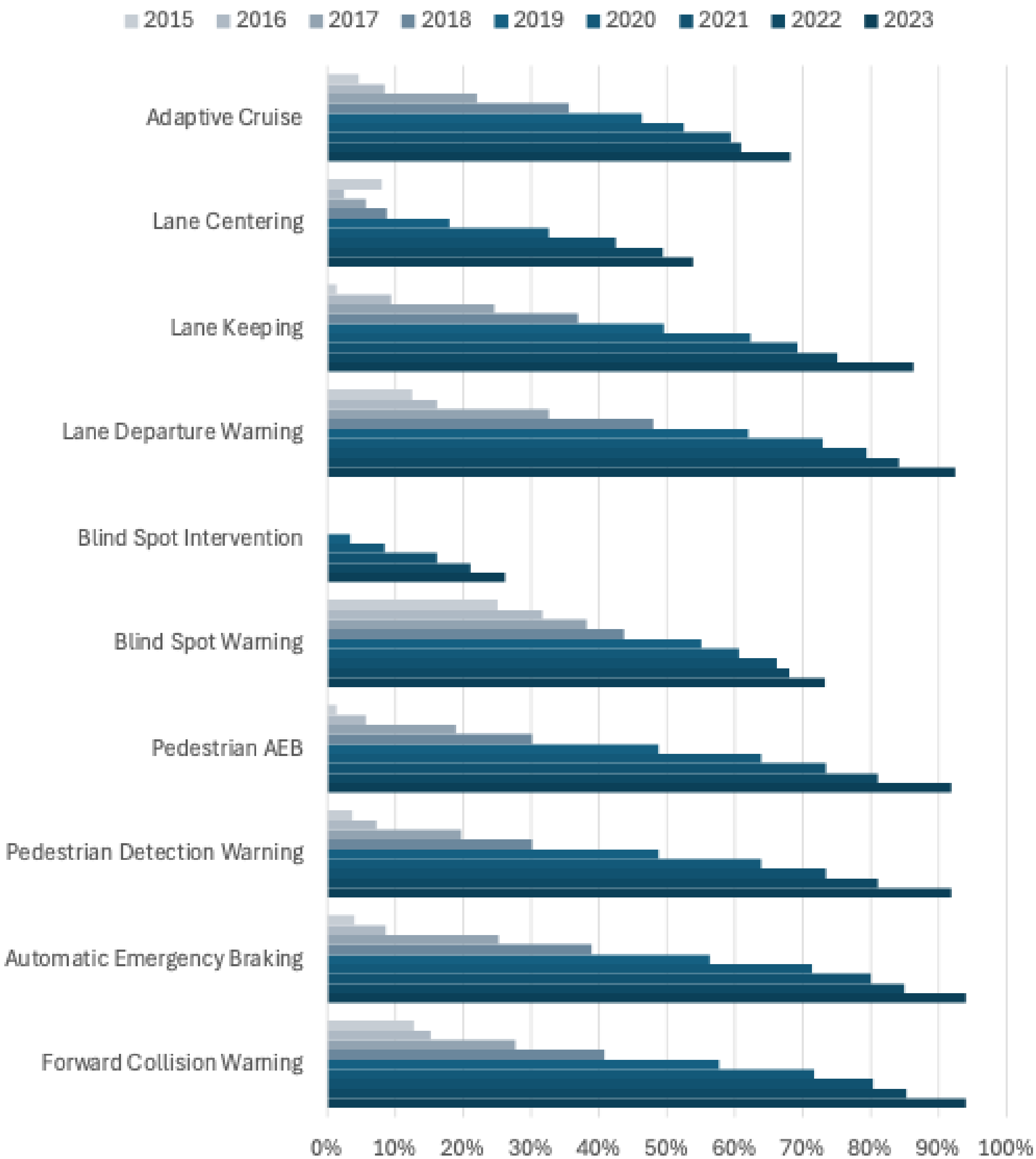


Figure 44. Penetration of advanced driver-assistance systems, 2015-2023 (PARTS data collected and reported by MITRE)

Over most of the past decade, penetration rates for ADAS in new vehicle models has increased dramatically (see Figure 44). 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 for 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 (Partnership for Analytics Research in Traffic Safety, 2024a). 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 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.

Chapter 4. Landscape of Policy Solutions

By: Matthew Raifman, Celia Johnson, Federico Vaca, and Julia Griswold

4.1 Overview of Federal, State, and Local Authorities

A patchwork of federal, state, and local regulations governs California's roadways, vehicles, and road users. At the federal level, the National Highway Traffic Safety Administration (NHTSA) oversees the specific design and safety standards for the manufacturing of motor vehicles through the Federal Motor Vehicle Safety Standards, and conducts car safety rating tests (NHTSA, 2025b). The Federal Highway Administration (FHWA) provides oversight for the federal interstate highway system. California's departments of transportation, environment, and motor vehicles regulate and set standards for vehicle registration, emissions, and the operation of vehicles on the state's freeways and road network. Local governments are responsible for managing local roads and the built environment in which their road users drive. States and local governments can also levy taxes for infrastructure and roadway repairs and improvements. This interagency, multijurisdictional approach to transportation policy offers several potential policy avenues for reducing the road safety risk of large vehicles.

California's state-level vehicular policies have the potential to impact the nation, both through other states adopting similar policies and by shaping the market for vehicles. This is perhaps best evidenced within the unique context of vehicle emissions standards. Emissions standards are set by the California Air Resources Board and are more stringent than national standards under a waiver from the United States Environmental Protection Agency (USEPA)(California Air Resources Board, 2025a). Seventeen states have implemented California's standards (California Air Resources Board, 2025c). This pooled policy approach has the potential to shape demand for vehicles nationwide with implications on vehicle design and manufacturing. The policy also showcases California's ability to lead the nation through policy action.

California's waiver from USEPA to enact more stringent clean air standards also reveals some of the challenges present in developing regulations and policies for vehicles. Firstly, because vehicles are mobile and cross state lines, standards around their design and manufacture generally are set at the federal level. These federal regulations, whether for vehicle emissions through USEPA or for safety through NHTSA, preempt state regulations on the design of vehicles. California received a waiver to allow more stringent emissions standards under the Clean Air Act. While not a legal opinion, our policy analysis suggests that a similar exemption from federal preemption may be required if California sought to implement more stringent design standards for vehicles on the grounds of safety. We are not aware of any attempts by the State to determine whether a similar exemption would be obtainable from NHTSA. Secondly, as has been shown with the Clean Air Act exemption for California, there is a risk of legal challenge that would come with any potential exemption as well as the potential for Presidential executive orders to revoke a state's exemption (Dan Zukowski, 2025). A similar challenge exists in the implementation of new toll schemes, which require Congressional authorization.

The California Clean Air Vehicle Decal program that allowed zero emission and hybrid vehicles free access to carpool lanes was cancelled on September 30, 2025 after US Congress authorization expired and was not renewed (Garcia, 2025).

The following literature review and research synthesis examines existing, proposed, and potential policy mechanisms for addressing vehicle weight in California, the US, and international settings. While we do consider policy areas where federal authorization is needed, we prioritize state-level actions. Our policy analysis examines the trade-offs of policy alternatives identified in the literature review for vulnerable road user safety, economic impacts, equity, and potential for implementation.

4.2 Current California Passenger Vehicle Weight Classes and Fees

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

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, number of axles, fuel type, and where the vehicle is registered.

Currently, fees are only applied to commercially registered vehicles in the State of California (*Registration Fees*, 2024). However, pickup trucks are treated as commercial vehicles and therefore currently subject to a weight-based fee due at registration. Vehicles weighing more than 8,001 lbs. unladen and/or 11,499 lbs. gross vehicle weight rating are treated differently under the Commercial Vehicle Registration Act and required to file a Declaration of Gross Vehicle Weight with a separate fee schedule (California Department of Motor Vehicles, 2025). *(*Examples of pickup trucks that meet these criteria include the Chevy Silverado 3500 HD, Ford F-450 Super Duty, and GMC Hummer EV).

California's fees due at registration include several fees beyond the simple registration fee for the vehicle (see Table 6). For the particular scenario of a gas-powered 2023 Ford F-150 registered in 2024 in Sacramento, the weight-based fee of $80 represents 15% of the total fees due at registration. When the vehicle is purchased, a one-time sales tax (or use tax for used vehicles) is also due at registration.

Table 6. Fees due at Registration in 2024 for a 2023 Ford F-150 Pickup Truck housed in Sacramento, California

Fee Category	Amount
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	$2.00
Current Transportation Improvement Fee	$118.00
Reflectorized License Plate Fee	$1.00
Total (excluding sales taxes)	**$551.00**

Table 7. Commercial Two-Axle Weight Fee Schedule of the California Department of Motor Vehicles (Registration Fees, 2024)

Unladed 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

Electric vehicles are covered under a separate fee scheme. All electric vehicles are exempted from three smog-related fees due at registration. As with gasoline vehicles, only commercial electric vehicles are subject to an additional weight-based fee, but the fee schedule differs from that for gas and hybrid vehicles (see Table 7 and Table 8). The result of this approach is that owners of electric non-commercial passenger vehicles pay around

$20 less at registration than owners of equivalent gas-powered vehicles (i.e., the smog fees). Because pickups are treated as commercial vehicles, owners of electric pick-up trucks are subject to a higher weight-based fee than owners of gas pick-up trucks.

Table 8. Commercial Electric Vehicle Fee Schedule of the California Department of Motor Vehicles (Registration Fees, 2024)

Unladed Weight (lbs)	Annual Supplemental Fee
0 – 5,999	$87
6,000 – 9,999	$266
10,000 or more	$358

While not directly relevant for the current approach to collecting weight-based fees, California does use FHWA's vehicle weight classes in other applications. For example, the California Energy Commission reports data on zero emissions vehicle registrations by these weight classes (California Energy Commission, 2025). The FHWA vehicle weight classes are based on gross vehicle weight rating. 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 45). 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 Department of Motor Vehicles and Energy Commission vehicle classes if desired.

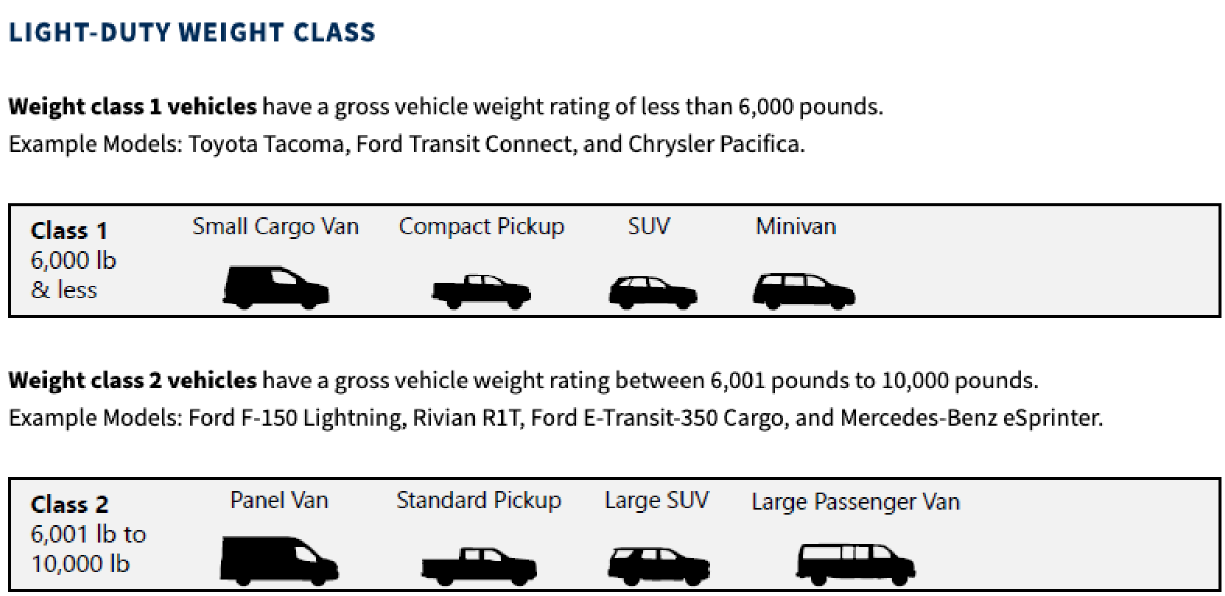


Figure 45. FHWA Light-Duty Vehicle Weight Classes, California Energy Commission.(California Energy Commission, 2025)

4.3 Current National Passenger Vehicle Weight Fees

Nationally, 25 states and the District of Columbia have some type of weight-based vehicle registration fee that applies to passenger vehicles, with considerable variation (see Figure 46). 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 45). In other states, the weight classes are more refined. For example, the District of Columbia's registration fee structure includes three distinct weight classes for vehicles under 6,000 pounds (Washington DC Law Library, 2024). Of the states that collect a weight-based fee, some do so in a conditional way, for example applying it only 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 Figure 46, California is shaded as a conditional weight-based fee because even privately owned pickup trucks are treated as commercial vehicles for registration and therefore subject to a weight fee. 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.

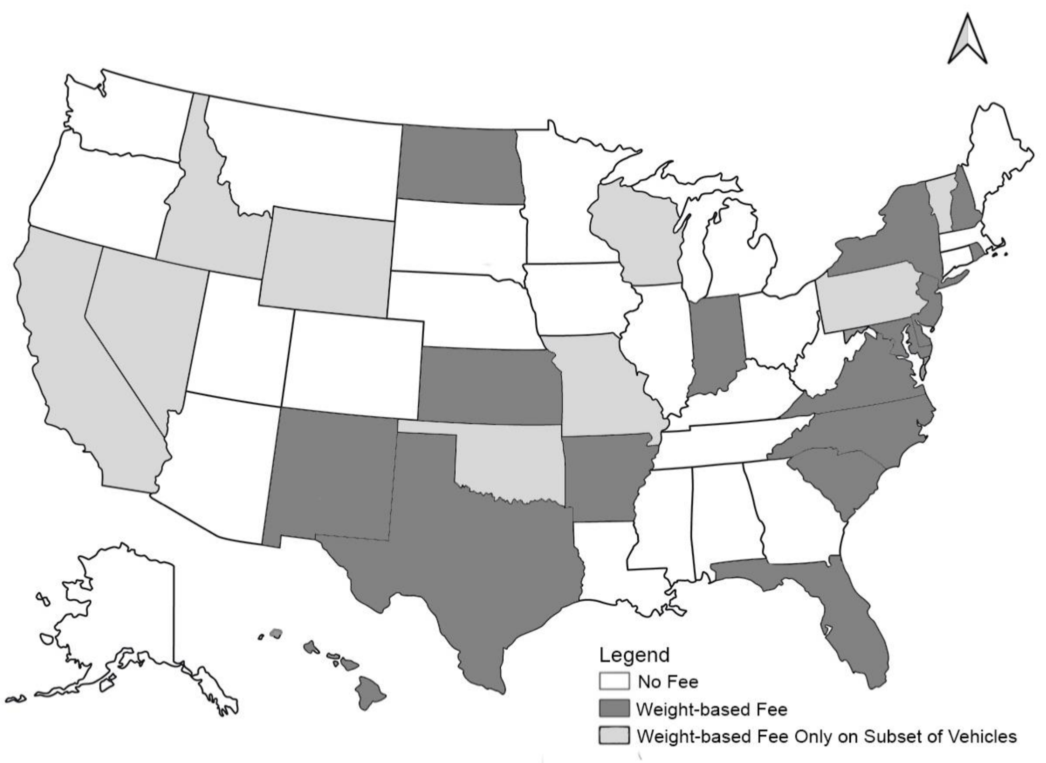


Figure 46. States with Weight-based Fees for Passenger Vehicles, 2024

To provide additional context on the scale and variation in passenger vehicle registration fees across the US, we calculated the effective total registration fee for the best-selling vehicle nationally in 2023: the Ford F-Series pick-up truck (Wayland, 2024). Specifically, we compare registration fees across states (see Figure 47) for the most affordable trim, the 2023 Ford F-150 Regular Cab XL pick-up (curb weight: 4,021 pounds; Manufacturer's Suggested Retail Price [MSRP] $34,585). The registration fee varies across states, ranging from $13.50 (Arizona) to $562 (New Hampshire), with an average fee of $110. California's registration fee of $551.00 is the second highest total fee due at registration and includes a weight 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 an annual registration fee of $66. (This analysis was conducted in 2024 for all 50 states and may be inaccurate in future years due to fee updates.)

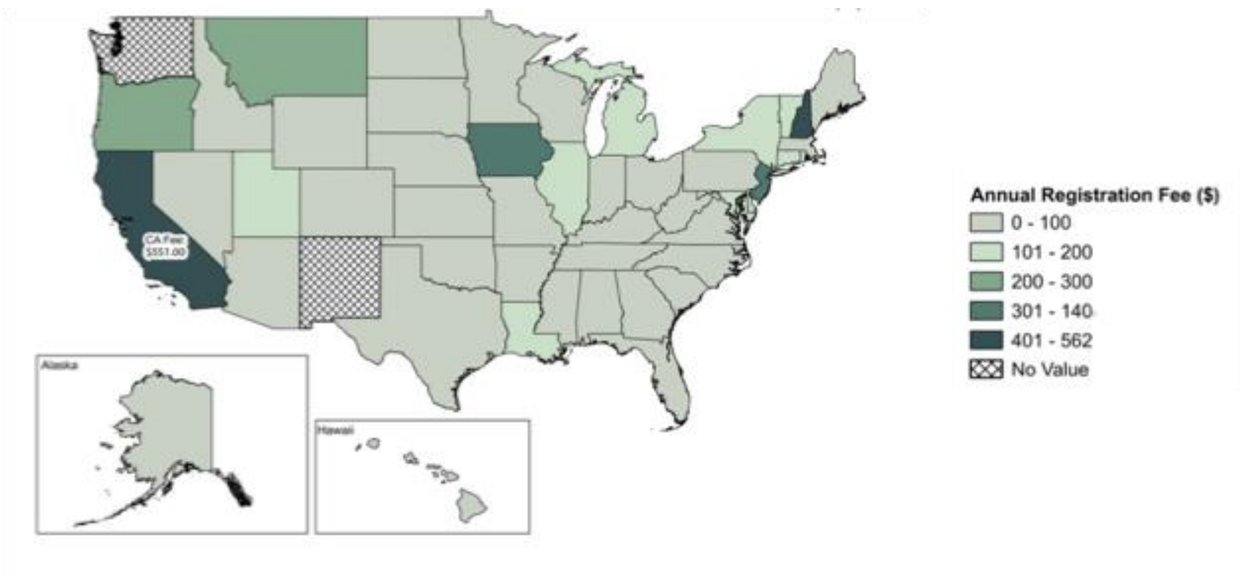


Figure 47. Estimated Vehicle Registration Fees by State for a 2023 Ford F-150 Regular Cab XL (Manufacturer's Suggested Retail Price [MSRP] $34,585)

Each state also has a different approach to setting weight-based fees. For example, some states (e.g., Maryland and Florida) separate passenger vehicles into car and truck classes and then charge a different fee based on three weight classes within each vehicle class. In the case of Maryland, a 4,000 pound vehicle would have a different registration fee if it is a car vs. a truck, a difference based exclusively on vehicle body type (Maryland Vehicle Administration, 2025). While Washington, DC does not differentiate by vehicle type, its weight-based fee climbs rapidly to $500 for vehicles that weight 6,000 pounds or more, but this is reduced to $36 for two years for all electric vehicles.

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

4.4 Overview of the Policy Landscape

In this chapter, we aim to characterize the potential landscape for vehicle-based policies aimed at reducing vulnerable road user fatalities and serious injuries in California. These policy solutions can broadly be classified into three categories: 1) fee-based; 2) regulatory; and 3) involving changes to the built environment.

Fee-based policy mechanisms span registration fees and taxes, toll fees, parking fees, cordon pricing, and road user charges. They are frequently used to generate revenue for funding public goods and services, such as infrastructure improvements or active mobility programs, and they can also influence consumer behavior. As such, these taxes and fees may disincentivize harmful behavior while simultaneously generating resources for reinvestment to incentivize behavior that is beneficial to public health.

Regulatory policies include setting standards for vehicle design and safety, vehicle safety assessments, and roadway design and safety features. These policies play an important role in shaping vehicle supply, such as how vehicles are manufactured and sold. As regulatory polices, they do not generate revenue for reinvestment. They are flexible in that they allow government entities to shape vehicle design based on criteria that specify outcomes and leave design up to the discretion of the manufacturer (i.e., a market-based approach). As noted, the ability of the state of California to implement vehicle design regulations is limited by federal preemption.

Finally, built environment policies shape the larger environment in which road users move from place to place, transport goods, and interact in public spaces. They include traffic calming measures, roadway design, and safety measures implemented along roadways.

4.5 Fee-Based Policy Solutions Related to Vehicle Size

As described elsewhere in this report, the academic literature describes the strong relationship between vehicle size and road user safety (Behnood & Mannering, 2017; Crocetta et al., 2015; IIHS, 2023b; J. A. Thomas & Walton, 2008; Tyndall, 2024a; Yin et al., 2017). All things equal, in the event of a crash between two vehicles, the party with greater vehicle mass transfers more kinetic energy than the party with less mass, increasing the risk of fatality or injury for occupants of the lighter vehicle (Anderson, 2008b; Tyndall, 2021b). There is also likely an interaction between vehicle size incompatibility and crash configurations, with greater likelihood of severe injury or death for occupants of smaller vehicles involved in crashes with side impact and overlapping configurations (Farmer et al., 1997; P. Thomas & and Frampton, 2002). In the special case of vulnerable road users (VRUs), the enormous differential between the weight of a striking vehicle and the weight of a pedestrian or cyclist exacerbates this physical relationship. Further, research evidence suggests that even when weight (i.e., mass) is adjusted for, the form factor and physical size of vehicles may also impact the likelihood of injury in a collision of a vehicle with a vulnerable road user, with taller and less-rounded vehicles more likely to result in injury in the event of a crash (IIHS, 2023b; Tyndall, 2024b; Yin et al., 2017). This chapter describes five common fee-based policies implemented in California or elsewhere that might be used to address the safety effects of increasing vehicle weight. These include registration fees, sales tax, toll fees, road user charges, and parking fees.

4.5.1 Passenger Vehicle Registration Fees

Currently, the California Department of Motor Vehicles collects annual fees at registration for the passenger vehicle fleet for several state agencies. The specific registration fee amount is dependent on the vehicle's classification, age, value, and location. California does not collect weight-based fees for most passenger vehicles, such as sedans, minivans, and sport utility vehicles (SUVs). Pickup trucks are classified as commercial vehicles and are subject to the California Commercial Vehicle Registration Act's weight-based fee schedule. Notably, California does collect weight-based fees for commercially registered electric vehicles, including smaller passenger vehicles like sedans. Revenue collected from California's fees paid at registration are distributed to various government entities and this distribution can change from year to year. For FY 2024-25 the registrations fees were distributed to local government (35.6 percent), Caltrans (26.4 percent), California Highway Patrol (21.1 percent), Department of Motor Vehicles (10.2 percent), General Fund (2.1 percent), Air Resources Board (1.2 percent), and other agencies (2.6 percent) for purposes including maintaining roadways and transportation infrastructure, environmental programs, and law enforcement ("Where Does the Money Go?," 2026).

Across the US, there is significant variability in how vehicle registration fees are assessed for passenger vehicles. Our review of existing registration fees found that in 2024, 25 states and the District of Columbia have vehicle registration fees tied to the vehicle's weight or size. These policies vary greatly in how weight is classified and the relative costs of fees. Hawaii is currently the only state to assess vehicle registration fees on a per-pound stepped sliding scale, with higher weight classes paying a higher fee rate. In Iowa, passenger vehicle registration fees are a function of vehicle weight and list price, where the weight-based fee is assessed on a per 100-pound basis. Some states differentiate between gasoline and electric vehicles. For instance, Michigan's electric vehicle and plug-in passenger hybrid vehicle fees differ for passenger vehicles and trucks.

As every vehicle owned and operated in the state needs to be registered annually, it may be possible to incorporate a weight-based registration fee in California using the existing registration system. It is not clear to what extent buyers account for registration fees in their vehicle purchases, however, and therefore, the impact of a weight-based registration fee on consumer demand for large vehicles is uncertain. Theoretically, if buyers are aware of the higher expense to register a larger vehicle, it may affect their purchasing decisions (J. H. Beck & Bennett, 2003).

Weight-based registration fees can be implemented equally across all vehicles or differentially applied for policy objectives. As a blunt instrument, registration fees could be applied to all registrations using the same criteria (e.g., a set fee per pound) resulting in similar impact for every vehicle owner subject to the weight of their vehicle. It is possible, however, to implement more nuanced registration fees that account for socioeconomic status through means-based fees, exemptions for certain professional application (e.g., farmworkers), and other approaches to make registration fees more targeted to mitigate their regressive effects. Notably, tailored approaches like this require verification of income, employment, and other factors that generally carry additional administrative burden for applicants and government agencies. Take, for example, the idea of a means-based, weight-based registration fee. Applicants may be asked to provide proof of income below a certain threshold (e.g., previous year's tax returns) to be eligible to for a reduced weight-based fee. Policymakers may wish to consider these caveats in any potential implementation of any weight-based fee due at registration.

4.5.2 Passenger Vehicle Sales Taxes

Separate from the recurring annual vehicle registration fees associated with owning a passenger vehicle in California, when an individual buys a vehicle from a dealership in California, they pay a one-time point-of-sale tax on the car (California Department of Tax and Fee Administration, 2025). For vehicles purchased from out of state or from private parties, individuals pay a use tax when they register the vehicle to their name (California Department of Tax and Fee Administration, 2025). In California, the base vehicle sales tax (and use tax) is 7.5 percent of the value of the vehicle, slightly higher than the California sales tax. Local governments have the options to charge up to 2.5 percent additional sale tax on the sale (California Vehicle Tax, 2020). While the vehicle sales tax is 0.25 percent higher than the general sales tax in California, we can more readily compare general sales tax across the country. California had the highest statewide sales tax rate in 2025, at 7.25 percent (Auto Tax Rates by State, 2024; California Department of Tax and Fee Administration, 2025). California's sales tax is a uniform tax on the total purchase price of the vehicle, but other states determine tax rates based on vehicle characteristics. California could consider differentially taxing vehicles based on their weight at the point of purchase for sales in California and upon import for vehicles purchased outside of CA and imported into the state. One example of a state already doing this is Connecticut, where vehicles weighing more than 12,500 pounds are charged a higher tax rate, but California could consider a multi-step weight-based point of sale tax schedule (Auto Tax Rates by State, 2024).

4.5.3 Road User Charges

Road user charges (RUC) are mileage-based user fees. Three states (Oregon, Utah, and Virginia) have active RUC programs for passenger vehicles. Oregon, Utah, and Virgina's programs are volunteer alternatives to the state gas tax or annual highway use fees, whereby volunteers opt in the program and receive a either a credit for gas taxes paid at the pump or substitute the RUC for typical annual fees. Hawaii's program is a bit different. In July 2025, Hawaii began requiring electric vehicle owners to choose between an annual fee or a per mile fee not to exceed the annual fee (similar to Virginia's program). However, Hawaii has also stated that they plan to transition to implementing their RUC on all light-duty vehicles by 2033. Road user charge programs vary state-to-state with respect to scope, policy objectives, and participation.

California has conducted several studies and pilots on a potential road user charge since 2017 and most recently piloted a monthly road charge fee at a rate of 2.8 cents per mile for vehicles under 10,000 pounds (*California Explores Charging People for How Many Miles They Drive*, 2025). The pilots tested measuring miles traveled via different technologies, including "plug-in devices, vehicle telematics, and photographed odometers" (*California Explores Charging People for How Many Miles They Drive*, 2025). All of the State's pilots in this area to date have been to evaluate potential "revenue-neutral" replacements to state fuel excise taxes, and not mechanisms to generate additional revenue beyond existing levels. None of the California RUC pilots have explored a weight-based or vehicle size-based RUC. To date, California has not implemented a statewide RUC.

Road user chares are a potentially useful form of cost recovery for infrastructure construction and maintenance as the fee directly relates to road use. This is in contrast with the traditional form of cost recovery that is notably not aligned with improving vehicle efficiency, including the transition to electric vehicles: the federal and state gas tax. While initial RUCs are linked only to miles traveled, it is conceptually possible to adjust fee rates based on vehicle weight, axles for weight distribution, and vehicle safety performance for all road users.

As such, an RUC represents one way for California to collect revenue that is otherwise lost due to the decline of gas and diesel consumption and associated excise tax revenue. Depending on how the RUC might be structured, it could also incentivize lighter vehicles (through a lower charge) and penalize heavier vehicles (which could be charged a higher rate per mile travelled). Assuming that a vehicle weight-based RUC would change consumer behavior (e.g., fewer miles travelled by heavy vehicles or consumers shifting from heavy vehicles towards lighter passenger vehicles), which has not been thoroughly established in practice, an RUC could have downstream effects on vulnerable road-user safety.

Implementing a weight-based road user charge comes with substantial challenges as well. Currently, there is no RUC program operational in California and previous pilots did not consider adjusting the fee based on vehicle weight. Even if California decided to proceed with an RUC, it may prove to be too challenging to develop a single charge that simultaneously addresses declining revenue from the gas tax while also attempting to shift consumer demand towards lighter, smaller, and/or safer vehicles. Instead, developing two separate policy instruments (e.g. an RUC and a separate weight-baesd fee) might be more effective and less prone to unintended consequences. Further, RUCs may increase administrative burden. A policy analysis of states that proposed or considered implementing RUCs found that administrative costs would increase as compared to the status quo of administrating gas excise taxes (Chakraborty et al., 2023). Notably, technological advancements are making classifying vehicles and capturing vehicle data easier and may address some of administrative burden currently felt by applicants and state regulators alike.

4.5.4 Parking Fees

Some cities have initiated weight-based parking permit fees to address vulnerable road-user safety, traffic congestion, and vehicle wear and tear on roadways. In 2023, the Canadian municipality of Rosemont-La Petite-Patrie implemented a weight-based parking permit system. Gas-powered vehicles weighing more than 1,850 kg

(4,079 pounds) pay a higher fee than smaller vehicles, and electric vehicles and hybrid vehicles are subject to further discounted fees (La Presse Canadienne, 2023). In addition, in Rosemont-La Petite-Patrie, it is possible for those with lower income or reduced mobility to apply for a reduced fee. As justification, city officials cited the decrease in parking spaces due to the increasing size of average vehicles, impacts on infrastructure, and safety impacts such as greater risk of collisions due to limitations in visibility from large vehicle designs as reasons for this policy (La Presse Canadienne, 2023).

Similarly, residents of Paris, France voted to implement size-based parking fees on non-residents in early 2024 (*Paris Introduces Triple Parking Fees for SUVs - EU Urban Mobility Observatory*, 2024). The Paris fee, known as the "SUV tariff" applies to all vehicles weighing more than 1,600 kilograms. The program is implemented differentially across the city, with an hourly cost of 18 Euro in central districts and 12 Euro in outer districts (*Paris Triples Parking Fees for Heavy Vehicles*, 2024). Vehicle weight is determined by scanning the vehicle license plate, which is linked to the car model's information, including vehicle weight. Taxis, commercial vehicles, and vehicles for those with disabilities are exempted from the fee (Glon, 2024).

We found no evidence of weight-based parking fees in the US; however, cities such as Needham, Massachusetts are changing their urban parking landscape by creating new regulations that allow for greater use of compact car spaces (*Traffic Deaths Decreased in 2018, but Still 36,560 People Died*, n.d.). Needham's zoning regulations allow up to 50 percent of off-street parking spaces to be designated for compact cars (Un, 2010). It is unclear how this zoning change may influence the number of large vehicles within city limits, such as impacts on traffic congestion and driver and road user behaviors.

Parking-based fee collection for larger vehicles has the potential to shape the vehicle fleet makeup and congestion patterns, most notably by steering large vehicle users away from urban and suburban centers, where vehicles may be more likely to interface with vulnerable road user traffic (NHTSA, 2020). Given that most parking fees are collected by municipalities or private firms (e.g., private parking garages in large urban areas), statewide implementation of a weight- or size-based parking fee system would present integration challenges. Likewise, for consumers, the availability and distribution of private, off-street parking could result in differential impacts of a parking-based fee across the state. Parking alternatives and the relative salience of parking fees would need to be considered in determining the impact on vehicle-buying behavior.

Given that municipalities exercise regulation over local streets, there is a limited role for the State in parking fee implementation. However, should the State seek to shift parking policy, it could do so through several mechanisms, including establishing communities of practice for municipalities, implementing weight-based parking fees for state-run parking facilities, and even, at the extreme end, scoring grants or tying funding to vehicle weight-based parking policies.

4.6 Potential Fee-based Policy Solutions with Federal Dependency

The weight-based fees due at registration and sales taxes referenced above could likely be implemented by the State of California without federal or local authorization. In addition, here we consider several weight-based fees and policies in our landscape analysis that could be implemented but would require either federal or local government collaboration and, in some cases, authorization.

4.6.1 Weight-based Toll Fees

Tolls are a fee charged for access to a specific infrastructure facility in California, including bridges (e.g., accessing San Francisco from Marin County via the Golden Gate Bridge), toll lanes (e.g., any vehicle accessing I-15 Express Lanes in San Diego), and high-occupancy toll lanes (e.g., vehicles with fewer than three occupants accessing I-880 Express Lanes in Alameda County). In the case of bridge access, tolls are generally assessed based on the number of vehicle axles, but not weight (except commercial vehicles). California toll roads are divided into systems with regional authorities (e.g., the Bay Area Toll Authority that oversees state-owned bridges in the Bay Area and the Orange County Transportation Authority that manages toll roads including I-405). Toll revenues finance bonds used to fund regional transportation improvement and maintenance projects, including those approved by local voters in regional measures (*Regional Funding | Metropolitan Transportation Commission*, 2021). Assembly Bill 194, enacted in 2015, amended the State Streets and Highways Code, expressing the intent of the legislature that across the state, highway tolling shall not be used for the sole purpose of revenue generation but rather for performance optimization and improvement projects on transportation corridors (Assembly Member Frazier, 2015).

Tolls can additionally be leveraged for purposes other than funding specific roadway or infrastructure projects. In California, one example of this is the implementation of high-occupancy toll lanes. The high-occupancy toll lanes charge a dynamic price for access based on congestion, as well as time of day and day of the week. Most California high-occupancy toll lanes allow carpools and, until September 2025, allowed electric vehicles at a discounted or waived fee. As such, they can provide economic incentives for sharing rides and using zero-emission vehicles, as well as price willingness to pay to avoid congestion. Conceptually, the same tolling mechanism that has been employed to incentivize carpooling and lower emissions could also be applied to disincentivize use of vehicles that increase the risk of injury to others in a crash through a vehicle aggressivity rating (Les & Fildes, 2001; Monfort & and Nolan, 2019; Newstead, S.V., Cameron, M.H., Le, C.M, 2000).

However, there are some important caveats that would affect the ability of the State of California to implement weight-based tolling access. In the case of access to high occupancy lanes (i.e., Express Lanes in California), a change in federal law (23 U.S. Code § 166 – HOV Facilities) may be required to implement weight-based access fees. The current code explicitly authorizes states to implement tolls with differential pricing for congestion management and higher occupancy, but not specifically weight (Federal Highway Administration, 2016). Until September 2025, a special rule allowed states to offer alternative fuel vehicles reduced tolls or free access to high-occupancy toll lanes (Garcia, 2025). This special rule expired after the US

Congress did not approve its extension in 2025. Differential tolling by vehicle weight or vehicle class may be possible as long as different vehicle classes are established with an infrastructure rationale (e.g., heavier vehicles damage infrastructure more or larger vehicles take up more space on the road resulting in more congestion). However, we found no evidence of weight-specific tolls for passenger vehicles in the US that could serve as examples or provide legal basis for its implementation. As a result, prudent legal review is recommended if the State pursues differential weight-based tolling.

4.6.2 Weight-based cordon pricing

Similar to the way tolls restrict access to road infrastructure, cordons use access fees to restrict access to certain areas, typically urban centers and central business districts. Cordons are distinct from infrastructure tolling in that they restrict to access to an area rather than access to a linear thruway. Recently, New York City implemented its Congestion Relief Zone, which charges a toll for access to areas of Manhattan south of 60th street (*Congestion Pricing Program · NYC311*, 2025). Notably, the New York City implementation includes a low-income discount or low-income tax credit option, introducing the concept of means-based cordon pricing to limit the inherent regressive nature of a fee. It does not exempt low-emissions vehicles, but some international case studies (e.g. London's Congestion Charge) do exempt fully electric vehicles. Other implementations simply restrict access to areas based on emissions rather than differentially charge for access. For instance, in multiple European countries (e.g., Germany, Netherlands, France, Belgium, Italy), low emissions or zero emissions zones are used to restrict high-emitting vehicles from specific geographic areas (Sadler Consultants Europe GmbH, 2025). These implementations of cordon pricing or restricted access have tended to focus on either reducing congestion or improving air quality. The concept could be extended to reducing risk to vulnerable road users through a differentially priced cordon price by vehicle weight or vehicle type, or simply restricting access to smaller vehicles.

Restricting access to any road that received federal funding for construction or improvement would likely require federal approval through the Value Pricing Pilot Program run by FHWA. For example, New York City's implementation of a congestion zone includes parts of FDR Drive and the Battery Tunnel, both of which are federal facilities. Further, the objective of the Value Pricing Pilot Program is to reduce congestion and it is not clear if a weight or vehicle size-based cordon pricing program would meet this criteria. As such, consideration should be taken with undertaking any cordon pricing program that requires access to roads funded by federal resources.

As noted above, most applications of cordon pricing around the world occur in cities. Should California cities be interested in implementing weight-based or vehicle-type based access to city centers through cordons, these programs may be possible if no federally funded roads are included. In practice, this restriction may be hard to satisfy, however, given the breadth of federally funded roads that cross California's cities. It is also not clear whether additional state legislation would be needed to authorize cities to implement cordon pricing.

That said, there is a reasonable rational for the implementation of cordon pricing to limit access to central business districts that differentially affects heavier and larger vehicles. As demonstrated in this report, there is growing academic evidence that heavier and larger vehicles pose a greater risk to vulnerable road users than lighter and smaller vehicles do. Urban areas, where cordon pricing is more often implemented, are the primary areas where vehicles interact with vulnerable road users. Limiting access to those areas may improve safety for non-vehicle occupants. Further, urban areas tend to have more scarce land resources. Vehicles with a larger footprint take up more space on the road, while driving and parking.

4.7 Equity and Distributional Concerns for Fee-Based Mechanisms

By universally targeting passenger vehicles based on weight or size, fee and tax-based policy solutions do not account for dependency of specific vehicle types that might be associated with specific professions (e.g., farm workers or construction workers) and those living in rural versus urban areas. We know from our previous analysis of vehicle registrations in California that rural areas have a higher share of pick-up truck registrations than urban areas. Additionally, the universal policy mechanisms may have regressive effects, as they apply the same tax or fee to all people regardless of their economic status.

These potential equity concerns are something policymakers should consider. It may be possible to implement tax schedules based on income, certain professions, family size, or other factors to address equity concerns. These adjustments would likely require data integration across government, including for example, verifiation of income via tax returns or employment status. Several policies discussed here include means-based adjustments (e.g., New York City's Congestion Relief Zone and Canada's Rosemont-La Petite-Patrie). To improve equity it is preferential, where possible, to apply adjustments at the point of transaction rather than as a tax credit. For a lower income household, including adjustments in the point-of-sale transaction means the credit is applied immediately, freeing up resources to be used for other expenses in contrast to a tax credit, which requires the recipient to wait until their tax refund to receive the adjustment.

4.8 Regulatory Policy Solutions Related to Vehicle Size

Whereas fee-based policy mechanisms have the potential to internalize negative externalities associated with vehicles and shift consumer behavior, regulatory policies specify the rules and standards for designing, manufacturing, and operating vehicles (Chu, 2016). By specifying vehicle standards rather than a fee, regulations would apply to all applicable vehicles and restrict the type of vehicles that have access to the market. To an extent, this removes consumer preference and willingness to pay from the equation. It is possible to conceive of implementing regulatory policies that restrict sale of vehicles in California to those below a certain weight, volume, size, or design; however, most of the most impactful policies would need to be implemented at the federal level.

4.8.1 State Versus Federal Regulatory Authority

At the state and federal levels, regulatory authorities have different roles, responsibilities, and rule-making powers. Federally, regulatory agencies under the US Department of Transportation include the National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Administration. Federal regulations determine how vehicles are designed (e.g., the inclusion of turn signals, airbags, automatic emergency braking, etc.) and how Federal Highway administered projects are designed and maintained. NHTSA also runs the New Car Assessment Program (NCAP), which is the national program for testing and rating the safety of new passenger vehicles on the market against specified criteria (*New Car Assessment Program*, 2022).

States have the ability to regulate and enforce how vehicles are purchased, maintained, and operated by individuals (e.g., wearing a seatbelt, smog checks, speed limits). In California, the major regulatory agencies are the Department of Motor Vehicles, California Air Resource Board, and California Department of Transportation (Caltrans). State transportation authorities can also collect taxes, tolls, and fees for revenue generation and fund state roadway and transportation infrastructure. In considering how these regulatory authorities might address vehicle size and road safety, California policymakers could theoretically shift how vehicles are operated, and which vehicles are purchased.

4.8.2 Vehicle Design Standards and Safety Ratings

Vehicle safety standards play an important role in the safety of vehicle occupants and vulnerable road users. These standards are implemented at the federal level. Vehicle safety has increasingly become a policy and regulatory priority over the past four decades, as exemplified by the implementation of standards requiring newly manufactured vehicles be equipped with devices such as seat belts, airbags, electronic stability control, automated emergency braking, and, most recently, back-up cameras (*Federal Motor Vehicle Safety Standards; Automatic Emergency Braking Systems for Light Vehicles*, 2024).

These advancements have tended to focus on the safety of vehicle occupants as opposed to those outside the vehicle. Vehicle safety standards in the US have diverged from those in other nations, particularly concerning vehicle safety testing and rating systems (Bellon, 2020). The European New Car Assessment Programme, for example, requires vehicle testing for pedestrian collision outcomes, with tests that evaluate pedestrian head injury risks, which are largely moderated via vehicle front-end designs, such as front-end height and slope (Tyndall, 2024b). As of November 2024, however, the National Highway Traffic Safety Administration's (NHTSA) New Car Assessment Program (NCAP) finalized a rule change that will add a crashworthiness pedestrian protection program to its five-star rating standards over the next decade (NHTSA, 2024e). It is unclear how or whether this rule change will significantly change vehicle design and sales going forward. In September 2025, NHTSA issued a notice of delay that postpones inclusion of crashworthiness pedestrian protections in the NCAP testing by one year, so it will commence for model year 2027 vehicles (Federal Register, 2025). Additionally, H.R. 9408, known as the Pedestrian Protection Act, was introduced to Congress during the 2023-24 session and would have codified vehicle safety standards for pedestrians and cyclists by requiring newly manufactured vehicles to meet specific vehicle height and front-end design standards (Rep.

Scanlon, 2024). The bill was referred to the House Committee on Energy and Commerce but was not read by the committee (Rep. Scanlon, 2024).

California's economy accounted for 14 percent of the national gross domestic product in 2023, and it is the state with the most vehicle registrations in 2022. As such, California's state regulations have the potential to shape the vehicle market (Sarah Bohn and Jenny Duan, 2024). Potential regulatory changes to the state's vehicle code may have profound economic and political ripple effects beyond the state, as other states follow the standards set by California. The emissions standards implemented by California's Air Resources Board are an example of what is possible through state-level regulations; however, the precarity of California's ability to regulate vehicle emissions is also exhibited by the current state of the California Air Resources Board standards. The total impact of California's clean air regulations was amplified by the 17 states that have adopted at least one of California's light-duty vehicle emissions regulations, together accounting for 40.2 percent of all new registered light-duty vehicles in the US (California Air Resources Board, 2025b). However, these regulations are part of a unique waiver flexibility granted to California in the Clean Air Act of 1967 (Dan Bosch, 2022). In June 2025, President Trump signed three joint resolutions under the Congressional Review Act that revoked California emissions waivers. California and ten other states filed a lawsuit to challenge the use of the Congressional Review Act for revoking the waivers. As of December 2025, the case remained unsettled (Genovese, 2024).

One can imagine a similar policy to allow California to restrict sales of vehicles that are exceptionally dangerous to vulnerable road users. This would be novel policymaking and it is unclear what legal authority the state would have to implement similar more stringent standards for road safety or if a waiver would be needed. However, given the current policy environment—where California's emissions waiver and its ability to require new cars and trucks be zero emission have been revoked by Congress—it seems unlikely that California would be granted a new wavier to stipulate what size vehicles can be operated in the state.

California could also consider developing its own version of the New Car Assessment Program (NCAP) whereby it undertakes assessment of new vehicle safety and communicates safety assessments to the public, possibly in collaboration with other states concerned about road safety and vehicle size. Among other things, this would afford California the potential to develop a more comprehensive safety rating that includes, for example, the safety of non-vehicle occupants even if this approach is not taken at the federal level. As NCAP ratings do not directly restrict the sale of vehicles, a state-based NCAP rating could be less likely to trigger legal challenge; though, this report is not a legal review and only a survey of the policy landscape. Comprehensive legal analysis is advised for all policy options considered.

Ultimately, while regulatory approaches are appealing on the grounds that they can require changes in vehicle design and safety, there is limited potential for the State of California to implement regulations that affect the way vehicles are built.

4.8.3 Equity and Distributional Concerns for Regulatory Policy Solutions

Regulatory changes that apply to all passenger vehicles can increase the safety of all new available vehicles and thereby increase the safety of the overall vehicle fleet over time, as consumers gradually replace their vehicles. The vehicle design regulations are complicated to interpret and may increase or decrease the equity of vehicle safety. On the one hand, regulations are arguably more equitable than fee-based mechanisms because they can apply to all vehicles, improving safety for the entire fleet with no ability to pay to opt out (e.g., paying a vehicle weight fee to own a larger vehicle). On the other hand, regulations typically only target new vehicle sales and may result in disparities in who is able to benefit from them. Regulations that improve safety would only be experienced by those who own newer vehicles or, in the case of pedestrian safety improvements, those who live in areas where new vehicles are purchased. Likewise, blanket regulations (e.g., a requirement that all vehicles be under 6,000 pounds) could generate potential disparities across professions and urban-rural divides, where vehicle ownership patterns differ with regard to vehicle size.

4.9 Roadways and Built Environment

In the US, roadway design standards are broken down by jurisdictional ownership, ranging from the Federal Highway Design Code, to the FHWA Manual on Uniform Traffic Control Devices for Streets and Highways to the Caltrans Highway Design Manual to county and municipal planning standards (Petek, 2023). Physical modifications to the built environment, such as the addition of various roadway safety devices or countermeasures, impact safety for all road users, especially vulnerable road users, and can also play a role in moderating human fallibility as part of a Safe System Approach (Office of Traffic Safety, 2026).

Unlike vehicle design regulations, relevant state and local agencies can shape the built environment through design standards and infrastructure investment decisions. To formalize and simplify the menu of built environment improvements that improve road safety, Caltrans has incorporated the 28 Proven Safety Countermeasures identified by the Federal Highway Administration into its “Four Pillars of Traffic Safety” (Caltrans, 2026; FHWA, 2026). Organized into a collection of overarching categories (i.e., speed management, roadway departure, intersections, pedestrians and bicyclists, and crosscutting countermeasures), the 28 Proven Safety Measures are a paired down list from the broader research and implementation literature of interventions that have strong evidence of effectiveness. As such, the challenge before California is not so much identifying the ways that resources could be invested to improve safety through infrastructure improvement but rather the allocation of sufficient resources to state and local government agencies to implement those countermeasures on California’s roads. Should California implement weight-based policies that generate resources for investment, those funds could be invested in Proven Safety Countermeasures to create a virtuous cycle of improved road safety.

While the 28 Proven Safety Countermeasures in FHWA and Caltrans guidance were selected based on the best possible evidence supporting their significant and measured safety impact, their evidence base is retrospective. The growing weight and size of the US vehicle fleet may require reassessment of the effectiveness of certain existing countermeasures and, possibly, revision of the Proven Safety Countermeasure list. Larger and heavier vehicles may require enhanced countermeasures to dissipate higher kinetic energy loads or adjustments to address reduced visibility and increased stopping distance. Additionally, generational improvements in Advanced Driver Assistance Systems may interact with existing countermeasures differently than the vehicles of the past. Caltrans's 28 Proven Safety Countermeasures are themselves based on the 28 recommended by FHWA, which were updated in 2012, 2017, and 2021 (FHWA, 2026). As the vehicle fleet shifts, maintaining this frequency of reassessment will likely be necessary to properly calibrate the recommended list of countermeasures to the evolving vehicle fleet.

4.9.1 Equity and Distributional Concerns for Built Environment Solutions

Funding for infrastructure improvements comes from local governments and thus is dependent on the local tax base or local funding priorities. There is a risk that more affluent areas will be able to implement safety improvements more easily. Without specifically targeting investments in low-income or otherwise disadvantaged communities, the distribution of safety improvements could be inequitably concentrated across communities. Continuing to invest state funding with a focus on addressing inequities in access and local resource allocation will be important for ensuring that all Californians benefit from built environment improvements.

Additionally, the built environment plays an important role as a social determinant of health that contributes to health inequities (Barajas & Braun, 2021; U.S. Health and Human Services, 2025). Frequently, racial and ethnic minorities, low-income, and/or rural communities are systematically and inequitably exposed to environmental conditions such as transit deserts or pollutants (Tehrani et al., 2019). They also historically have less access to protected pedestrian and bicycling infrastructure (Braun et al., 2019). Built environment safety investments and modifications can play a role in rectifying past injustices, but policymakers would be wise to also consider gentrification processes that may be associated with safety improvements (Chapple et al., 2018; Tehrani et al., 2019).

Chapter 5. Weight Fees and Consumer Behavior

By: David Brownstone

5.1 Background

Heavy and tall light duty vehicles cause more damage when they hit smaller vehicles, bicyclists, or pedestrians. Current California insurance rates and registration fees do not fully account for these safety externalities. Therefore, there is scope for public policies and regulations to reduce the damage from accidents and also cost less than the benefits of lower deaths and injuries.

From an economics perspective, the efficient solution would be to charge heavy and/or tall vehicles a per mile fee based on time and location (since the risk of accidents varies by time and location). For example, the risk to pedestrians is minimal on freeways. This report looks at second (or third) best solutions – levying a fee on heavy vehicles at time of purchase or levying an annual registration fee based on weight (and/or body type). These fees may cause consumers to change their purchase behavior and cause vehicle manufacturers to change the weight of the vehicles they offer for sale. Due to time and budget constraints the research reported here just examines consumer behavior, so the results should be interpreted as a lower bound on the impacts of the fees. We only examine the personal light-duty vehicle market in California. This represents more than 90% of the light-duty vehicles currently registered in California. We will focus on answering:

- How high do weight/body fees need to be to get substantial changes in vehicle purchase behavior?
- How much government revenue can be raised by imposing weight/body fees?
- Do these weight/body fees conflict with other policy goals (e.g. reducing greenhouse gas emissions)?
- Is it possible to design weight/body fees that accomplish the policy objectives without imposing undue burden on some locations and consumer groups?

Most of our analysis is aimed at answering the first two questions above. We also look at scenarios where electric vehicles are excluded from paying the weight/body fees, and these scenarios provide a partial answer to the last two questions. Our research does not address the key question of how to best spend the fee revenue. Presumably the revenue could be used to subsidize the purchase of lower weight vehicles, improve the safety of California's current roads and/or increase enforcement of speed limits and impaired driving laws.

5.2 Personal Vehicle Purchase Models

In 2024 there were 15,681 unique combinations of Make, Model, fuel type, and year light-duty vehicles registered in California for a total of 29.4 million vehicles. If we knew the weight of each of these vehicles we could calculate the revenue from any weight-based fee using a spreadsheet. These results would only be valid if we assume that consumers do not change their purchase behavior in response to the fees.

Of course, one of the reasons for considering a weight fee is to incentivize consumers to purchase lighter (and/or) smaller vehicles. If heavier vehicles become more expensive to purchase and/or operate, people will switch to lighter ones. If fees only apply to new vehicles, then people will switch to used vehicles and/or keep their existing vehicles longer. This may change used car prices.

Vehicles are expensive and last a long time, so consumers will take many years to adjust to new fees. About 25% of registered vehicles in California are more than 14 years old, 50% are more than 9 years old, and 10% are new vehicles. Important vehicle attributes (e.g. price and repair costs) are uncertain to both households and modelers. Much of the required data are either not publicly available or are very expensive to purchase.

5.2.1 CEC Models and Forecasts

The California Energy Commission (CEC) has been developing and using residential and commercial light duty vehicle choice models, and periodically updates these models based on California Vehicle Survey (CVS) data (Aniss Bahreinian, 2019). This analysis uses only Personal Vehicle Choice (PVC) models since it covers all California households that compose 90 percent of registered light duty vehicles in California.

The vehicle type choice models are estimated from CVS participants' responses to hypothetical vehicle choice experiments. This allows future technologies such as autonomous vehicles to be included in the forecasts but is not as realistic as models estimated from actual household vehicle transactions. It is very expensive to collect enough data from households who make actual transactions, and some of the vehicle types are not even on the market. These are key reasons for using hypothetical choices.

CEC forecasts the number (and types) of vehicles and fuel usage for all California vehicles over a 15 year period, which we have extended to 30-year period. We will use the personal vehicle choice sub-model (see Figure 48) with base year 2023 and predictions from 2024 through 2050. The most recent documentation for the California Vehicle Survey is for the 2017 survey – see (Fowler, Mark, Tristan Cherry, Thomas Adler, Mark Bradley, and Alex Richard., 2018). We are using survey data from 2019 and 2024 for the work reported here. The newer data and models differ from the 2017 survey since they use an expanded set of vehicle body type classifications.

The personal vehicle choice models depend on the joint distribution of household income, vehicle holdings, and household composition. CEC forecasts use current values and future forecasts of household income from Moody's and demographic forecasts from the California Department of Finance.

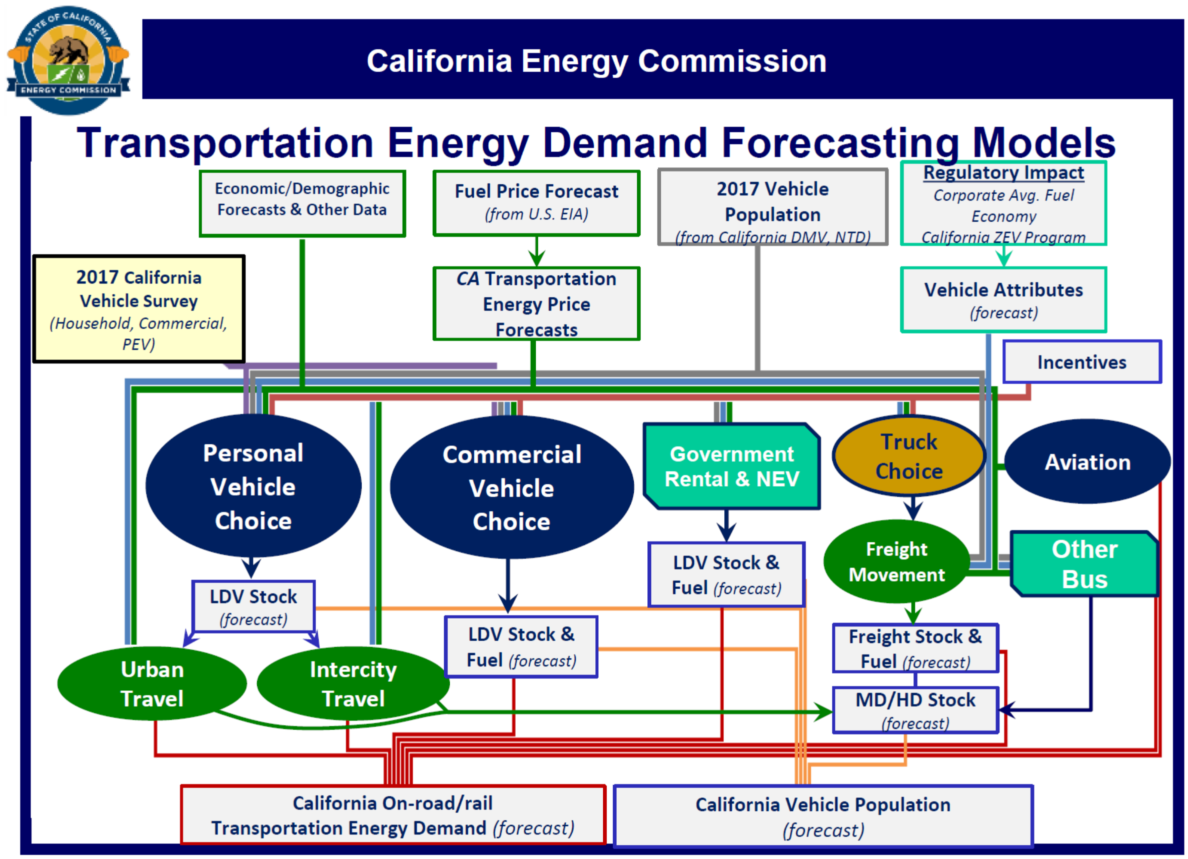


Figure 48. Transportation Energy Demand Forecasting Models (flow chart from Aniss Bahreinian, 2019)

Light-duty vehicles are grouped into 27 classes, 8 fuel types, and vintages going back to 1983. There are 1425 groups in 2024. The CEC has data on vehicle characteristics for each of these vehicle groups for each model year back to 1983. The CEC vehicle attribute forecasts do not include vehicle weight implying the assumption that consumers do not care about vehicle weight for a given set of vehicle characteristics including price, body type/vehicle class, fuel type, acceleration, and fuel economy. We purchased data on vehicle weights and new and used prices from JD Power, and we used these data together with separate vehicle weight data provided by CEC staff from DMV registration files to impute weights for all 1425 groups in the CEC's vehicle attributes file.

CEC staff process DMV registration data to generate base year vehicle population counts, and the PVC base year forecasts are calibrated to match these counts for 2023 base year. The CEC also develops and uses fuel price forecasts that are required in generating LDV forecasts.

CEC LDV models assume that manufacturers (and other states) will provide as many vehicle types as needed to satisfy the demand forecast for these vehicles.

5.3 Weight Fee Scenario Analyses

We will use the PVC baseline estimates of future vehicle and household attributes and compare results from simulations of various vehicle weight fees. We assume that the weights of future vehicles are the same as in 2024. Note that although vehicle prices and other attributes vary within the 1425 PVC vehicle groups, PVC only allows one price and annual maintenance fee for each group.

PVC assumes that used vehicle prices are given by new vehicle prices multiplied by a fixed depreciation factor. We used data purchased from JD Power for California light-duty vehicle transactions between 2015 and 2024 to update these depreciation factors for each of the 1425 PVC vehicle groups.

Table 9 shows the baseline forecast distribution of light-duty vehicle weights from PVC. These forecasts show that average vehicle weights are forecast to increase for all size classes and fuel types.

Table 9. Baseline forecast light-duty vehicle weight distributions (in pounds curb weight)

Size class	2024 Mean Weight	2024 Std. Dev.	2040 Mean	2024 – 2040 % increase	2024 Population %
Compact	3463	542	3924	13%	39%
Heavy	5879	706	6479	10%	2%
Large	4793	798	5189	8%	6%
Midsize	3749	554	4004	7%	31%
Minivan	4359	224	4612	6%	3%
Sport	3481	263	3531	1%	3%
Std	4878	436	5353	10%	8%
Subcompact	2986	412	3357	12%	8%
Total	3784	802	4115	9%	100%

Fuel Type	2024 Mean Weight	2024 Std. Dev.	2040 Mean	2024 – 2040 % increase	2024 Population %
diesel	5885	878	6152	4.6%	1.5%
electric	4317	606	4423	2.5%	5.4%
ethanol	4642	913	4918	6.0%	2.8%
gasoline	3697	738	3855	4.3%	82.7%
hybrid	3513	572	3763	7.1%	6.1%
plug-in hybrid	4168	668	4716	13.2%	1.5%

For each of the purchase price scenarios described below we compute the fee corresponding to the average curb weight of the vehicles comprising each of the 1425 PVC vehicle groups. We then add the fees to the vehicles' purchase prices, re-run PVC with the updated purchase prices and compare the results to the baseline forecasts which don't include the potential vehicle weight fees. We follow the same procedure for annual fee scenarios except the annual fees are added to PVC's values for annual maintenance costs. Finally, we compute the annual revenue raised by each potential fee.

5.3.1 New Purchase Fees

Fees on new vehicle purchases are the easiest to collect and only impact new car buyers. We charge $5/lb on the portion of vehicle weight exceeding 3,800 lbs (the approximate mean weight of all vehicles registered in 2024). This is the only policy we simulated that resulted in a meaningful reduction in the weight distribution of vehicles on the road in 2040.

Under this scenario, about 60% of new car buyers in 2024 will have a weight fee. The mean fee for those paying it in 2024 is 7% of the purchase price ($3871 corresponding to an average MSRP of $55,600), and the maximum fee is 20% of the purchase price ($19,500). The highest fee is for Premium Electric Heavy Pickups with an average 2024 MSRP of $100,000. The average weight for this group is 8660 lbs. Buyers of premium brand vehicles who pay the fee will pay $4017 corresponding to a mean MSRP of $67000 (6%). Buyers of standard brand vehicles who pay the fee will pay $3768 corresponding to a mean MSRP of $47600 (7.9%).

This proposed purchase fee leads to a small shift in the distribution of weights of all vehicles on the road. In 2040 90th percentile of weight declines 2.5% and mean weight declines 1.2% relative to the baseline forecasts without new weight fees. In 2040 the number of large SUVs drops 17%, and the number of heavy and standard pickup trucks declines 10.5%.

The proposed purchase fee generates substantial fee revenue. Annual fee revenues are forecast to be $3.17 billion in 2024 ($3.98 billion if no behavioral response), and $4.59 billion in 2040 ($5.3 billion if no behavioral response). This revenue is large (2024 CA revenue was about $240 billion), and revenue could be used for safety improvements and/or funding key state initiatives.

Table 10. Percent Change in Vehicle Holdings Compared to 2040 Baseline PVC forecasts

Class	Purchase Fee	Purchase Fee except EV	Purchase Fee except EV & PHEV	Annual Fee	Annual Fee newer than 2023
Compact	3.0	1.9	1.6	0.5	0.3
Heavy	-7.7	-3.4	-3.9	-7.0	-0.6
Large	-13.1	-6.7	-6.1	-2.2	-2.0
Midsize	2.7	-0.5	-0.2	0.4	0.3
Minivan	-7.9	-9.3	-8.2	-1.0	-0.7
Sport	8.3	4.2	3.2	0.9	0.8
Std	-10.7	-5.7	-5.1	-2.8	-1.8
Subcompact	-8.6	4.1	3.0	1.1	0.8

Fuel	Purchase Fee	Purchase Fee except EV	Purchase Fee except EV & PHEV	Annual Fee	Annual Fee newer than 2023
diesel	-2.3	-4.9	-5.3	-5.4	0.1
electric	-2.3	3.7	2.7	-0.4	-0.5
ethanol	3.4	1.4	1.0	-2.4	0.9
gasoline	3.0	-1.3	-2.1	0.4	0.4
hybrid	-3.0	0.7	-0.3	0.9	0.7
hydrogen	0.0	-8.4	-9.8	0.0	-0.2
plug-in hybrid	-4.3	-8.4	2.5	-1.0	-1.2

The purchase fee example (see first column of Table 10) predicts 2.3% fewer electric and 4.3% fewer plug-in hybrid vehicles in 2040 compared to the baseline. We ran scenarios exempting just electric and both electric and plug-in hybrids from the purchase fee. Just exempting electric vehicles (Column 2 of Table 10) implies a 3.7% increase in electric vehicles and an 8.4% decrease in plug-in hybrid vehicles. Note that the counterintuitive result that the number of subcompacts declines by 8.6% (Column 1 of Table 10) is due to many EVs in the subcompact class. Exempting both electric and plug-in hybrids (Column 3 of Table 10) implies a 2.7% increase in electric and a 2.5% increase in plug-in hybrid vehicles. Predicted 2040 revenues dropped from $4.6 billion/year to $1.8 billion/year (just electric) and to $1.3 billion/year (both electric and plug-in hybrids). Either exemption results in no change in the overall weight distribution

5.3.2 New Annual Fees

Annual fees can be collected through annual registration fees. We charge $.10/lb on the portion of vehicle weight exceeding 3,800 lbs (the approximate mean weight of all vehicles registered in 2024). We simulate applying this fee to all registered vehicles beginning in 2024 (Column 4 of Table 10) or applying to all registered vehicles with model year 2024 or newer beginning in 2024 (Column 5 of Table 10).

About 40% of all registered vehicles in 2024 will have no weight fee. The mean annual fee for those paying it is $77, and the maximum fee is $390. These fees are higher than Florida's but lower than Washington DC. California's current annual car registration fees range from around $200 to over $800 for a new car and depend on factors like vehicle value, type, age, and city/county of residence.

These proposed annual fees lead to almost no change in the distribution of vehicle weights. In 2040 mean weight declines 0.26%, the number of large SUV drops 4%, and the number of heavy and standard pickup trucks declines 3%. However, these fees generate substantial fee revenue-$850 million in 2024 ($78 million if only applied to 2024 and newer) and $1.45 billion in 2040 ($1.2 billion if only applied to 2024 and newer).

5.3.3 Summary

The results presented above provide a lower bound on the change in on-road vehicle weight distributions and an upper bound on the revenue that could be raised by imposing vehicle weight fees. This analysis did not include forecasts of how vehicle manufacturers will react to these fees. It is likely that they will change their vehicles to lower their weight. This response will lead to a greater reduction in on-road vehicle weight and a reduction in the forecast revenues.

The forecasts presented above show that reasonable weight fees can modestly reduce the weight of the heaviest vehicles on the road in California, but these impacts are significantly reduced if EVs and/or PHEVs are exempted. Vehicle purchase fees are likely more effective than annual registration fees since they are immediately salient when considering a vehicle purchase. The overall welfare impact of these fees will depend on whether the cost of the fees is greater than or less than the safety benefits from reducing vehicle weight and (more importantly) spending the fee revenue on infrastructure improvements and/or safety law enforcement.

Chapter 6. Analysis of the relationship between passenger vehicle weight and road degradation

By: John T. Harvey

This memorandum addresses the scope of Task 7, which is to synthesize research on the relationship between passenger vehicle weight (and, if relevant, vehicle weight distribution) and degradation of road infrastructure, including but not limited to pavement impacts.

The effects of vehicles on pavement, the primary road infrastructure asset, have been studied since the 1920s. The original work developed by O.J. Porter identified failures in terms of subgrade shear leading to rutting and excessive deflections leading to fatigue cracking from repeated axle loads (National Archives, 2025). He developed asphalt and aggregate base thickness design curves based on field observations for different soils classified by his new test, the California Bearing Ratio (CBR) test for soil shear strength. He went to the Army Corps of Engineers where the CBR test and design curves were updated for bombers and used around the world for highways and airfields (John Harvey, PE, 2020). A key outcome was that axle loads (in terms of the wheels on the ends of the axles) control pavement damage, not gross vehicle weights (GVWs).

His successor, Francis Hveem (California State Pavement Engineer 1945-1971) helped pioneer better quantitative characterization of the damaging effects of different axle loads and repetitions of those axle loads starting with the Western Association of State Highway Officials (WASHO) Road Test in the 1940s, where the damaging effects of relative loads on axles were first quantified for thin asphalt pavements, and the more comprehensive American Association of State Highway Officials Road Test from 1958 to 1960, where a much wider range of pavements (various thicknesses of asphalt, concrete, and bases) and trucks (varying axle loads and configurations) were used to determine axle load damage rates. Trucks with different loads and configurations were driven for several years on their own closed-circuit tracks with different pavement types and thicknesses in each loop and pavement damage and cracking and rutting were measured as the cumulative axle loads increased on each pavement section. The lightest truck of the 10 truck types in the experiment had 2,000 lb axle loads on a two-axle vehicle (4,000 lb GVW), essentially a pickup truck, and the heaviest had five axles and a 108,000 GVW, with the axle loads exceeding the current Caltrans legal limit by 41%.

The outcome was a set of tables relating the damaging effects of axles with different loads on different pavement structures and a simplified rule to calculate a quick approximation of those effects called the "4th power law"[2]:

$$Damaging\ effect\ of\ an\ axle\ load = \left(\frac{Load}{Reference\ Load}\right)^4$$

Using this quick approximation the following can be seen:

- The damaging effect of one pass of the heaviest axle on the heaviest Tesla car compared to the damaging effect of one pass of a 20,000 lb truck with California's legal maximum single axle load = $(3,360/20,000)^4$ = 0.000797; taking the inverse, this means that it takes approximately 1,255 passes of the Tesla axle to cause the same damage as one pass of the truck's legal limit single axle (Lisa Conant, 2024).
- The damaging effect of one pass of the manufacturer's maximum rear axle load on a Super Duty ¾ ton Ford pickup (F250) compared to the damaging effect of one pass of a 20,000 lb truck with California's legal maximum single axle load = $(6,340/20,000)^4$ = 0.0010098; taking the inverse, this means that it takes approximately 99 passes of the pickup axle to cause the same damage as one pass of the truck's legal limit single axle.

Due to the insignificant damage caused by cars of any weight, including typical personal use or trade use pickups up to ¾ ton models, they have been completely excluded from consideration of pavement thickness design and pavement structural damage calculation (rutting and fatigue cracking on asphalt pavement, cracking on concrete pavement) since pavement design methods were first developed.

Since 2006, Caltrans has been developing increasingly sophisticated pavement structural analysis and design methods for asphalt and concrete pavements. In the early 2020s, Caltrans completed the most comprehensive calibration of those pavement design methods ever undertaken globally, using data collected for the entire 50,000 lane-mile network from 1978 to 2018 (Saboori et al., 2021).

Those asphalt and concrete pavement programs can consider the pickup load shown above and the effect on the pavement life, as well as the range of heavier truck axle loads occurring on state and local roads. As an example, using CalME,[3] the Caltrans asphalt pavement design method, the damaging effect of 10 million passes of each of the following three axle loads on an asphalt pavement with 4.8 inches of asphalt and 6 inches of aggregate base on a clay subgrade are:

- 6,340 lb F-250 Super Duty rear axle maximum allowable load: the pavement has a 95% chance of lasting 40 years before it needs a minor rehabilitation

[2] The Caltrans pavement design method from the 1964 to 2006 used an exponent of 4.2 instead of 4 based on Hveem's combining AASHO Road Test results with California field observations.

[3] https://www.ucprc.ucdavis.edu/calme/

- 10,000 lb single axle load: the pavement has a 95% chance of lasting 8 years
- 20,000 lb legal single axle load: the pavement has a 95% chance of lasting 6 months

For these reasons, and because the car and pickup axle examples shown (heaviest Tesla car, heaviest pickup) are extremes, **it is expected that heavier cars and light trucks, including those with electric batteries and fuel cells, will continue to have a minor effect on pavement damage and pavement maintenance and rehabilitation costs.**

A 2022 report for the legislature looked at the effects of battery electric and fuel cell implementation in medium and heavy trucks and similarly found a small impact on pavement (Harvey et al., 2020). **Extrapolating those results to heavier cars and light trucks, there should be insignificant effects on pavement.** Looking at the analysis in that report of the effects of heavier trucks on bridges, **it is expected that heavier cars, including battery electric and fuel cell vehicles, and light trucks will have no effect on bridge maintenance and rehabilitation**.

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