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Evaluation and Update of MASH Test Vehicles

FINAL REPORT

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Disclaimer

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16. Abstract

The Manual for Assessing Safety Hardware (MASH) requires full-scale crash testing of roadside features using worst practical impact conditions, which are supposed to be representative of the composition of vehicles involved in run-off-road crashes and roadside departure speeds and angles. For this research effort, the composition of the United States vehicle fleet was investigated using three data sources: state Department of Transportation (DOT) crashes; state and national vehicle registrations; and new vehicle sales. New vehicle sales were the most convenient and economical data source, and was determined to be representative of both crash and registration data; therefore analysis was recommended using new vehicle sales.

A sales-based cumulative distribution for new vehicle weights was used to identify the 5th and 95th percentile weights to update criteria for the 1100C small car and 2270P pickup truck, respectively. The 5th percentile weight was determined to be 2,800 lb and 4-door, gas-powered, base trim candidate small car options were recommended. Relatively few pickup truck options were identified at the 95th percentile weight of 5,850 lb, and because recent 2018 and 2019 model year pickup truck weights were much lower for Chevrolet and Ram models, a 92.5 percentile weight of 5,400 lb was selected, and a pickup truck with four-wheel drive (4WD), ½-ton suspension, and crew cab trim was recommended. Recommendations were provided to update the 1500A mid-size car; it was recommended that compact (crossover) utility vehicles (CUVs) be considered as they accounted for 40% of all new vehicle sales in 2017. A crash test pilot program should be implemented to begin testing of the recommended MASH small and large passenger vehicles. Updated MASH passenger vehicle properties and a method for continually updating vehicle selection criteria are herein recommended.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in.	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short ton (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela per square meter	cd/m^2
		FORCE & PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in.
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yard	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliter	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or “metric ton”)	1.103	short ton (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
		FORCE & PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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CHAPTER 1 Executive Summary

The Manual for Assessing Safety Hardware (MASH) requires full-scale crash testing of roadside features using worst practical impact conditions. Historically, the selection of worst-practical case conditions relied on defining critical distributions of vehicle and roadside departure attributes. Vehicle attributes primarily relied on curb weight distributions, but other relevant parameters included vehicle body styles involved in crashes (cars and light truck vehicles), age, and center-of-mass (CM) or center-of-gravity (c.g.) heights were also critical inertial parameters. Vehicle selection for full-scale crash testing is intended to be representative of the contemporary passenger vehicle fleet. Supplementary research underway for NCHRP Project No. 22-42 is intended to define the impact conditions associated with worst practical impact conditions, which are expected to be independent of vehicle attributes.

Researchers at the Midwest Roadside Safety Facility (MwRSF) investigated attributes of passenger vehicle sales to determine if the vehicle selection criteria shown in MASH should be revised to accommodate changes in the vehicle fleet. Initially, three different methodologies were evaluated to determine which was most economical, reliable, efficient, and accurate means of determining recommended test vehicle attributes. The methodologies were: crash history and/or in-service performance evaluation (ISPE) of real-world crash data and collection of vehicle attributes; vehicle registration data from national and state sources; and national sales data for new vehicles. Based on the effort and difficulties of collecting representative data for each method, as well as the time and consistency concerns between methods, the new vehicle sales distribution method was recommended for future studies.

Representative vehicles were documented using sales data, and registration and crash data were observed to validate sales data use. Findings suggest compact utility vehicles (CUVs), small cars, mid-size cars, and pickup trucks comprise the most common vehicles on U.S. roadways, and based on new sales data, the sustained volume and percentage of CUVs for new vehicle sales warrants consideration in roadside system crash testing.

New vehicle sales data indicated that the 5th and 95th percentile weights were approximately 2,800 lb and 5,850 lb, respectively. A suite of 4-door, gas-powered, base trim level car options was identified which was consistent with the targeted small car weight, and the Hyundai Elantra was recommended as the MASH small passenger vehicle. Relatively few pickup truck options were identified at the 95th percentile weight. Therefore, the 92.5 percentile weight of 5,400 lb was recommended for the large passenger vehicle. A four-wheel drive (4WD), ½-ton suspension, crew cab pickup truck was identified as the target vehicle class, and the Ram 1500 was recommended as the MASH large passenger vehicle.

Potential intermediate passenger vehicles were also explored, and four vehicle classes (two mid-size sedans and two CUV classes) were identified as potential passenger vehicle candidates. It was recommended that a pilot crash-testing program be conducted using CUV vehicles to explore vehicle-barrier interactions for guardrails, bridge rails, and other critical roadside systems. CUVs have never been used in crash testing, and implementation of a CUV crash testing program or ISPE is imperative to begin to evaluation CUV impact behavior with different roadside hardware (guardrails, concrete barriers, cable barriers, etc.). CUVs may have different vulnerabilities compared to other test vehicles, including vehicle instability, which could result in a unique evaluation of roadside systems.

A crash test program should be implemented to begin testing of all the recommended MASH small and large passenger vehicles. These studies will provide a critical evaluation of the adequacy of the recommended test vehicle attributes and may be used to determine which standardized vehicle attributes are most desirable. A recommended standard methodology for conducting similar studies as was completed herein was also recommended.

Due to rapid changes in the vehicle fleet, the rise of sales volumes and percentages of alternative power source (APS) vehicles including hybrid-electric, battery-electric vehicles (BEVs), and fuel cell vehicles, as well as motorcycles, the trajectory of new vehicle sales may warrant re-evaluation prior to the next revision to MASH vehicle selection and test performance criteria. Furthermore, recent production of the largest models of half-ton pickup truck sales were significantly lightened, and weights of new Dodge Ram 1500, Chevrolet Silverado 1500, GMC Sierra 1500, and Ford F-150 vehicles may no longer be representative of the 92.5 percentile weights.

CHAPTER 2 Introduction

2.1 Background

Modern guidelines for conducting full-scale crash tests of passive roadside features, including roadside barriers, are described in detail in the American Association of State Highway and Transportation Officials' (AASHTO's) *Manual for Assessing Safety Hardware* (MASH-2016) [1]. The primary objective of MASH is to guide the evaluation of roadside safety hardware with standardized criteria which ensures its crashworthiness and provides adequate safety for vehicle occupants in the event of a collision with roadside hardware. Full-scale vehicle crash testing procedures are incrementally revised to remain representative of real world, "worst practical conditions" for impact scenarios. Impact scenarios are defined using test matrices which include vehicle selection guidelines, and impact speed, angle, and location depending on the test article. Evaluation criteria are used to verify the crashworthiness of roadside features, which include measurements and analysis of deformation and intrusions, impact accelerations and velocities, and vehicle post-impact trajectories and stability.

It is impractical to conduct full-scale crash tests on all roadside features using every potential vehicle and impact condition. Instead, researchers have relied on evaluation criteria and test conditions judged to be conservative, based on the assumption that real-world impact conditions are generally less severe than impact conditions used in full-scale testing. Standardized impact conditions which are deemed conservative have been based on results of crash reconstruction studies involving run-off-road (ROR) crashes, which provide ROR vehicle speeds and angles, as well as the types of vehicles typically involved in crashes. Likewise, vehicle selection was only based on sales distribution of vehicle curb weights. Dimensional properties of each test vehicle were selected to represent test vehicles in the target weight range [1].

Test criteria utilize passenger vehicles whose curb weights and geometries are representative of upper and lower bounds of modern, new passenger vehicle sales. It is intended that the differences in passenger vehicle weights and sizes will “bracket” the performance for other, untested vehicle and impact condition combinations. Over time, test criteria and standardized passenger test vehicles evolved to reflect changes in the vehicle fleet.

- In the 1970s, cars comprised nearly 80% of the vehicle fleet and ranged from very light (mini-compact) to heavy, full-size sedans. Full-scale crash testing procedures established by TRC 191 (1978) [2] and NCHRP Report No. 230 (1981) [3] used a small and large sedan as test vehicles to represent passenger vehicles.

- Pickup trucks were introduced in 1989 under AASHTO’s *Guide Specifications for Bridge Railings* [5] as one of seven passenger vehicle sizes, which included four cars and three vans/pickup trucks. Commercial vehicles, such as the single-unit truck and tractor-trailer vehicles, were also introduced. Three barrier performance levels were also established by this mandate (PL-1, PL-2, and PL-3) to evaluate different impact scenarios.

- In 1993, the publication of NCHRP Report No. 350 [6] established subcompact and mini-compact cars and a ¾-ton pickup truck as passenger test vehicles. Test conditions and evaluation criteria also evolved with a gradation of performance levels ranging from Test Level 1 (TL-1) (31-mph impact at 25 degrees for a 4,409-lb pickup truck and 20 degrees for 1,808-lb small car) to TL-6 (62-mph impact for passenger vehicles and 50-mph impact at 15 degrees for a tank-trailer vehicle).

Current full-scale crash testing guidelines are described in AASHTO’s MASH, which strives to capture the worst practical conditions for vehicle-to-hardware impact scenarios [1]. A comprehensive review of new vehicle sales was conducted in the early 2000s to determine the distributions of vehicle dimensions, weights, sizes, and body styles. Sales data from 2002 indicated that the passenger vehicle fleet experienced many changes in body styling, crashworthiness, weight, dimensions, and features since the 1990s. Additionally, most lightweight cars, such as the 1,808-lb vehicles, were no longer being produced. The nominal targets for standardized passenger vehicle selection were the 5^{th} and 95^{th} percentile weights. Size specifications of the vehicle fleet and sales data showed that in 2002, the 95^{th} percentile passenger vehicle weight was approximately 5,420 lb, which was an increase of nearly 1,000 lb from the pickup truck used under NCHRP Report No. 350 guidelines. However, to moderate the significant increase in weight between NCHRP Report No. 350 vehicles and MASH recommendations, the weights of the passenger car and pickup truck were reduced to approximately the 2^{nd} and 90^{th} percentiles. Three passenger vehicle sizes were selected for use in MASH's crash testing matrices:

- 2,420-lb Small Car (1100C)
- 3,300-lb Mid-Size Car (1500A)
- 5,000-lb Pickup Truck (2270P)

MASH also recommends that passenger vehicle criteria be updated periodically; however, an incremental period to review the vehicle fleet is not established. Unfortunately, the criteria for MASH passenger vehicle selection have not been revised since the early 2000s. A recent study conducted by RoadSafe LLC showed that while heavy duty vehicles are mostly unchanged since this time, passenger vehicles were in need of evaluation [8]. Some vehicle models ceased production, new models have been produced, and significant body style and dimensional alterations have been made to long-running vehicle models. Recent analysis by crash testing laboratories determined that there were no modern mass-production vehicles in the U.S. capable of meeting the recommended vehicle properties for the MASH small car vehicle. The current sales weight distribution of passenger vehicles is unknown, and MASH passenger vehicles are required to be representative of the current fleet. Furthermore, little to no research has been performed to evaluate how modern light trucks have changed and whether the currently-used pickup truck is the correct vehicle for replicating worst practical conditions, as described by MASH [1]. In addition, the emergence of "crossover" or compact utility vehicles (CUVs) and alternatively-powered vehicles (electric, hybrid, and plug-in hybrid) have prompted the need to review standard specifications for MASH passenger vehicle selection and determine what revisions, if any, are necessary to MASH vehicle specifications.

2.2 Research Objective

The research objective of this project was to investigate attributes and sales volumes of vehicles in the U.S., identify representative vehicles based on weight distribution, and recommend revisions to MASH vehicle selection specifications, if any. In addition, techniques for conducting future vehicle update studies were discussed. Updated vehicle specifications for MASH passenger vehicles and methods for incrementally updating specifications are recommended herein.

2.3 Research Approach

The research objective was proposed and completed through execution of the following tasks: (1) literature review of historical guidelines for test vehicle criteria justifications; (2) techniques for updating future passenger test vehicle specifications; (3) identification of common passenger vehicle body styles through analysis of crash, registration, and sales data; (4) creation of vehicle sales weight distribution to identify target passenger vehicle weights; (5) selection of passenger vehicle candidates and dimensional properties based on target weights and vehicle availability; and (6) summary report, test vehicle recommendations, and methodology discussion for maintaining relevance with the evolving U.S. vehicle fleet.

CHAPTER 3 Literature Review

3.1 Background

Guidelines for previous full-scale crash testing procedures were reviewed to observe methodologies for selection of passenger test vehicle properties and weights and justifications of vehicle selection. Historical crash test procedures included few justifications for passenger vehicle selection for full-scale crash testing. Vehicle selection justifications were summarized and described when available, and for those not accompanied by justifications, parameters of vehicle selection were discussed.

Additionally, the National Highway Traffic Safety Administrations (NHTSA) and Insurance Institute of Highway Safety (IIHS) with the Highway Loss Data Institute (HLDI) each conduct generalized crash tests to obtain vehicle safety ratings. These tests may be indicative of which vehicles exhibit the greatest occupant risk during general crash scenarios. Vehicle classification systems were also reviewed to determine a consistent passenger vehicle classification system to use during crash, registration, and sales data analysis.

3.2 Historical Crash Testing Standards

3.2.1 Historical Crash Test Guidelines

The first uniform full-scale crash testing procedures for guardrails were published in 1962 in *Highway Research Correlation Services Circular (HRC) 482* [3]. This one-page document defined test conditions based on vehicle weight, impact speed, and impact angle. Full-scale crash testing procedures were further standardized during NCHRP Project 22-2 to develop new crash test standards with justifications, culminating in NCHRP Report No. 153, published in 1974 [9]. The revised procedures contained test matrices defining vehicle type, speed, and impact angles which applied to longitudinal barriers, crash cushions, and breakaway supports. Two passenger vehicle sizes were selected by weight: a 2,250-lb subcompact sedan and a 4,500-lb large sedan.

Passenger test vehicles were approximately representative of low- and high-mass ends of vehicle mass distributions. Passenger vehicles were required to have suspension and handling characteristics found in common vehicles. Vehicle bumper height, weight distribution, and vehicle structure were to be documented for each test vehicle. Vehicles could be ballasted with additional mass to meet specified mass criteria. The report also suggested using passenger vehicles without specifying the manufacturer because it allows a more general evaluation of the tested hardware design.

In 1978, NCHRP Report No. 153 was revised with Transportation Research Circular (TRC) 191 [2]. The same two passenger vehicle sizes were used under TRC 191 and NCHRP Report No. 153. Bumper height, mass distribution, and vehicle structure were added as tracked parameters, and the vehicle was specified to have a front-mounted engine. The passenger vehicle age was indicated to be within four model years of the crash test, with a maximum age of six years, suggesting that vehicles used in crash testing be representative of the modern vehicle fleet.

Substantial revisions to TRC 191 were implemented as part of NCHRP Project 22-2(4), which culminated in the publication of NCHRP Report No. 230 in 1981 [3]. Researchers had observed a trend toward smaller-sized vehicles due to the gasoline crisis of the late 1970s. Subcompact and large sedan classes were redefined, and an 1,800-lb mini-compact sedan was added to the test matrices. Vehicle type, impact speed and angle, and target impact severity were each specified in the test matrices and were dependent on the appurtenance being tested. The test vehicle specifications for full-scale crash testing performed according to NCHRP Report No. 230 are shown in Table 1.

Table 1. Test Vehicle Specifications Denoted in NCHRP Report No. 230 [4]

Designation	1800S	2250S	4500S	20,000P	32,000P	40,000P	80,000A	80,000F
Type	Minicompact Sedan	Subcompact Sedan	Large Sedan	Utility Bus	Small Inter-city Bus	Large Inter-city Bus	Tractor/ Van Trailer	Tractor/ Fluid Tanker
Mass—lb								
Test Inertial[b]	1800 ±50	2250 ±100	4500 ±200	13,800 ±500	20,000 ±750	29,400 ±1000	—	—
Dummy[c]	165	165 ±165	165 ±165	6,200 ±500	6,000 ±1,000	6,000 ±1,000	—	—
Ballast (loose)[d]	0	0	0	0	6,000 ±1,000	4,000 ±1,000	—	—
Gross Static[e]	1950 ±50	2500 ±100	4500±300	20,000 ± 500	32,000 ± 750	40,000 ± 1000	80,000 ±2000	80,000 ±2000
Typical Mass Moments of Inertia[f] lb-ft-s^2								
I_{zz}—Yaw	667[h]		4167	48,000		125,000		
I_{yy}—Pitch	496[g]		4625	51,600		156,500		
I_{xx}—Roll	150[g]		—	5,660		23,000		
Typical Center of Mass-in.								
g—Height from grade	19.5	21.8	27.0	41		55.8		
h—From front axle	32.1	40.5	49.8	159		216		
c—Wheel base	87.0	97	121	254		260		
Reference								
DOT-FH	11-9287 11-9486	11-9462	11-8130	11-9462		11-9462		

Vans and pickup trucks were first introduced as passenger test vehicles in 1989 under the evaluation criteria established in AASHTO's *Guide Specifications for Bridge Railings* [5]. AASHTO recognized an evolution in roadside safety design that required an update to NCHRP Report No. 230, thus, thirteen vehicles were specified for crash testing, as shown in Table 2. Three performance levels (PL-1, PL-2, and PL-3) were also developed to differentiate strength and design needs for bridge railings.

Table 2. AASHTO Guide Specifications for Bridge Railings Test Vehicle Descriptions [5]

Vehicle Type	Weight (lb)	Width (ft)	Length (ft)	C.G. Height (in.)
Passenger Cars	2,000	5.5	13.5	19.0
	2,700	6.0	15.0	20.0
	3,635	6.5	18.0	21.0
	4,500	6.5	18.0	21.5
Vans and Pickup Trucks	4,000	5.5	15.0	27.0
	5,500	6.5	16.5	30.0
	7,000	7.5	18.0	36.0
Single-Unit Trucks	8,000	7.5	18.0	43.0
	17,500	8.0	30.0	53.0
	30,000	8.0	35.0	68.0
Combination Trucks	30,000	8.0	55.0	52.0
	50,000	8.0	55.0	63.0
	75,000	8.0	55.0	78.0

In 1993, NCHRP Report No. 350 was published and encompassed a wider range of test procedures for barriers, terminals, crash cushions, breakaway support structures, truck-mounted attenuators, and work zone traffic control devices [6]. Researchers observed significant increases in a "light truck" vehicle class which predominantly consisted of pickup trucks and some vans. Nearly 25% of all passenger vehicles during this time were considered "light trucks," thus a ¾-ton, single-cab, full-size pickup truck was introduced as a standard vehicle in place of the 4,500-lb large sedan. Test vehicle selection was standardized and the classes are shown in Table 3. Passenger vehicle test specifications are shown in Table 4.

Table 3. Test Vehicle Weights and Classes Used in NCHRP Report No. 350

Test Vehicle	Curb Weight (kg)
Mini-Compact Car	700
Small Car	820
Pickup Truck	2,000
Single-Unit Cargo Truck	8,000
Tractor Trailer	36,000

Table 4. NCHRP Report No. 350 Passenger Vehicle Test Specifications [7]

Property	700C (Small Car)	820C (Small Car)	2000P (Pickup Truck)
MASS (kg)			
Test Inertial	700 ± 25	820 ± 25	2000 ± 45
Dummy	75	75	---
Max. Ballast	70	80	200
Gross Static	775 ± 25	895 ± 25	2000 ± 45
DIMENSIONS (cm)			
Wheelbase	230 ± 10	230 ± 10	335 ± 25
Front Overhang	75 ± 10	75 ± 10	80 ± 10
Overall Length	370 ± 20	370 ± 20	535 ± 25
Track Width[b]	135 ± 10	135 ± 10	165 ± 15
CENTER OF MASS LOCATION[a] (cm)			
Aft of Front Axle	80 ± 15	80 ± 15	140 ± 15
Above Ground	55 ± 5	55 ± 5	70 ± 5
LOCATION OF ENGINE	Front	Front	Front
LOCATION OF DRIVE AXLE	Front	Front	Rear
TYPE OF TRANSMISSION	Manual or Automatic	Manual or Automatic	Manual or Automatic

NCHRP Report No. 350 required that vehicles used in crash testing be free of major body damage, have a maximum six-year vehicle model age, and that all structural components be intact. It was recommended that the 700C and 820C small cars be selected from one of the top two selling vehicle models for a given year. NCHRP Report No. 350 also mandated the measurement of curb mass, test inertial mass, loose ballast mass, gross static mass, and dummy mass to meet test vehicle documentation, and further specified that passenger vehicles should be selected so that minimal adjustments to the curb mass are necessary to reach the test inertial mass.

3.2.2 MASH Testing Guidelines

3.2.2.1 Test Vehicle Selection

In the early 2000s, as researchers observed the continued expansion of light truck vehicles, lightweight mini-compact cars became challenging to find. Vehicle sales from 2002 were reviewed in detail and heavier vehicles were recommended. The ¾-ton, single-cab, full-size pickup truck was replaced by a ½-ton, quad-cab, mid-size box pickup truck, and the specified weight was increased by approximately 600 lb. The first edition of MASH, published in 2009, updated the guidelines for full-scale scale crash testing and vehicle selection compared to NCHRP Report No. 350 [10]. The primary philosophy behind MASH crash testing is that a crash test event should be representative of practical worst-case impact conditions. Test parameters indicative of practical worst-case conditions included test vehicle mass and center-of-gravity (c.g.) height, impact speed and angle, and point of impact on the system. Additionally, MASH prescribed that passenger vehicles in crash testing have a maximum six year age, and to ensure the vehicle was representative of characteristics of the vehicle fleet, the test vehicle should have a minimum of 50,000 units sold and desired to have at least 100,000 unit sales per year [1]. Recommended properties of the passenger vehicles used in MASH crash testing are shown in Figure 1.

TABLE 4-1. Recommended Properties of 1100C, 1500A, and 2270P Test Vehicles

Property	1100C (Small Car)	1500A (Intermediate Car)	2270P (Pickup Truck)
MASS, lb (kg)			
Test Inertial	2420 ± 55 (1100 ± 25)	3300 ± 75 (1500 ± 35)	5000 ± 110 (2270 ± 50)
Dummy	165 (75)	Optional[a]	Optional[a]
Max. Ballast	175 (80)	440 (200)	440 (200)
Gross Static	2585 ± 55 (1175 ± 25)	3300 ± 75 (1500 ± 35)[a]	5000 ± 110 (2270 ± 50)[a]
DIMENSIONS, in. (mm)			
Wheelbase	98 ± 5 (2500 ± 125)	N/A	148 ± 12 (3760 ± 300)
Front Overhang	35 ± 4 (900 ± 100)	N/A	39 ± 3 (1000 ± 75)
Overall Length	169± 8 (4300 ± 200)	N/A	237 ± 13 (6020 ± 325)
Overall Width	65 ± 3 (1650 ± 75)	N/A	78 ± 2 (1950 ± 50)
Hood Height	24 ± 4 (600 ± 100)	N/A	43 ± 4 (1100 ± 75)
Track Width[b]	56 ± 2 (1425 ± 50)	N/A	67 ± 1.5 (1700 ± 38)
CENTER OF MASS LOCATION,[c] in. (mm)			
Aft of Front Axle	39 ± 4 (990 ± 100)	N/A	63 ± 4 (1575 ± 100)
Above Ground (minimum)[d]	N/A	N/A	28.0 (710)
LOCATION OF ENGINE	Front	Front	Front
LOCATION OF DRIVE AXLE	Front	Front or Rear	Rear
TYPE OF TRANSMISSION	Manual or Automatic	Manual or Automatic	Manual or Automatic

a If a dummy (surrogate occupant) is used, the gross static vehicle mass should be increased by the mass of the dummy.
b Average of front and rear axles.
c For "test inertial" mass.
d 2270P vehicle must meet minimum c. g. height requirement.

Figure 1. Recommended Properties of 1100C, 1500A, and 2270P Passenger Vehicles [1]

MASH targeted the 5th and 95th percentile weights of passenger vehicles as the desired test vehicle weights. These values were assumed to encompass the majority of vehicle collisions with roadside features, such that if both the small and large representative passenger vehicles were successfully crash tested, it should provide good performance for almost all vehicle sizes in between [1]. Based on the distribution of vehicle sales in 2002, significant increases in test vehicle weight were required for both the small car and pickup truck classes to meet the 5th and 95th percentile weights. Therefore, a compromise solution was adopted to temper the increase in test vehicle weights such that the existing roadside hardware would not abruptly fail most crashworthiness criteria. As well, it was unknown in the aftermath of September 11, 2001, if rising fuel prices and increased stringency for emissions standards would result in reduced weights of passenger vehicles. The final recommended test vehicle weight for the small passenger vehicle was 2,420 lb, which conformed to the 2nd percentile vehicle weight and which had many viable vehicle sales with similar curb weights. The MASH 1100C vehicle was targeted to weigh approximately 620 lb more than the NCHRP Report No. 350 820C small car, which weighed approximately 1,808 lb. Likewise, the MASH 2270P light truck vehicle weight was selected to conform to the 90th percentile vehicle weight of 5,000 lb. This represented an increase of approximately 600 lb compared to the 4,400-lb, 2000P light truck vehicle in NCHRP Report No. 350 [1].

An intermediate passenger vehicle (1500A) was added to the standard test vehicle selection, specifically intended for evaluating the performance of staged energy absorbing systems such as crash cushions and end terminals. The 1500A was specified to be 3,300-lb sedan because it was determined to be the most representative vehicle body style and mass for exploring occupant risk measures in evaluation of staged energy absorbing devices. In 2016, a revision to MASH was published which included some language and evaluation criteria clarifications and additional test matrices for cable median barrier testing, which included the 1500A test vehicle. Although MASH recommends reviewing the vehicle fleet periodically, the revision to MASH did not incorporate any review or revision of test vehicle specifications.

Three examples of MASH passenger vehicles are shown in Figure 2.

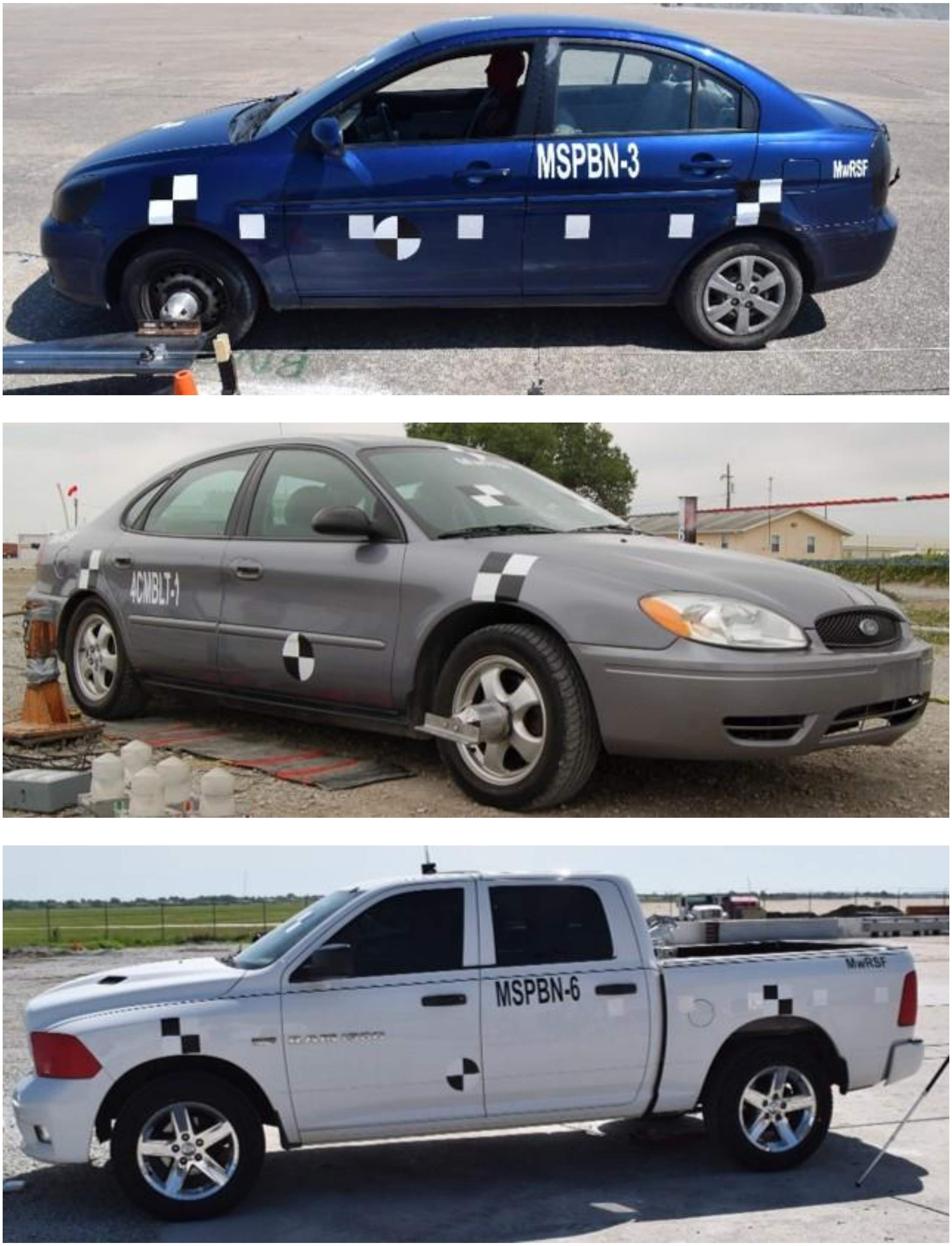


Figure 2. 1100C, 1500A, and 2270P MASH Passenger Vehicles [11-13]

Next, criteria were established to ensure that the test vehicles selected for crash testing would be standardized with similar geometrical profiles. For each vehicle class, a set of potential test vehicles with curb weights within 2.2% of the MASH target weight were identified, and the range of vehicle attributes for similar vehicles in the set were used to bracket the test vehicle geometrical specifications. For light truck vehicles, the center-of-gravity (c.g.) height was also deemed critical. A review of the distributions of vehicle c.g.'s based on National Highway Traffic Safety Administration (NHTSA) New Car Assessment Program (NCAP) and empirical equations for c.g. height based on sample measurements indicated that newer light truck vehicles, including vans, pickups, and large sport utility vehicles (SUVs), had relatively high c.g.'s. Thus, a minimum c.g. height of 28 in. was adopted as a large passenger vehicle requirement.

In the fall of 2019, new guidelines were issued by AASHTO to address a critical need for small car vehicles, because no mass-production, unmodified small car in the United States satisfied all the geometrical and weight requirements described in MASH. The new guidelines permitted some flexibility for small car parameters but did not change the test vehicle target weight. As a result, the test vehicles required in MASH still generally conform to a distribution of vehicle sales and weights based on data from sales distributions in 2002. This has prompted the need to evaluate the changes in the U.S. vehicle fleet to determine vehicles that are representative of real-world crash events. In addition, it is desired to establish guidelines to readily and consistently update MASH passenger vehicle selection criteria in the future.

3.2.2.2 MASH Evaluation Criteria and Vehicle Stability

During full-scale crash testing, MASH evaluation criteria are established for both the vehicle and the roadside hardware. Evaluation criteria consists of structural adequacy, occupant risk, and post-impact vehicular response [1]. Structural adequacy refers to the ability of a test article to contain and redirect impacting vehicles with controlled lateral deflection of the test article. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact response shows the potential of a vehicle to collide with other vehicle and/or fixed objects after impacting the test article. Standard evaluation criteria for longitudinal barriers are shown in Table 5, and additional test evaluation criteria can be found in MASH 2016.

Table 5. MASH 2016 Evaluation Criteria for Longitudinal Barrier [1]

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="11">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

Evaluation criteria in MASH dictates that test vehicles must remain upright during and after collision with roll and pitch angles not exceeding 75 degrees [1]. While rollover occurs in less than 10% of crashes involving passenger vehicles, it accounts for nearly one-third of passenger vehicle occupant fatalities [14]. MASH has historically used c.g. height as an indicator of risk for rollover. Since June 2000, NHTSA has used a measure known as Static Stability Factor (SSF) to estimate a vehicle's potential for rollover. SSF is a ratio that is equal to one-half of a vehicle's track width divided by its c.g. height, as shown in Equation 1.

$$SSF = \frac{Track\ Width}{2 * C.G.Height} \quad \text{(Eq 1)}$$

Binary-response models ("rollover" or "no rollover") developed by NHTSA showed that SSF is a reliable indicator of rollover potential in single-vehicle crashes. Research has justified the use of SSF in NHTSA's star rating system for vehicle safety, specifically rollover resistance. Corresponding NHTSA star ratings with chance of rollover in a single-vehicle crash are shown in Table 6.

Table 6. SSF as an Indicator of Vehicle Rollover in a Single Vehicle Crash [14]

Rating	SSF	Chance of Rollover
5-star	> 1.45	< 10%
4-star	1.25 - 1.44	10% - 20%
3-star	1.13 - 1.24	20% - 30%
2-star	1.04 - 1.12	30% - 40%
1-star	< 1.03	> 40%

3.3 NHTSA and IIHS/HLDI Vehicle Safety Ratings

Vehicle damage can be indicative of injury severity experienced by a vehicle occupant. NHTSA and IIHS/HLDI each conduct frontal and side impact crash tests to determine vehicle occupant safety. NHTSA and IIHS/HLDI then assign each vehicle a safety rating based on the results of each crash test. These safety ratings can be indicative which vehicles potentially exhibit the greatest occupant risk during crashes in general.

3.3.1 NHTSA Safety Ratings

In the 1970s, NHTSA incorporated NCAP, a series of crash tests to observe the safety performance of available vehicles in the U.S. marketplace [15]. Vehicles are rated on a scale of 1 to 5 stars based on their performance in three crash test scenarios (1 star for poor performance, 5 stars for optimal performance). The frontal crash test scenario simulates a head-on collision with a fixed barrier at 35 mph. The side barrier crash test scenario simulates an intersection type collision during which the tested vehicle is impacted perpendicularly to the driver-side door. The side pole crash test scenario simulates an impact speed of 20 at 75 degrees into a 1-in. pole [15]. Lastly, NCAP observes the SSF of the vehicle to determine the likelihood of vehicle rollover to occur during a crash event. Impact locations for each test scenario are shown in Figure 3.

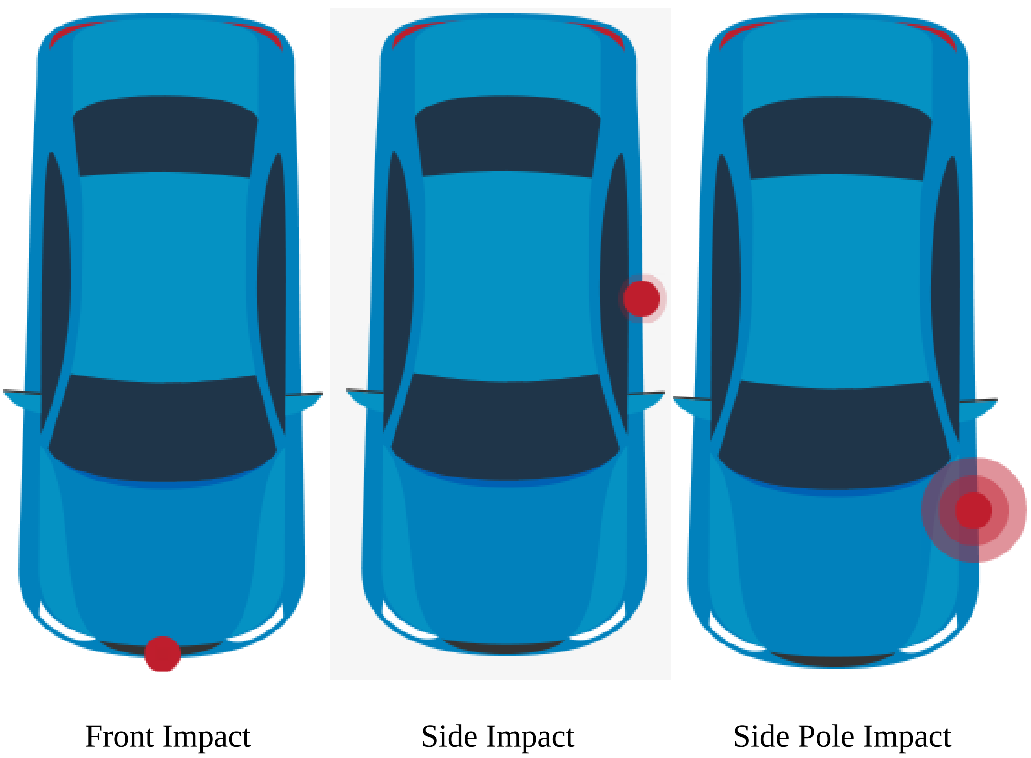


Figure 3. Impact Locations of NHTSA Crash Test Scenarios [15]

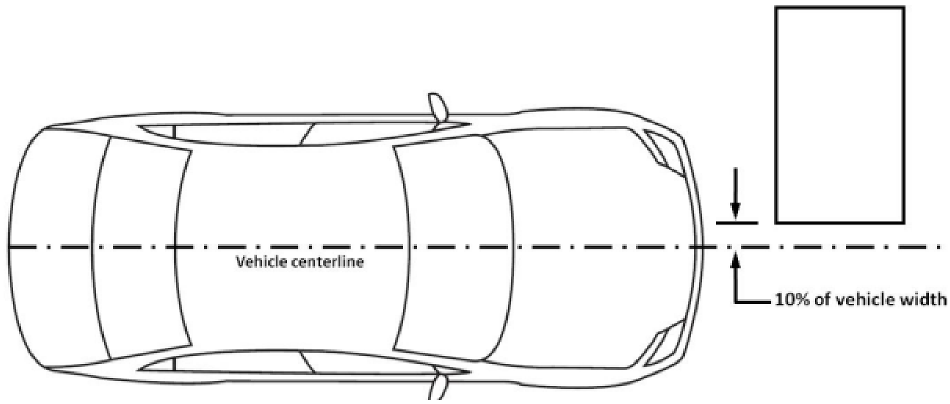
3.3.2 IIHS Safety Ratings

IIHS similarly evaluates the crashworthiness of vehicles using six tests: moderate overlap front, driver-side and passenger-side small overlap front, side, roof strength, and head and seat restraints [16-19]. Additional testing applicable to Advanced Driver Assistance Systems (ADAS)-equipped vehicles for automatic emergency braking may also be conducted, depending on vehicle systems under evaluation. Schematics of test setups are shown in Figure 4, and examples of the crash test scenarios are shown in Figure 5. Some of the test descriptions are provided below:

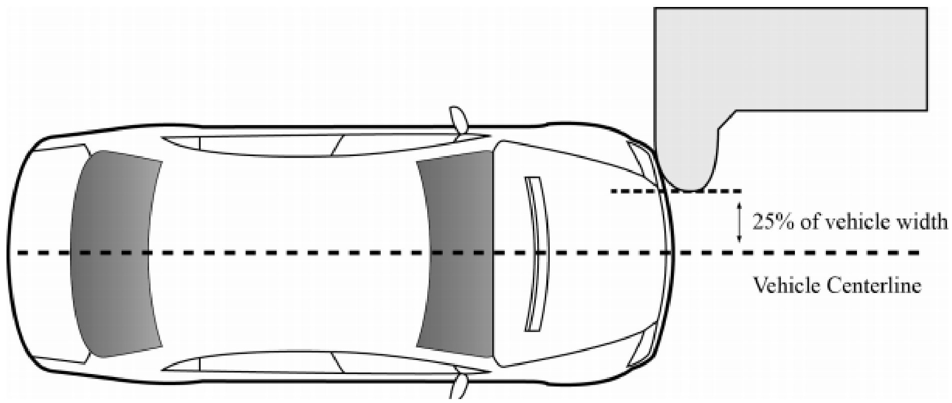
- Moderate Overlap: Frontal collision at 40 ± 0.6 mph and 40 ± 1 percent overlap of the width of the vehicle with a deformable barrier. (Left side only)
- Small Overlap: Frontal collision at 40 ± 0.6 mph and 25 ± 1 percent overlap of the width of the vehicle with a rigid barrier. (Right and left sides)
- Side-Impact: Stationary test vehicle is impacted on the left (driver) side at 31.1 mph (50 km/h) with a vehicle weighing approximately 3,300 lb (1,500 kg).

Vehicle overlap is defined as a percent of the vehicle width. A 25 percent overlap in the small overlap test is determined by offsetting the centerline of the vehicle by a quarter of the vehicle's width away from the reference point on the barrier. Likewise, the 40 percent overlap test is configured such that the test vehicle centerline is offset by 10 percent of the vehicle's width from the reference point on the deformable barrier.

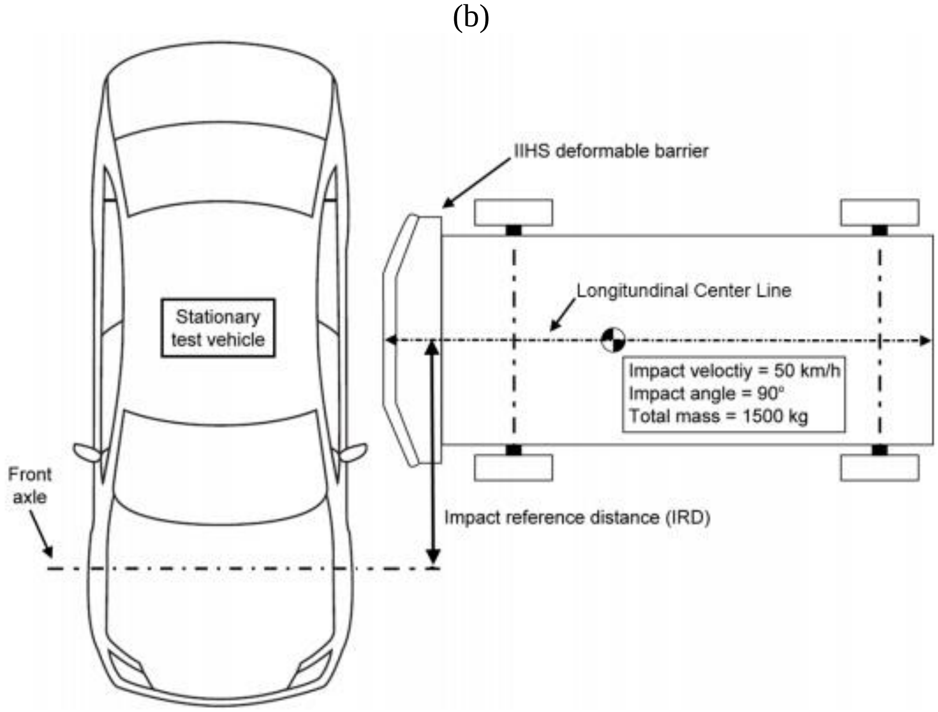
Crash test summaries include ratings describing each individual test result as well as the overall safety performance of the vehicle. From best to worst, a vehicle can attain one of four rating classifications: good (G), acceptable (A), marginal (M), or poor (P). Ratings are based on vehicle crush measurements and dynamic measurements, which are a function of seat parameters and forces in the test surrogate dummy's neck.



(a)



(b)



(c)

Figure 4. IIHS Test Configurations (a) Moderate Overlap [17] (b) Small Overlap (left-side shown) [18] (c) Side Impact [19]

Moderate Overlap Front

Small Overlap Front Driver Side

Side Impact

Small Overlap Front Passenger Side

Figure 5. Examples of IIHS Test Conditions [16]

3.4 Vehicle Classifications

A variety of classifications exist for vehicles, and each classifying organization segments vehicles based on their own criteria. A few of the most common vehicle classification standards are those of NHTSA, Federal Highway Administrations (FHWA), and Environmental Protection Agency (EPA). Vehicle manufacturers typically classify vehicles based on configuration and size. Vehicle configurations refer to body style, drive wheels, engine location, transmission, and suspension. Manufacturer vehicle sizes include subcompact, compact, small, mid-size, and large.

3.4.1 Classification Systems

NHTSA categorizes vehicles by their class and curb weight. While utility vehicles, pickup trucks, and vans are visibly distinguishable by their class, passenger cars are subdivided into five groups that are used by vehicle manufacturers for classification, as shown in Table 7. These passenger car classifications are used during vehicle analysis in later chapters.

Table 7. NHTSA Passenger Car Classification Criteria [15]

Passenger Car Classification	**Curb Weight (lb)**
Mini	1,500 - 1,999
Light (Sub-Compact)	2,000 - 2,499
Compact	2,500 - 2,999
Medium (Mid-Size)	3,000 - 3,499
Heavy (Large)	3,500 and over

The FHWA classifies vehicles using two approaches, one of which uses gross vehicle weight rating (GVWR) to segment vehicles classes, as shown in Table 8. The other method assigns a vehicle to a class based on body style and the number of axles [20].

Table 8. FHWA Vehicle Weight Classes and Categories [21]

Vehicle Class	GVWR Category
Class 1: < 6,000 lb	Light Duty < 10,000 lb
Class 2: 6,001 – 10,000 lb	
Class 3: 10,001 – 14,000 lb	Medium Duty 10,001 – 19,500 lb
Class 4: 14,001 – 16,000 lb	
Class 5: 16,001 – 19,500 lb	
Class 6: 19,501 – 26,000 lb	Light Heavy Duty 19,501 – 26,000 lb
Class 7: 26,001 – 33,000 lb	Heavy Duty > 26,001 lb
Class 8: > 33,001 lb	

The EPA segments vehicles based on their duty (light-, medium-, and heavy-duty) as well as vehicle weight. Segmentation of vehicles is associated with the amount of greenhouse gas that is permitted in vehicle exhaust. In general, smaller light-duty vehicles are required to meet more stringent emission requirements than larger, heavy-duty vehicles. Additionally, the U.S. Fuel Economy Guide distinguishes cars based on interior passenger and cargo volume and light trucks based on their gross vehicle weight rating [22].

3.4.2 Wards' Vehicle Classification Criteria

Vehicle sales data was obtained from Wards Intelligence, which provided a unique annotation of vehicle classification based on vehicle body style and size, but assignments were made subjectively. Criteria from 2017 separated vehicles into eight general groups: four car groups and four light trucks groups [23]. Passenger cars include all small, middle (also known as mid-size), large, and luxury cars and were differentiated based on overall length and price, as shown in Figure 6. Passenger cars can additionally be sub-classified by body styles such as sedan, coupe, hatchback, wagon, and convertible. Sedans fall under each of the four Wards Intelligence passenger car segments, coupes and hatchbacks are generally small and mid-size cars, and wagons tend to be mid-size to large cars. Any car body style may be considered luxury because luxury classification is based on cost.

The light truck groups include CUVs, SUVs, pickup trucks, and vans. CUVs are of unibody construction; whereas, SUVs are constructed body on frame. CUVs generally have less off-road capabilities than SUVs, which sometimes include low-speed transfer case gearing or an all-terrain management system. Additionally, SUVs are specified to have a minimum 7.5-in. ground clearance. Additional details of vehicle segmentation are shown in Figure 6. In addition to NHTSA's car-size classifications, Wards Intelligence 2017 segmentation criteria are used for vehicle analysis in the later chapters. It should be noted that the classification of a specific vehicle model may vary due to changes to the vehicle model body style over time (i.e. Nissan Sentra dimensions have changed since their inception). Additional documentation of the vehicle classifications used in the sales and crash data analysis can be found in APPENDIX A . Note that the "Typical Price Range" refers to an estimated or average price of a baseline model in 2017.

Segment	Typical Price Range (2017 baseline model)	Typical Length	Other Factors
Small Car			
Lower Small Car	Under $17,500	Under 175 ins.	4- or 5-door the dominant body style
Upper Small Car	$17,500 to $22,999	Under 185 ins.	4- or 5-door the dominant body style
Small Specialty Car	Under $28,000	Under 180 ins.	Predominately 2-door, 4-passenger or 2+2 seating
Middle Car			
Lower Middle Car	$23,000 to $25,999	180 to 194 ins.	4- or 5-door the dominant body style
Upper Middle Car	$26,000 to $33,999	180 to 194 ins.	4- or 5-door the dominant body style
Middle Specialty Car	$28,000 to $39,999	Under 200 ins.	2-door, 4-passenger or 2+2 seating only
Large Car			
Large Car	Under $34,000	200 ins. and over	Large sedans with overall dimensions bigger than typical Middle segment cars
Luxury Car			
Lower Luxury Car	$34,000 to $44,999	-	4- or 5-door the dominant body style
Middle Luxury Car	$45,000 to $69,999	-	4- or 5-door the dominant body style
Upper Luxury Car	$70,000 and over	-	4- or 5-door the dominant body style
Luxury Specialty Car	$40,000 and over	-	2-door, 4-passenger or 2+2 seating only
Luxury Sports Car	$40,000 and over	-	2-passenger or 2+2 seating with performance a dominant characteristic
Cross Utility Vehicle			
Small Cross/Utility Vehicle	Under $34,000	Under 180 ins.	Typically wagon body style with unibody construction, front- or all-wheel-drive and passenger vehicle qualities the dominant characteristic with limited off-road capability.
Small Luxury Cross/Utility Vehicle	$34,000 and over	Under 180 ins.	Same as above
Middle Cross/Utility Vehicle	Under $36,000	180 to 194 ins.	Same as above
Middle Luxury Cross/Utility Vehicle	$36,000 and over	180 to 194 ins.	Same as above
Large Cross/Utility Vehicle	Under $45,000	195 ins. and over	Same as above; third-row seats usually standard
Large Luxury Cross/Utility Vehicle	$45,000 and over	195 ins. and over	Same as above; third-row seats usually standard
Sport Utility Vehicle			
Small Sport/Utility Vehicle	Under $36,000	Under 180 ins.	Off-road capabilities a strong characteristic, body-on-frame or unibody construction, offering standard or optional low-speed transfer case gearing or all-terrain management system and minimum 7.5-in. (91-mm) ground clearance.
Middle Sport/Utility Vehicle	Under $36,000	180 to 199 ins.	Same as above
Middle Luxury Sport/utility Vehicle	$36,000 and over	180 to 194 ins.	Same as above
Large Sport/Utility Vehicle	Under $55,000	200 ins. and over	Same as above; third-row seats usually standard
Large Luxury Sport/Utility Vehicle	$55,000 and over	195 ins. and over	Same as above; third-row seats usually standard
Van			
Small Van	Under $36,000	Under 210 ins.	Sliding doors
Large Van	Under $40,000	210 ins. and over	Sliding doors
Pickup			
Small Pickups	-	200 ins. and over	Lower overall dimensions and less cargo space than Large Pickups
Large Pickups	-	200 ins. and over	Heavier duty with bigger overall dimensions and more cargo space than Small Pickups

Figure 6. Wards Intelligence Vehicle Segmentation Criteria, 2017 [23]

CHAPTER 4 Methodology

4.1 Database of Vehicle Attributes

The objectives of this research study were to determine attributes of vehicles which were representative of potential MASH passenger vehicles, and to recommend a methodology for reviewing and updating vehicle selection parameters for future studies. Researchers considered three distributions of vehicles which could be used to standardize passenger vehicle selection: (1) vehicles which were involved in a police-reported crash; (2) registered vehicles, which are statistically the most representative distribution of vehicles which could be involved in a crash; and (3) a review of new vehicle sales, which may be predictive of future trends in vehicle registrations and crashed vehicles.

4.1.1 Crash Data Analysis

Crash data provided a summary of actual vehicles involved in crashes. Crash data can be linked to the performance of roadside devices (in-service performance evaluations or ISPEs); in-vehicle safety measures such as airbags, anti-lock brakes, or traction stability control; ages of crashed vehicles; and summaries of injuries sustained in crashes. Crash data analysis is an excellent method of standardizing passenger vehicle selection as it is a useful method for researchers to correlate vehicle type, classes, impact conditions, and roadside features with roadside device performance to determine how to improve barrier design, hardware, and safety practices. However, crash data analysis is time-consuming and expensive, only utilizes data from the past and may not be predictive of the future, and may be sensitive to the geographic region of crash data collection.

For this research study, crash data was collected and analyzed from NHTSA [24] and seven state departments of transportation (DOTs) spanning five years each. All crash types in the database. Commonly crashed vehicle body styles were identified within the selected states.

Additionally, high-crash frequency vehicle models were compared to high-sales volume vehicle models to review consistency between crash and sales datasets.

4.1.2 Registration Data Analysis

Researchers also reviewed national and local vehicle registration data. Vehicle registrations were believed to accurately represent a cross-section of vehicles in operation each year. As a result, registered vehicles represented the distribution of vehicles for which a run-off-road crash (or any other crash) was statistically possible. Changes in registration data between years would suggest changes in the distribution of vehicles involved in crashes. Registration data is voluminous and would not likely be sensitive to small changes in new vehicle purchases year-on-year, and as such would accurately reflect changes in the expected percentage of light truck vs. passenger cars involved in crashes, vehicle ages, and consumer preferences. However, registration data sizes and analysis could be costly and time-consuming.

Researchers reviewed available registration data from the FHWA [25], IHS Markit [27], and the Bureau of Transportation Statistics [28] to tabulate vehicle ages, attributes, and body styles. National registration statistics were available in all three datasets, and state registration data was included in data from FHWA High Statistics Series. Although agreements were sought with state departments of motor vehicles (DMVs) for bulk data collection and analysis, no agreements could be completed and executed within the time and budget limits of this study.

4.1.3 New Vehicle Sales Data Analysis

New vehicle sales data was believed to offer a good perspective of changes in future vehicle fleet attributes. Sales data fluctuated significantly year-on-year, but was a prime indicator of consumer selection in vehicle purchases and therefore was strongly correlated with national changes in registration data. In addition, because robust data regarding new vehicle sales data were available, analysis of new vehicle sales had the potential to be the least expensive and time-consuming method of standardizing passenger vehicle attributes.

New vehicle sales were analyzed from Wards Intelligence [29] for 2017, and compared and confirmed with Edmunds, Cars.com, and Carsalesbase.com [30, 31, and 32]. Vehicle types were classified using Wards Intelligence Segmentation Criteria [23] and total annual vehicle sales were compared to registration data to determine how much a single year of sales data affected the composition of vehicles on the roadway.

Although data were available for domestic and international sales, vehicle sales were rarely differentiated by between trim, suspension, powertrain, and payload capacity variations. Various weight distributions were applied to bracket maximum and minimum ranges for 5^{th}, 50^{th}, and 95^{th} percentiles, as well as estimated distributions based on mean and median weights. A “high-weight” distribution estimated that all new vehicle sales were associated with the heaviest curb weight of a given model year. Likewise, a “low-weight” distribution assumed that all new vehicle sales consisted of the lightest vehicle weight in the model year. Two additional distributions were reviewed: a distributed-trim sales model, in which the number of vehicles sold with each trim level was assumed to be equal for all variations in trim and powertrain; and a “median-weight” distribution was created which assumed that the majority of vehicle sales were associated with the median weight of the vehicle trim and powertrain model options. Additional

In addition to the vehicle attribute selection, researchers also identified makes and models of vehicles with total annual sales greater than 100,000 units. MASH previously recommended that a minimum of 50,000 units and recommended 100,000 units be sold of a passenger vehicle to ensure adequate and lasting vehicle supply [1].

4.2 Passenger Vehicle Attribute Standardization

Researchers compared the three vehicle selection methods and results of vehicle attribute distributions. The most complete data analysis method, which required the least analysis time and provided the most detailed data, was new vehicle sales data. Researchers compared distributions of vehicle body style for crashed, registered, and new vehicle sales and identified trends and the time lag for new vehicle sales data to reflect registration and crash data. These data were used to evaluate the average age of vehicles at the time of a crash. Vehicle makes and models were classified and dimensions and inertial measurements obtained from the Canadian Vehicle Specifications database [33] and 4N6XPRT Expert Autostats [34]. Dimensions were used to identify passenger vehicle properties and plot distributions of vehicle attributes.

Next, researchers plotted the weight distributions of the new vehicle sales data using high-weight, low-weight, median-weight, and distributed-weight techniques for evaluating vehicle attribute distributions. Geometrical and inertial attributes of new vehicles were tabulated based on model sales. Vehicle weights were plotted, and it was determined that the median weight distribution was a reliable and likely representative technique for estimating the distribution of vehicle weights. The median-weight technique was used to estimate the 5^{th} and 95^{th} percentile vehicle weights and recorded for MASH passenger vehicle standardization. Using this information, vehicle makes, models, and trims with curb weights within tolerances of the target weight were identified.

Dimensional attributes of the target passenger vehicles were then recorded and used to define the tolerance ranges for passenger vehicle selections. The ranges were selected to encompass all vehicle attributes of potential target passenger vehicles with weights which were similar or equal to the target vehicle weights. When minimal diversity of geometrical attributes were identified (e.g., overall length, wheelbase, track width), tolerances were added to the vehicle attributes to account for potential future changes in vehicle body styles and dimensions.

4.3 Heavy Duty Test Vehicles

Passenger vehicles selection were the only criteria reviewed in this study. Heavy duty vehicles were previously evaluated by Roadsafe LLC which noted trends for heavy vehicle traffic distributions [8]. Results showed that the MASH 10000S and MASH 36000V remain appropriate choices for performance evaluation of roadside hardware. An 80,000-lb legal load limit exists in 35 states so a 99^{th} percentile tractor trailer weighing 80,000 lb is a suitable test vehicle for the upper end weight of heavy-duty vehicles. Because the standard vehicle attributes, weights, and specifications noted in MASH were shown to still be reasonable for contemporary vehicles, researchers did not consider heavy vehicles and no changes were recommended for heavy vehicle classes.

CHAPTER 5 Crash Data Analysis

5.1 National Crash Trends

National crash statistics were reviewed to determine overall trends and state data was used to investigate vehicle fleet composition on roadways. More than 85 million vehicles were involved in crashes from 2010 to 2017, and nearly 95% of vehicles in crashes were passenger vehicles [24]. Proportional shares of vehicle groups involved in crashes are shown in Figure 7. Of all vehicles involved in crashes, less than 0.5% resulted in fatalities, 29% resulted in injuries, and 71% were property damage only (PDO).

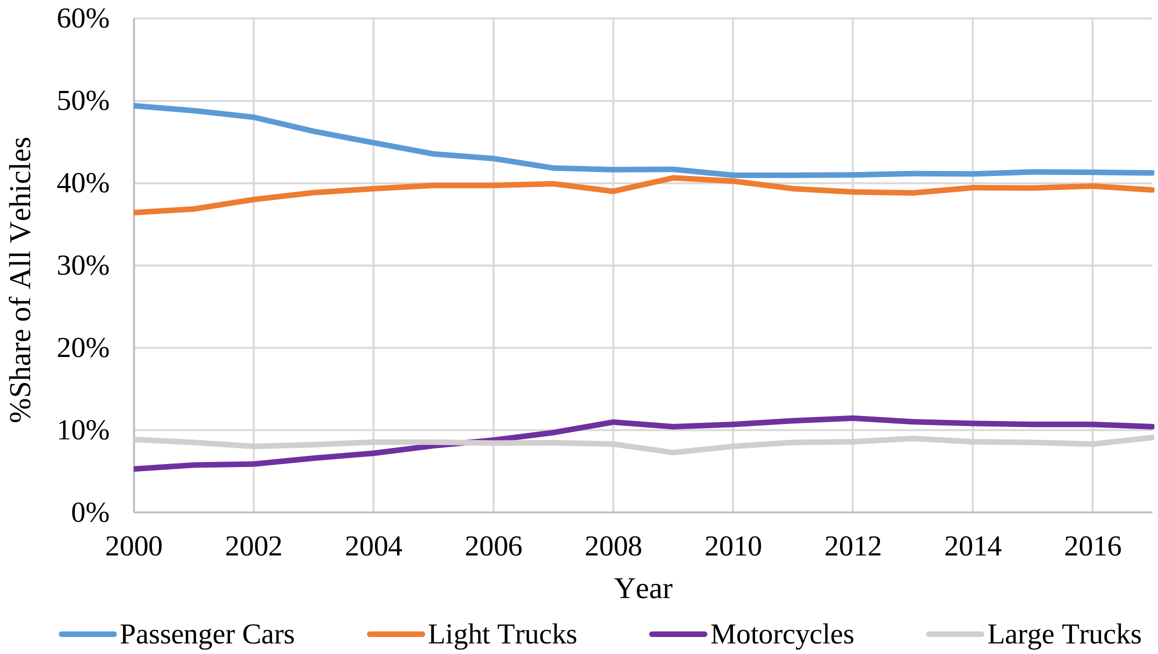


Figure 7. Shares of Vehicles involved in All Crashes [24]

Each year from 2000 to 2017, a minimum of 80% of vehicles involved in fatal crashes were passenger cars or light trucks [24]. The remaining vehicles included motorcycles and large, commercial trucks. Passenger cars comprised 43.2% of vehicles involved in fatal crashes, light trucks comprised 39.2%. The mean share of each vehicle group involved in fatal crashes is shown in Figure 8. From 2000 to 2007, the share of passenger cars involved in fatal crashes decreased from 50% to 41%. Light truck fatal crash share nearly converged with passenger car fatal crash share in 2009. Light truck and passenger car shares of total vehicles in crashes were approximately constant from 2010 to 2016, and the number of light truck fatal crashes never exceeded passenger cars in the dataset obtained. Motorcycle fatal crash share increased from 5% in 2000 to over 10% in 2017, and large trucks fatal crash share was largely unchanged over the same span.

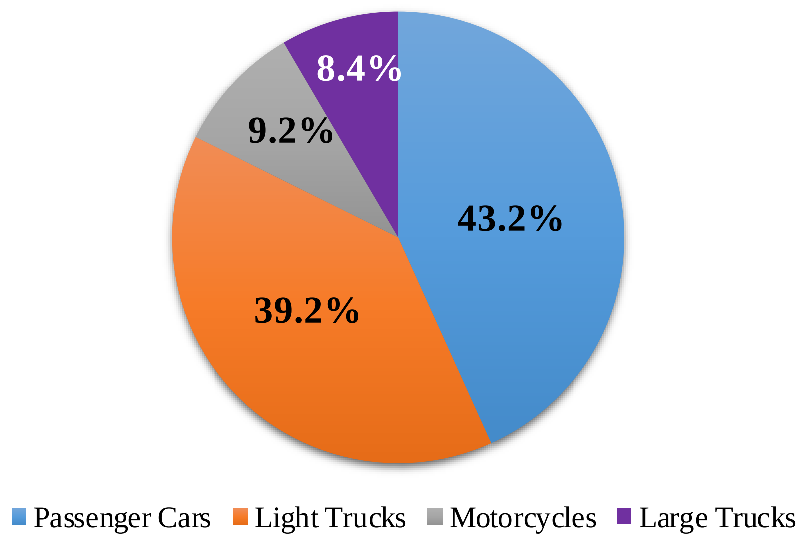


Figure 8. Mean Shares of Vehicles Involved in Fatal Crashes (2000-2017)

The annual percentage difference from the mean crash share was also plotted, as shown in Figure 9. The difference from mean share was calculated by subtracting the mean value distribution from each year's data; hence the sum of all differences is equal to zero. The share of passenger cars in fatal crashes decreased by approximately 8% from 2000 to 2010 and did not recover during the economic depression, indicating a net decline in passenger car sales and fatal crash numbers. Light trucks have been relatively constant, but demonstrated an increase of approximately 2.5% since 2000. and increased between 2000 and 2009 before plateauing at the yearly average from 2011 to 2017. The share of motorcycles involved in fatal crashes increased significantly between 2000 and 2012. The share of large trucks in fatal crashes was relatively constant over the sample span.

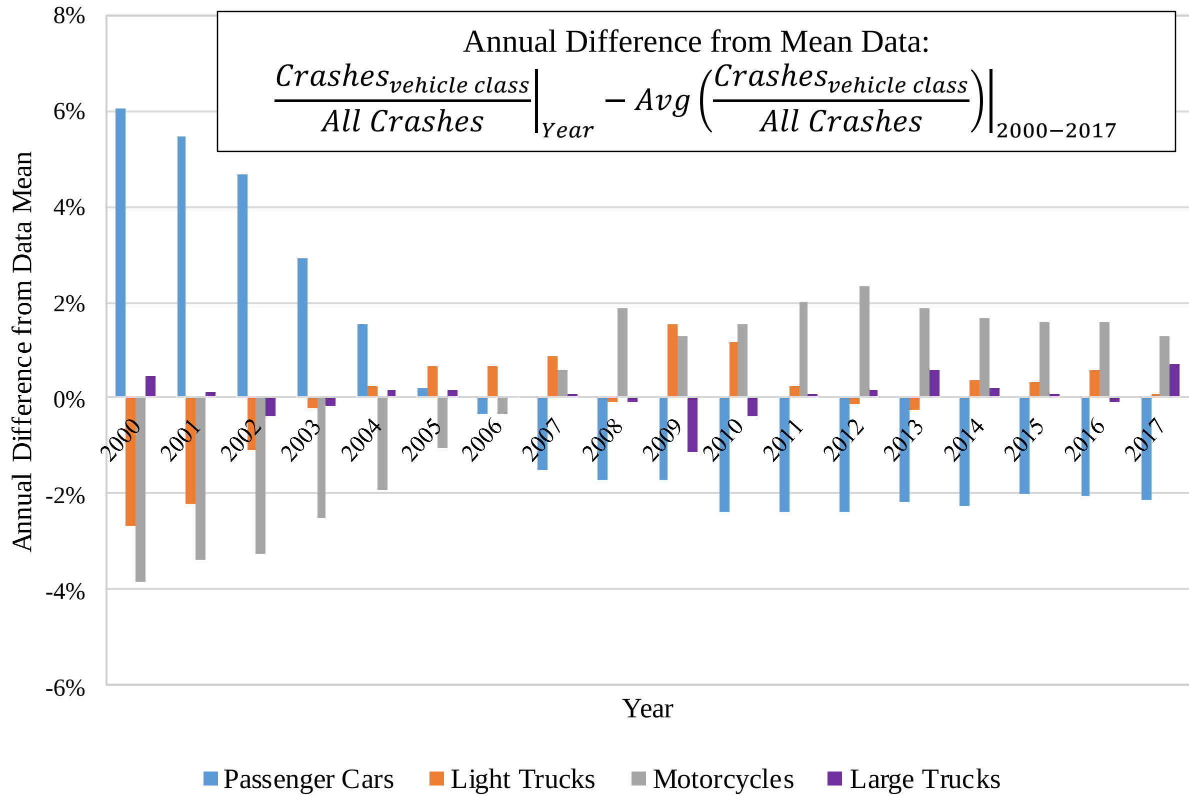


Figure 9. Annual Difference from Mean Crash Rates by Vehicle Type

5.1.1 Passenger Vehicle Distribution by Vehicle Type

Mean shares of passenger vehicles involved in fatal crashes from 2010 to 2017 are shown in Figure 10. Wagons, hatchbacks, and convertibles were combined into the “Other” category because each type comprised less than 5% of total crashes. Considering fatal crashes of all remaining passenger vehicle types (large trucks excluded), sedans were involved 32.6% of all fatal crashes. Pickup trucks and SUVs/CUVs accounted for 19.9% and 17.8% of fatal crashes, respectively. Motorcycles were the fourth most frequently crashed passenger vehicle at 11.9%, and vans and coupes combined were less frequently involved in crashes than motorcycles.

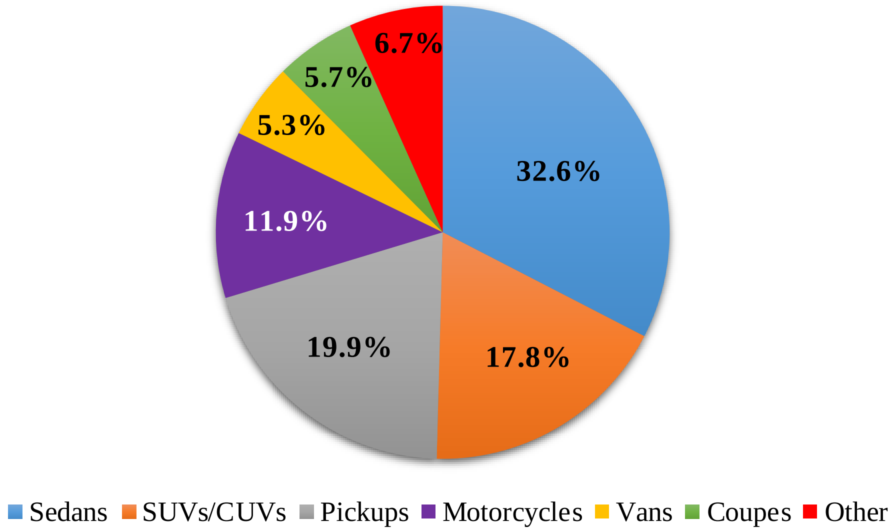


Figure 10. Passenger Vehicles Involved in Fatal Crashes by Body Style (2010-2017)

The annual percentage difference from the mean share of passenger vehicles involved in fatal crashes is shown in Figure 11. Results were not equivalent to overall share results because the only passenger vehicles considered were those most commonly involved in fatal crashes, which included sedans, SUVs/CUVs, pickup trucks, motorcycles, vans, and coupes. The most notable trend was a 2.3% cumulative increase in SUVs/CUVs in fatal crashes, which surpassed the share of pickup trucks in 2017 (19.3% SUVs/CUVS and 19.0% pickup trucks). The share of pickup trucks exhibited a declining trend, decreasing by 1.7% over 8 years, and other vehicle types exhibited a 2.3% increase. Sedans and motorcycles fluctuated about each of their average fatal crash shares and did not deviate by more than 0.4% or 0.7%, respectively. Shares of coupes and vans involved in fatal crashes each decreased since 2010.

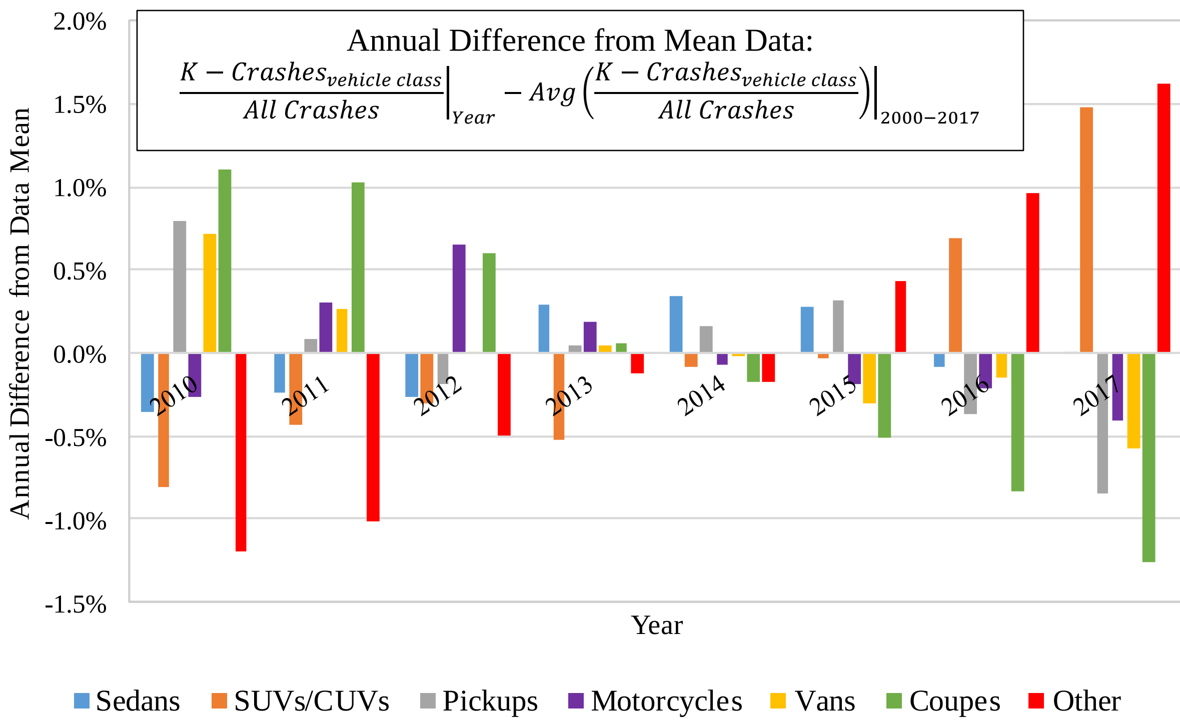


Figure 11. Yearly Difference from Mean - Vehicles in Fatal Crashes

5.1.2 Passenger Car Distribution

Mean shares of passenger cars involved in fatal crashes were observed from 2010 to 2017. Passenger cars do not include light trucks such as pickup trucks, vans, CUVs, and SUVs. Body styles were specified in NHTSA Traffic Safety Facts tables and were provided by the Fatality Analysis Reporting System (FARS). Since 2010, sedans have comprised over 72% of cars involved in fatal crashes, while the other 28% were made up of coupes, convertibles, wagons, and hatchbacks [24]. Additional details on passenger car types involved in fatal crashes are shown in Figure 12.

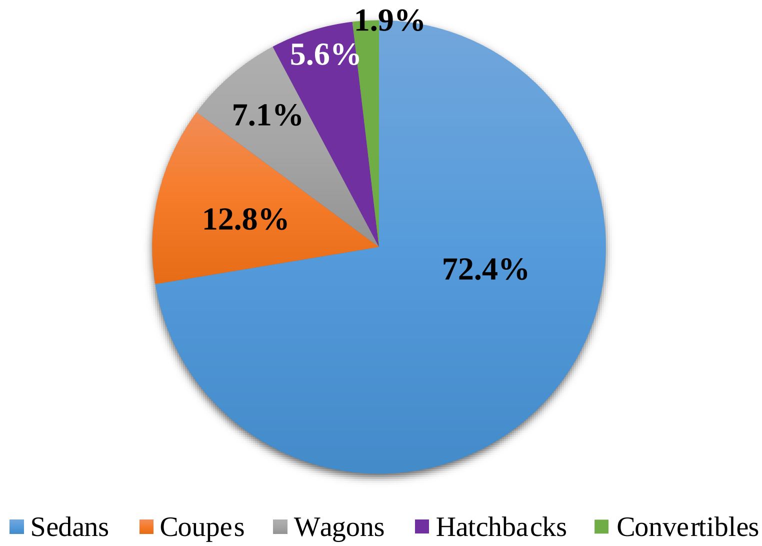


Figure 12. Shares of Passenger Cars Involved in Fatal Crashes by Body Style (2010-2017)

The annual percentage difference from the mean share of passenger cars involved in fatal crashes is shown in Figure 13. The overall percentage of sedans involved in fatal crashes remained steady at approximately the yearly average from 2010 to 2017. The share of coupes in fatal crashes decreased each year after 2010. Wagons and hatchbacks increased as a total percentage of fatal crashes between 2010 and 2017; the growth of wagons and hatchback classes were very similar for each year.

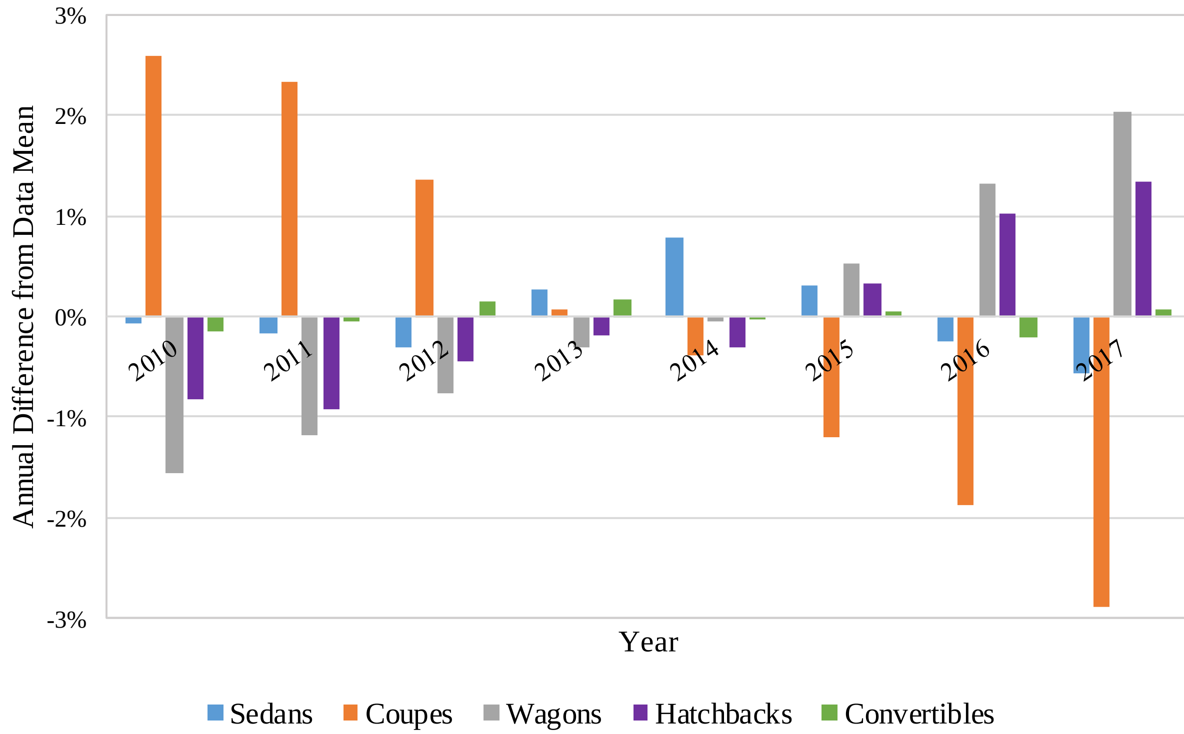


Figure 13. Yearly Difference from Mean Passenger Car Fatal Crash Rates

5.1.3 Light Truck Distribution

Mean shares of light truck body styles involved in fatal crashes from 2010 to 2017 are shown in Figure 14. Light trucks body styles are comprised of CUVs, SUVs, pickup trucks, and vans, and the available dataset merged CUVs and SUVs as one vehicle body style [24].

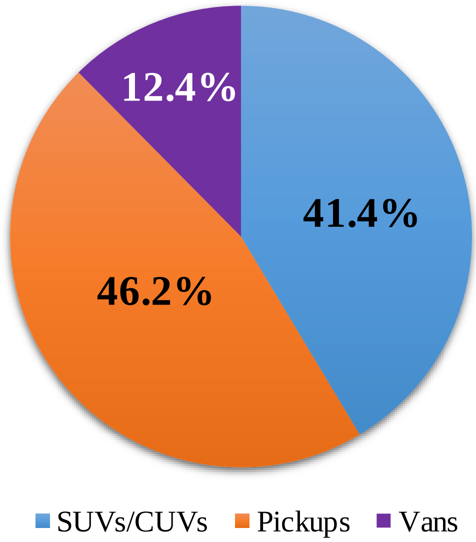


Figure 14. Light Trucks Involved in Fatal Crashes by Body Style (2010-2017)

The annual percentage difference from the mean share of light trucks involved in fatal crashes is shown in Figure 15. Fatal crashes involving SUVs/CUVs increased by a total of 5.9% over the eight-year sample.

Notably, the percent of fatal crashes involving SUVs/CUVs eclipsed the percent of fatal crashes involving pickup trucks for the first time in 2017. The percentage of fatal light truck crashes corresponding to SUVs and CUVs increased from 2010 to 2017, and the overall percentage of fatal crashes corresponding to light trucks and vans fell between 2010 and 2017. The overall number of pickup truck related fatal crashes was relatively constant while the number of SUV/CUV fatal crashes grew rapidly, which resulted in an effective reduction in the percent of fatal crashes related to pickup trucks.

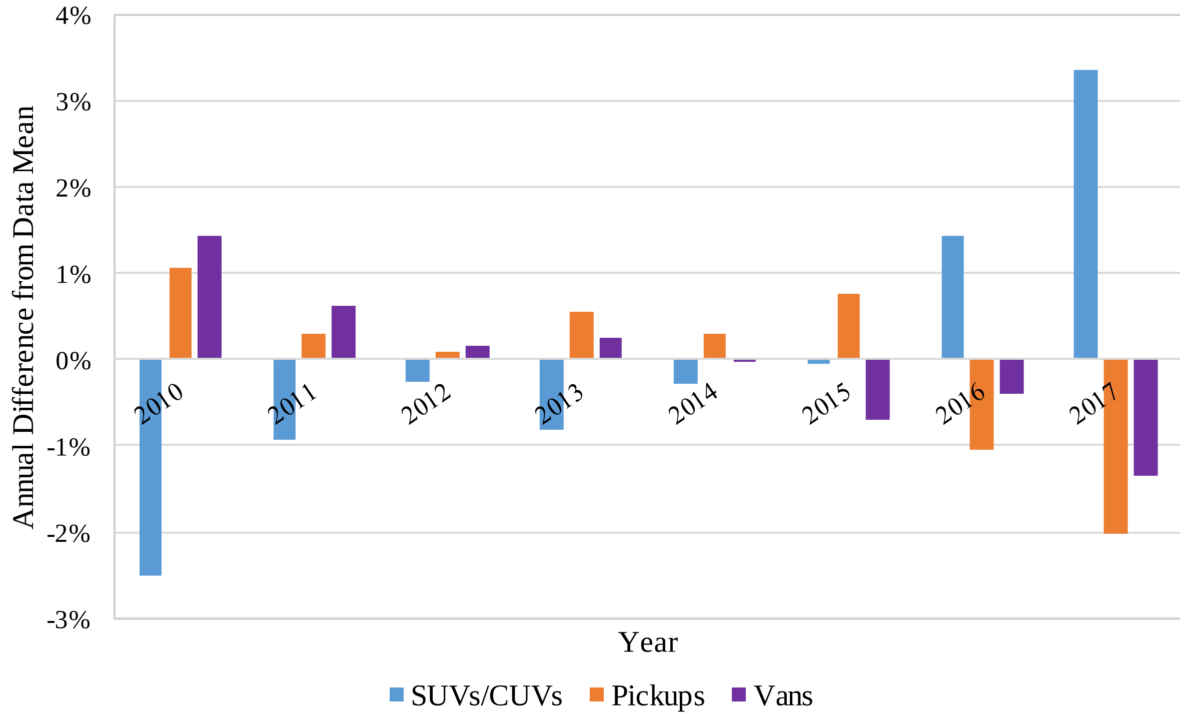


Figure 15. Yearly Difference from Mean Light Truck Fatal Crash Rates

5.2 State Crash Records

Crash data were obtained from the state DOTs of Indiana, Nebraska, North Carolina, Ohio, South Carolina, Utah, and Wyoming. Budgetary and time restrictions limited the scope of crash data investigation; however, crash records from Wyoming, Ohio, and Utah were analyzed to determine the distributions of vehicle types involved in crashes. Each of these states provided vehicle make, model, and year of vehicles involved in crashes. Make/models were assigned to a vehicle group (via Wards Intelligence segmentation criteria [23]) and the total number of vehicles in each group were documented. Data from Ohio and Utah were differentiated by vehicle year and crash date, but Wyoming crash records from 2013 to 2017 were not separated by crash year.

Crash documentation inconsistencies created some difficulty in analysis. For example, datasets from some states did not include vehicle make, model, or year, and other datasets included multiple years' worth of data combined into one file. Consistent state crash record documentation methods would be highly beneficial to timely, robust crash data analysis.

5.2.1 Wyoming DOT Crash Data

Vehicle groups crashed in Wyoming from 2013 to 2017 are shown in Table 9. Pickup trucks accounted for nearly 30% of all vehicle crashes in Wyoming. Mid-size and small cars together combined for about 23% of vehicle in crashes, and SUVs and CUVs combined for about 24%. "Other" refers to vehicle types such as single-unit trucks, tractor-trailers, RVs, and motorcycles.

Table 9. Vehicle Type Shares of Total Units in Crashes (Wyoming)

Vehicle Group	2013-2017	
	Units Crashed	**%Share**
Pickup Truck	40,684	29.6%
Mid-Size Car	18,398	13.4%
SUV	18,100	13.1%
CUV	15,390	11.2%
Small Car	13,762	10.0%
Van	5,954	4.3%
Large Car	4,807	3.5%
Luxury Car	4,768	3.4%
Other	15,789	11.5%

5.2.2 Ohio DOT Crash Data

Shares of vehicle groups involved in Ohio crashes are shown in Table 10. Mid-size and small cars accounted for nearly half of all crashed vehicles in Ohio, while light trucks comprised nearly 42% of vehicles crashed. CUVs saw the greatest change from 2014 to 2015, exhibiting a 1.1% crashed vehicle share increase.

Table 10. Vehicle Types Shares of Total Units in Crashes (Ohio)

Vehicle Group	2014		2015	
	Units Crashed	%Share	Units Crashed	%Share
Mid-Size Car	96,291	24.3%	101,815	24.2%
Small Car	82,220	20.7%	87,496	20.8%
CUV	53,620	13.5%	61,452	14.6%
Pickup Truck	46,692	11.8%	48,755	11.6%
SUV	36,648	8.7%	35,719	8.5%
Van	29,734	7.5%	30,916	7.3%
Large Car	25,840	6.5%	25,731	6.1%
Luxury Car	21,535	5.4%	22,471	5.3%
Other	6,334	1.6%	7,037	1.6%

The age distribution of crashed vehicles in Ohio is shown in Figure 16. Ohio crash records from 2014 and 2015 were reviewed, and vehicle age was determined by subtracting vehicle model year from crash year. Average crashed vehicle age was approximately 9.9 years in 2014 and 2015.

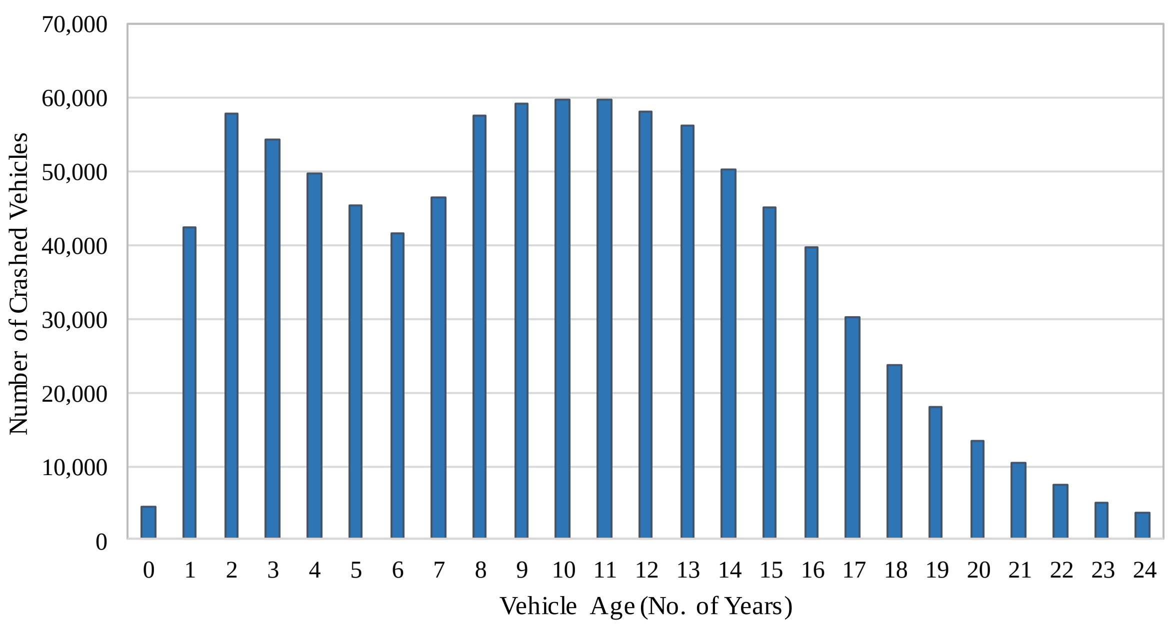
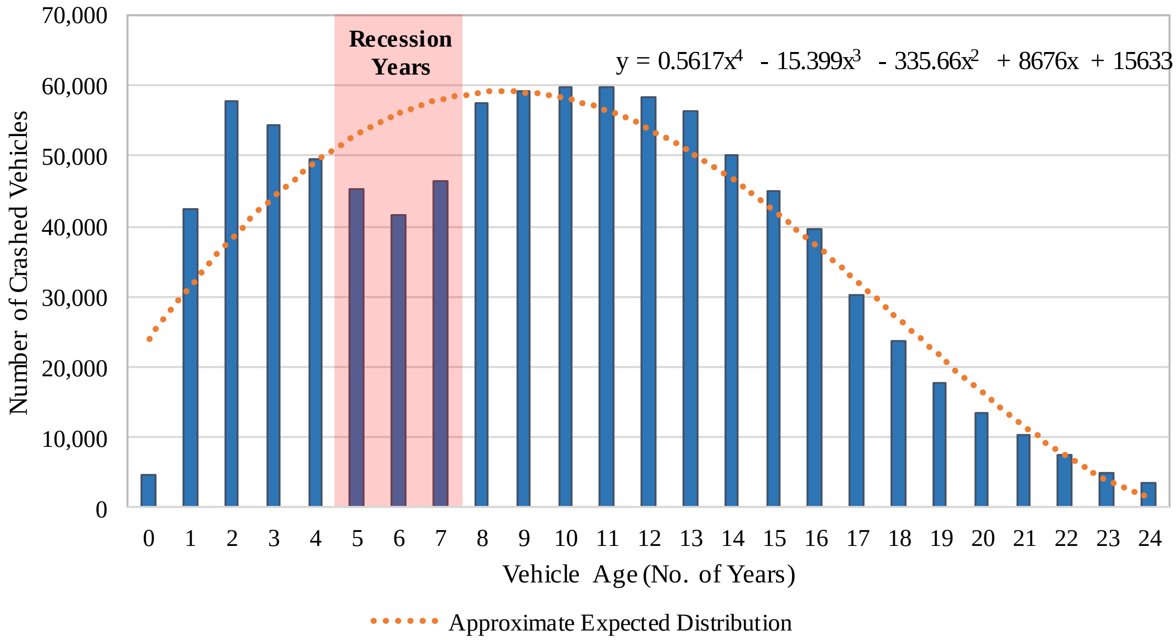


Figure 16. Age Distribution of Vehicles in Crashes in Ohio (2014-2015)

A non-predictive model was used to estimate an expected crash age distribution curve, as shown in Figure 17. The equation for approximate expected crash age distribution is also shown.

Disparities between the mathematical curve and the real distribution were observed, particularly during years corresponding to the U.S. recession, defined as 2007 to 2009 [36]. However, overall results were useful for identifying the peak age of vehicles at the time of a crash.



Note: expected distribution represents an approximated trendline and may not be predictive of future trends.

Figure 17. Age Distribution of Vehicles in Crashes in Ohio with Estimated Trendline (2014-2015)

5.2.3 Utah DOT Crash Data

Vehicle groups in crashes in Utah from 2013 through 2017 are shown in Table 10. The combined shares of mid-size and small cars in crashes decreased from 42.3% to 38.7% between 2013 and 2017, respectively. Pickup trucks and SUVs experienced little-to-no change in share of crashed vehicles, and CUVs saw the greatest increase from 9.5% to 13.3%. Mid-size and small cars were the two most commonly crashed vehicle types in Utah during the five-year span. However, CUVs were the only vehicle class to grow as a share of all crashes each year, rising steadily from 9.5% of all crashes in 2013 to 13.3% in 2017.

Table 11. Vehicle Classes Involved in Crashes in Utah, 2013-2017

Vehicle Group	2013	2014	2015	2016	2017
Mid-Size Car	21,363	20,437	20,440	23,345	21,780
Small Car	21,257	20,133	23,144	24,822	23,497
Pickup Truck	15,732	14,569	16,496	17,985	18,189
SUV	10,412	9,682	10,492	11,976	12,557
CUV	9,517	9,679	11,817	14,122	15,537
Luxury Car	5,835	5,830	6,621	6,128	6,374
Van	5,561	5,132	5,774	6,318	6,148
Large Car	1,891	1,631	2,995	2,136	2,911
Other	8,330	6,464	7,597	8,303	9,959

Table 12. Shares of Vehicles Involved in Crashes in Utah, 2013-2017

Vehicle Group	2013	2014	2015	2016	2017
Mid-Size Car	21.2%	21.6%	19.3%	20.1%	18.6%
Small Car	21.1%	21.3%	21.8%	21.4%	20.1%
Pickup Truck	15.6%	15.4%	15.5%	15.4%	15.5%
SUV	10.4%	10.3%	9.9%	10.3%	10.7%
CUV	9.5%	10.3%	11.1%	12.2%	13.3%
Luxury Car	5.8%	6.2%	6.2%	5.3%	5.4%
Van	5.5%	5.4%	5.5%	5.4%	5.2%
Large Car	1.9%	1.7%	2.8%	1.8%	2.5%
Other	9.0%	7.8%	7.9%	8.1%	8.7%

The age distribution of crashed vehicles in Utah is shown in Figure 18. Utah crash records from 2013 through 2017 were reviewed, and average crashed vehicle age ranged from 9.3 to 9.6 years each crash year.

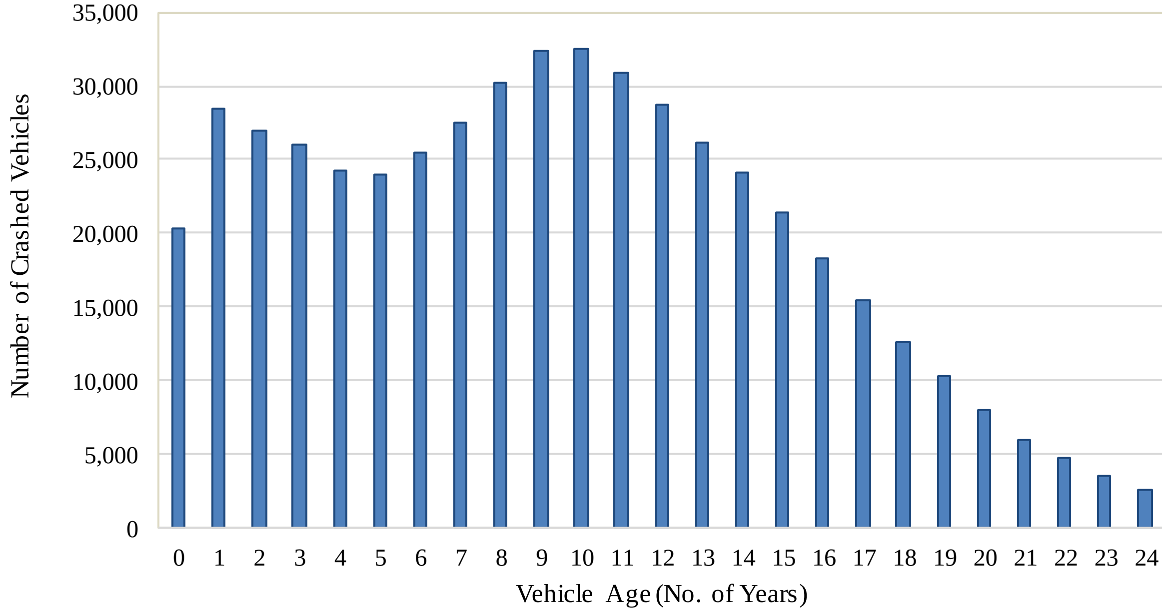
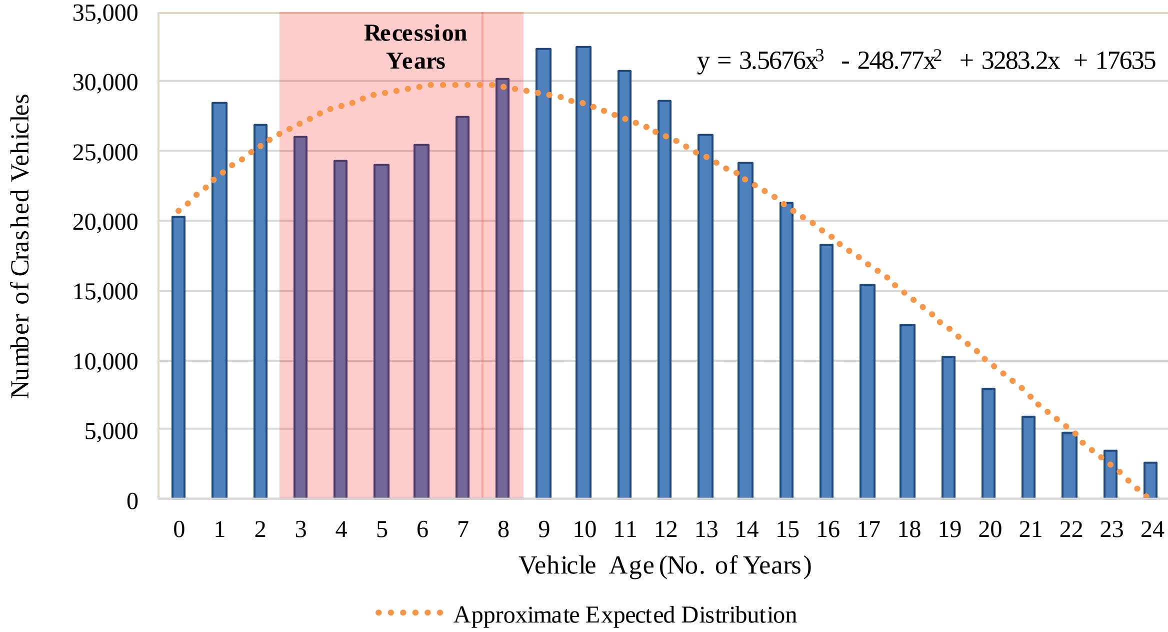


Figure 18. Average Age Distribution of Vehicles in Crashes in Utah (2013-2017)

A non-predictive model similar to that used for Ohio data was used to represent an approximate expected crash age distribution curve, as shown in Figure 19. The equation for approximate expected crash age distribution is also shown. The number of crashed vehicles did not follow the expected crash curve, as relatively few vehicles between three and eight years of age were involved in crash events. This may be attributed to economic recession because vehicles at these ages would have been produced around 2007 to 2010. Note that the effect of the U.S. recession was observed at the different vehicle age for crash years 2013 through 2017; the recession was 8 to 10 years before crashes in 2017, but only 4 to 6 years before crashes in 2013.



Note: expected distribution represents an approximated trendline and may not be predictive of future trends.

Figure 19. Age Distribution of Vehicles in Crashes in Utah with Estimated Trendline (2013-2017)

5.3 Results

Crash data were reviewed to observe distributions of vehicle types and body styles involved in crashes. Nationally, nearly 95% of vehicles in all crashes were passenger vehicles. Sedans remained the primary passenger car body style involved in fatal crashes. Due to consistent increase in crash frequency from 2010 to 2017, it may be beneficial to periodically review crash frequency of hatchbacks and wagons when selecting passenger vehicles for crash testing. Since 2016, there has been a sizable shift in the body styles of crashed vehicles, with a surge in light truck (primarily CUV) and decrease in passenger car impacts. The shift in fatal crash shares should continue to be monitored to observe whether light truck share continues to significantly increase.

SUV/CUV share of light truck fatal crashes has increased since 2010, and eclipsed pickup trucks in 2017. Pickup trucks and vans have each decreased over the same span. Among three states observed, mid-size cars, small cars, pickups, CUVs, and SUVs were the vehicle types most involved in crashes. Ideally, more state crash data would be analyzed to see if this trend is repeated; however, time and budgetary restraints prevented deeper analysis. Overall findings indicate SUVs/CUVs warrant consideration as a MASH passenger vehicle due to their increased crash frequency since 2010.

CHAPTER 6 Vehicle Registration Analysis

6.1 U.S. Vehicle Registrations

The total number of registered vehicles increased from nearly 226 million in 2000 to 269 million in 2016 [25]. Year-end vehicle registration trends were observed to determine the distribution of vehicle types legally allowed to travel roads. Registered passenger vehicle trends from 1994 to 2016 are shown in Figure 20. Since 1994, the percentage of vehicles registered as cars declined by 25% and light truck vehicles increased by 25% [25].

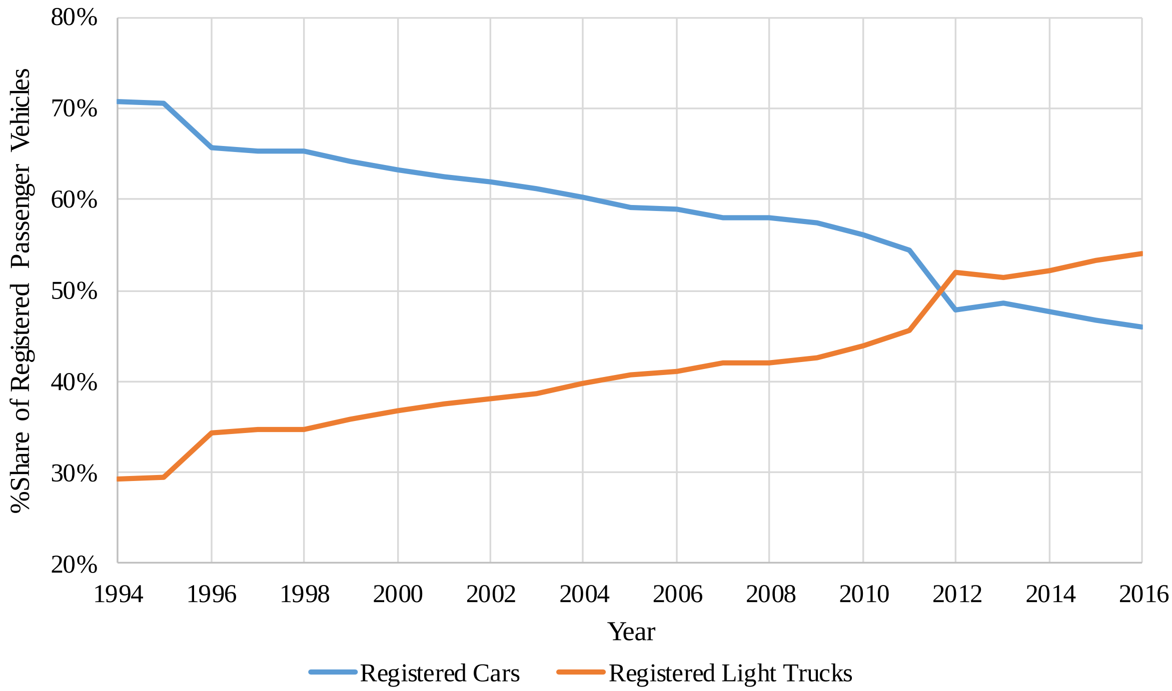


Figure 20. Registered Passenger Cars and Light Trucks in the U.S. [25]

The mean shares of passenger car registrations by body style from 2012 to 2017 are shown in Figure 21. A dataset was available from IHS Markit that approximated U.S. passenger vehicle registrations by vehicle type [27]. Registrations within this dataset favorably compared to those of the Bureau of Transportation Statistics [28]. Passenger cars were segmented into the following body styles: sedans, coupes, wagons, hatchbacks, and convertibles. From 2012 to 2017, sedans comprised the nearly 78% of car registrations. Hatchbacks were second with about 12% of registrations, and coupes, wagons, and convertibles combined for nearly 10%.

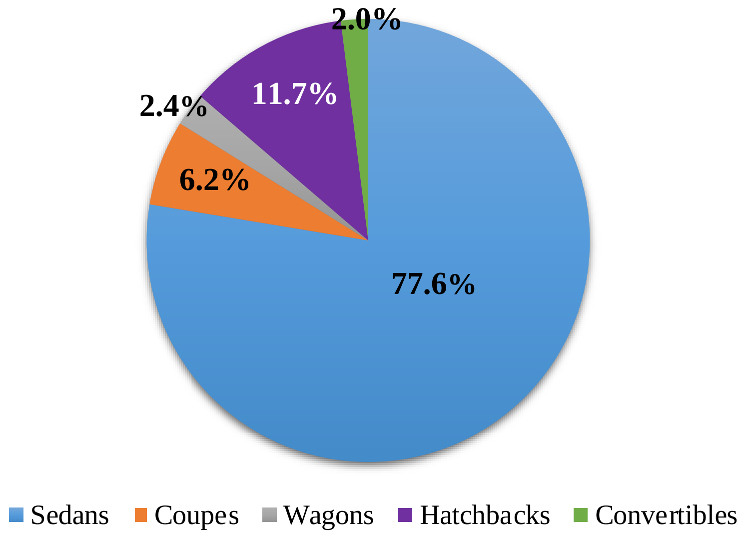


Figure 21. Mean Passenger Car Registrations by Body Style [27]

The annual percent differences from the mean share of registered passenger cars are shown in Figure 24. Between 2012 and 2016, sedan body style registrations climbed steadily, but abruptly dropped in 2017. Hatchback registrations dropped between 2012 and 2016, but increased between 2016 and 2017. Coupe, convertible, and stationwagon body styles did not have significant trends or deviations from the nominal mean between 2012 and 2017.

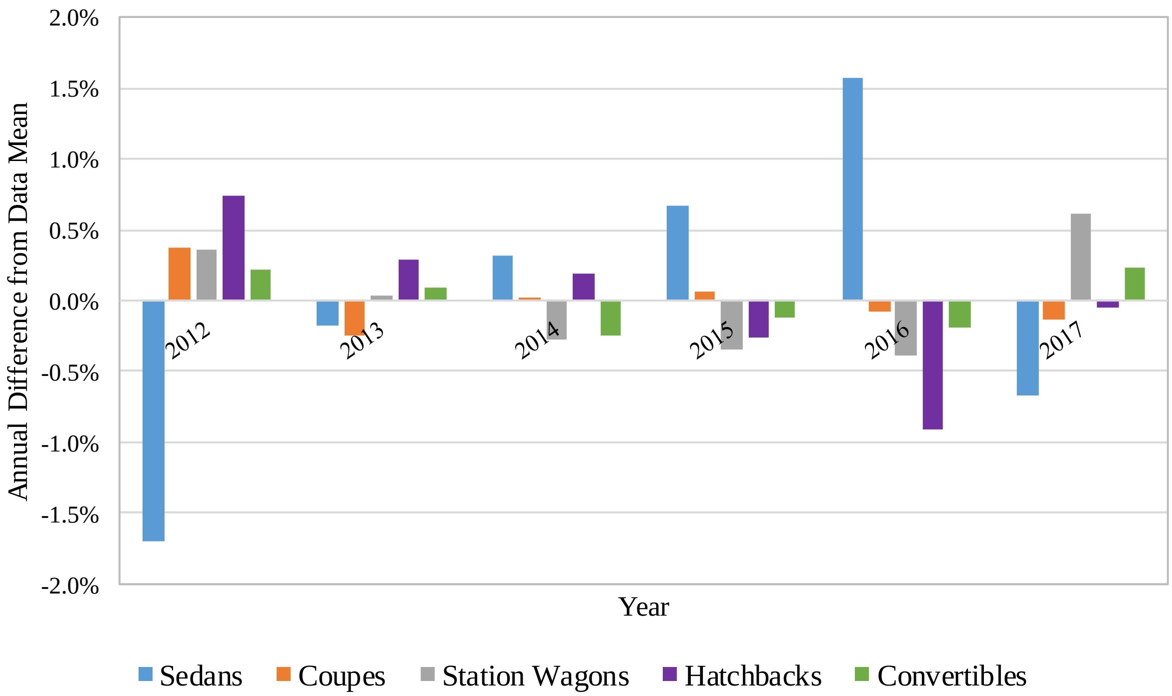


Figure 22 Yearly Difference from Mean Registrations [27]

The mean shares of light truck registrations by body style from 2010 to 2016 were obtained from an FHWA dataset [25] and are shown in Figure 23. SUV/CUV registrations share has been greater than pickup truck share each year since 2010. SUVs/CUVs comprised the largest portion of light truck registrations, followed by pickup trucks and vans.

The annual percent differences from the mean share of registered light trucks are shown in Figure 24. From 2010 to 2016, the registered share of SUVs/CUVs increased by a total of 9.3%. Pickup truck and van shares each consistently decreased by a total of about 4.7% over the same span. The trends demonstrate the clear consumer preference for SUV and CUV vehicles. The significant increase in registrations for SUVs and CUVs suggest that a greater percentage of future crashes will involve SUVs and CUVs.

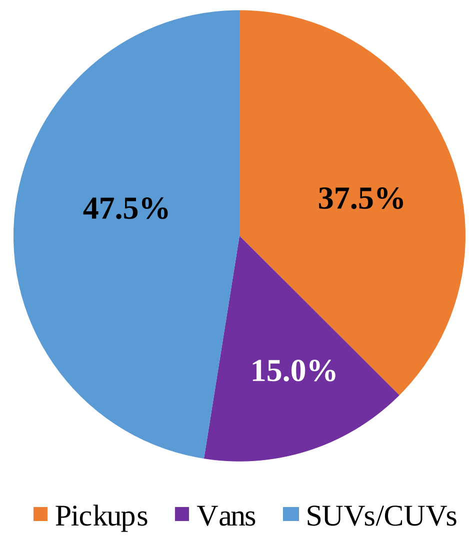


Figure 23. Mean Light Truck Registrations by Body Style [25]

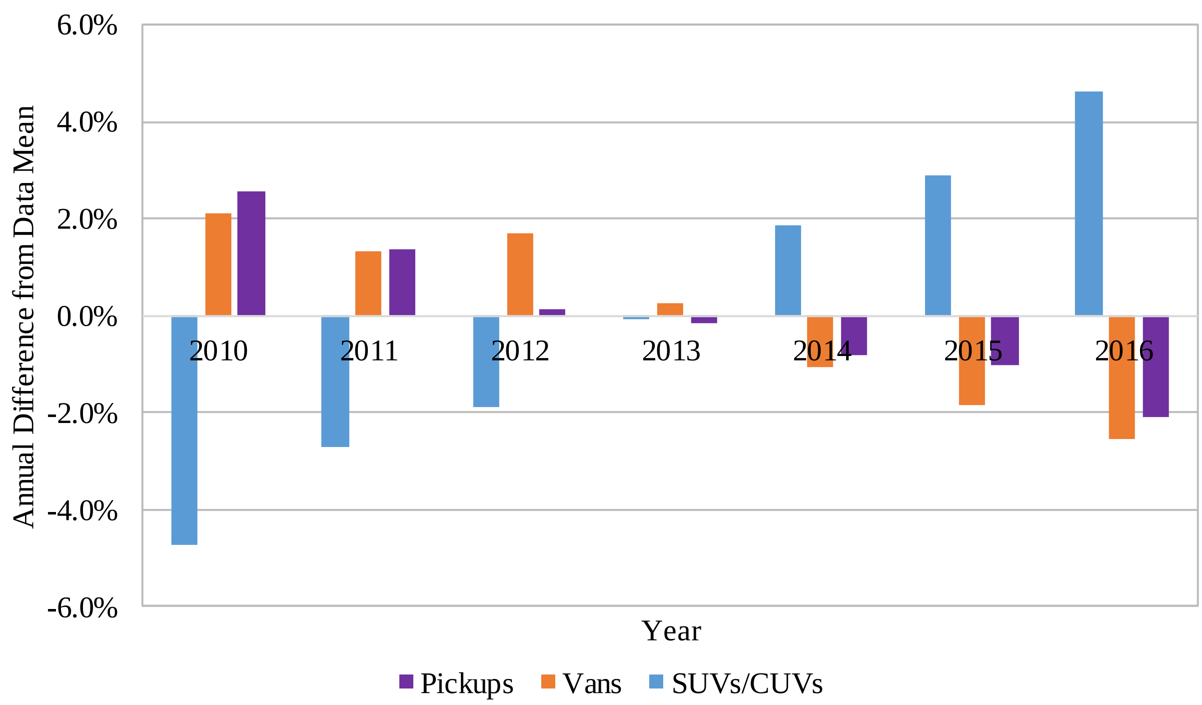


Figure 24. Yearly Difference from Mean Registrations [25]

6.2 U.S. Registrations and Crash Data

Number of vehicles registered and involved in fatal crashes from 2000 to 2017 are shown in Table 13. Vehicle types included passenger cars, light trucks, large trucks, and motorcycles.

Yearly shares and mean percent shares of vehicles registered and involved in fatal crashes are shown in the last row of Table 14. Note that fatal crash data was obtained from the FARS Encyclopedia [25]. Note that the totals shown for yearly crashes and fatal crashes only considered the four vehicle classes shown; buses and “other/unknown” were excluded from analysis.

Two additional perspectives were investigated to evaluate changes in vehicle ownership and their relationship to average fatal crash rates: (1) Mean Percent Share; and (2) Percent Difference from Mean Share.

- Mean percent shares were used as baseline values for year-to-year percent differences to identify trends in vehicles registered and involved in fatal crashes, which are shown in Table 15. The mean percent shares were calculated based on annual summary data as a share of all vehicle registrations and all fatal crashes, respectively. Since 2007, the mean share of passenger cars involved in fatal crashes has not exceeded 42%, nor fallen below 41%, even as registrations fell from 55.8% to 44.0% of all vehicles. The total Mean Share was calculated as the numerical average of each year’s percentage share.
- The Percent Difference from Mean Share evaluated how much the mean percent share changed varied from the mean spanning the entire evaluation period (2000 through 2016). Mean shares of vehicles registered and involved in fatal crashes were subtracted from yearly percent shares of total registrations and vehicles involved in fatal crashes for each vehicle type. A positive percentage indicates the share of vehicles for that year was greater than the mean. For example, the share of passenger cars registered decreased from 2000 to 2016, and the share of light trucks increased at a nearly proportional rate. The share of passenger cars involved in fatal crashes also decreased over the same span, and light truck and motorcycle fatal crash shares each grew to compensate for the passenger car decrease.

In addition to the changes from the nominal mean, annual year-to-year changes were also tabulated, as shown in Table 16. The year-to-year change was calculated by using the previous year's data as the baseline, and calculating the percentage change which occurred since the previous year. Results were surprising; except for the 2013-2012 period, light truck registrations and motorcycle registrations increased each year relative to the previous year. This result indicates that overall, consumers who purchase light truck and motorcycle vehicles retain them, and if a crash occurs, replace them with a similar vehicle. In contrast, passenger car registrations fell significantly; the largest change in passenger vehicle ownership occurred between 2012 and 2011, in which the yearly registrations for passenger cars decreased by 11.4%. This means that more than 1 in 10 passenger cars which were registered in 2011 were not re-registered in 2012. Moreover, this result followed a pattern; the annual passenger car registrations fell 1.6%, 3.0%, 4.0%, and 11.4% in each of 2009, 2010, 2011, and 2012, respectively.

Lastly, a ratio was taken of the total fatal crashes by vehicle type by the total number of vehicle registrations of that vehicle type per year. Results were expressed in terms of fatal crashes per number of registered vehicles. A low ratio (1 in 5,000 or more) was indicative of an infrequent fatal crash outcome; very low ratios (1 in 2,000 or less) indicated that severe crash outcomes happened much more frequently with that vehicle type. Results indicated that large trucks had a disproportionately severe crash outcome compared to other vehicle types, with an average of one fatal large truck crash for every 499 registered large trucks. In contrast, light truck vehicles averaged 1 fatal crash in 5,300 registered light truck vehicles between 2000 and 2016, but the trend was steady toward fewer fatal crashes between 2000 and 2014. Passenger cars similarly improved, but not to the same extent as light trucks. Passenger cars increased from 1 fatal crash per 4,806 registered cars in 2000 to 1 fatal crash per 7,352 registered cars in 2010. Alarmingly, since 2010, passenger car fatal crash rates have increased to 1 in 5,359 registered cars in 2016.

Table 13. Number of Vehicles Registered and Involved in Fatal Crashes by Vehicle Type

Year	Passenger Cars		Light Trucks		Large Trucks		Motorcycles		All Vehicles*	
	Registrations	**Involved in Fatal Crashes**	**Registrations**	**Involved in Fatal Crashes**	**Registrations**	**Involved in Fatal Crashes**	**Registrations**	**Involved in Fatal Crashes**	**Registrations**	**Involved in Fatal Crashes**
2016	112,961,266	21,077	132,715,671	19,920	2,582,751	4,562	8,679,380	5,467	256,939,068	51,026
2015	112,864,228	19,810	128,558,549	18,869	2,654,584	4,075	8,600,936	5,131	252,678,297	47,885
2014	113,898,845	17,895	124,680,609	17,160	2,617,189	3,749	8,417,718	4,705	249,614,361	43,509
2013	113,676,345	17,957	120,522,560	16,928	2,443,433	3,921	8,404,687	4,800	245,047,025	43,606
2012	111,289,906	18,269	120,846,948	17,350	2,581,245	3,825	8,454,939	5,113	243,173,038	44,557
2011	125,656,528	17,508	105,571,279	16,806	2,421,296	3,633	8,437,502	4,769	242,086,605	42,716
2010	130,892,240	17,804	102,702,321	17,491	1,889,166	3,494	8,009,503	4,651	243,493,230	43,440
2009	134,879,600	18,413	100,153,696	17,958	1,819,309	3,211	7,929,724	4,603	244,782,329	44,185
2008	137,079,843	20,474	99,570,332	19,179	1,930,378	4,089	7,752,926	5,409	246,333,479	49,151
2007	135,932,930	22,856	98,605,505	21,810	1,981,286	4,633	7,138,476	5,306	243,658,197	54,605
2006	135,399,945	24,260	94,674,393	22,411	1,966,248	4,766	6,678,958	4,963	238,719,544	56,400
2005	136,568,086	25,169	94,159,378	22,964	1,871,991	4,951	6,227,146	4,682	238,826,601	57,766
2004	136,430,651	25,682	90,383,407	22,486	1,876,118	4,902	5,780,870	4,121	234,471,046	57,191
2003	135,669,897	26,562	85,800,746	22,299	1,757,288	4,721	5,370,035	3,802	228,597,966	57,384
2002	135,920,677	27,374	83,783,719	21,668	1,790,430	4,587	5,004,156	3,365	226,498,982	56,994
2001	137,633,467	27,586	82,948,595	20,831	1,663,541	4,823	4,903,056	3,265	227,148,659	56,505
2000	133,621,420	27,802	77,796,827	20,498	1,587,611	4,995	4,346,068	2,975	217,351,926	56,270
Mean 2000-2016	**128,257,404**	**22,147**	**102,557,326**	**19,802**	**2,084,345**	**4,290**	**7,066,828**	**4,537**	**239,965,903**	**50,776**

*NOTE: Only registrations and fatal crashes including passenger cars, light trucks, large trucks, and motorcycles shown

Table 14. Percent Share of Vehicles Registered and Involved in Fatal Crashes by Vehicle Type

Year	Passenger Cars		Light Trucks		Large Trucks		Motorcycles	
	% of Total Registrations	% of Total Involved in Fatal Crashes	% of Total Registrations	% of Total Involved in Fatal Crashes	% of Total Registrations	% of Total Involved in Fatal Crashes	% of Total Registrations	% of Total Involved in Fatal Crashes
2016	44.0%	41.3%	51.7%	39.0%	1.0%	8.9%	3.4%	10.7%
2015	44.7%	41.4%	50.9%	39.4%	1.1%	8.5%	3.4%	10.7%
2014	45.6%	41.1%	49.9%	39.4%	1.0%	8.6%	3.4%	10.8%
2013	46.4%	41.2%	49.2%	38.8%	1.0%	9.0%	3.4%	11.0%
2012	45.8%	41.0%	49.7%	38.9%	1.1%	8.6%	3.5%	11.5%
2011	51.9%	41.0%	43.6%	39.3%	1.0%	8.5%	3.5%	11.2%
2010	53.8%	41.0%	42.2%	40.3%	0.8%	8.0%	3.3%	10.7%
2009	55.1%	41.7%	40.9%	40.6%	0.7%	7.3%	3.2%	10.4%
2008	55.6%	41.7%	40.4%	39.0%	0.8%	8.3%	3.1%	11.0%
2007	55.8%	41.9%	40.5%	39.9%	0.8%	8.5%	2.9%	9.7%
2006	56.7%	43.0%	39.7%	39.7%	0.8%	8.5%	2.8%	8.8%
2005	57.2%	43.6%	39.4%	39.8%	0.8%	8.6%	2.6%	8.1%
2004	58.2%	44.9%	38.5%	39.3%	0.8%	8.6%	2.5%	7.2%
2003	59.3%	46.3%	37.5%	38.9%	0.8%	8.2%	2.3%	6.6%
2002	60.0%	48.0%	37.0%	38.0%	0.8%	8.0%	2.2%	5.9%
2001	60.6%	48.8%	36.5%	36.9%	0.7%	8.5%	2.2%	5.8%
2000	61.5%	49.4%	35.8%	36.4%	0.7%	8.9%	2.0%	5.3%
Mean 2000-2016	**53.7%**	**43.4%**	**42.6%**	**39.1%**	**0.9%**	**8.4%**	**2.9%**	**9.1%**

*NOTE: Only registrations and fatal crashes including passenger cars, light trucks, large trucks, and motorcycles shown

Table 15. Percent Difference from Mean Share of Vehicles Registered and Involved in Fatal Crashes

Year	Passenger Cars**		Light Trucks**		Large Trucks**		Motorcycles**		All Vehicles**	
	Registrations	Involved in Fatal Crashes	Registrations	Involved in Fatal Crashes	Registrations	Involved in Fatal Crashes	Registrations	Involved in Fatal Crashes	Registrations	Involved in Fatal Crashes
2016	-9.74%	-2.09%	9.05%	-0.06%	0.11%	0.54%	0.48%	1.61%	7.07%	0.49%
2015	-9.03%	-2.03%	8.28%	0.30%	0.15%	0.11%	0.50%	1.62%	5.30%	-5.69%
2014	-8.07%	-2.27%	7.35%	0.34%	0.15%	0.22%	0.47%	1.71%	4.02%	-14.31%
2013	-7.31%	-2.22%	6.58%	-0.28%	0.10%	0.59%	0.53%	1.91%	2.12%	-14.12%
2012	-7.93%	-2.40%	7.10%	-0.16%	0.16%	0.18%	0.58%	2.38%	1.34%	-12.25%
2011	-1.79%	-2.41%	1.01%	0.24%	0.10%	0.11%	0.59%	2.06%	0.88%	-15.87%
2010	0.06%	-2.41%	-0.42%	1.16%	-0.12%	-0.36%	0.39%	1.61%	1.47%	-14.45%
2009	1.40%	-1.73%	-1.68%	1.54%	-0.16%	-1.13%	0.34%	1.32%	2.01%	-12.98%
2008	1.95%	-1.74%	-2.18%	-0.08%	-0.12%	-0.08%	0.25%	1.90%	2.65%	-3.20%
2007	2.09%	-1.54%	-2.13%	0.84%	-0.09%	0.08%	0.03%	0.62%	1.54%	7.54%
2006	3.02%	-0.39%	-2.94%	0.64%	-0.08%	0.05%	-0.10%	-0.30%	-0.52%	11.08%
2005	3.48%	0.17%	-3.17%	0.65%	-0.12%	0.17%	-0.29%	-0.99%	-0.47%	13.77%
2004	4.49%	1.51%	-4.05%	0.22%	-0.10%	0.17%	-0.43%	-1.89%	-2.29%	12.63%
2003	5.65%	2.89%	-5.07%	-0.24%	-0.13%	-0.17%	-0.55%	-2.47%	-4.74%	13.01%
2002	6.31%	4.63%	-5.61%	-1.08%	-0.11%	-0.35%	-0.69%	-3.20%	-5.61%	12.25%
2001	6.89%	5.42%	-6.08%	-2.23%	-0.17%	0.14%	-0.74%	-3.32%	-5.34%	11.28%
2000	7.78%	6.01%	-6.81%	-2.67%	-0.17%	0.48%	-0.90%	-3.81%	-9.42%	10.82%

*NOTE: Only registrations and fatal crashes including passenger cars, light trucks, large trucks, and motorcycles shown
**NOTE: Pink cells denote when yearly totals were less than the average spanning 2000-2016

Table 16. Year-to-Year Change in Registration and Fatal Crash Data

Evaluation Period	Passenger Cars		Light Trucks		Large Trucks		Motorcycles		All Vehicles	
	Year-to-Year Change in Registrations	Year-to-Year Change in Fatal Crashes	Year-to-Year Change in Registrations	Year-to-Year Change in Fatal Crashes	Year-to-Year Change in Registrations	Year-to-Year Change in Fatal Crashes	Year-to-Year Change in Registrations	Year-to-Year Change in Fatal Crashes	Year-to-Year Change in Registrations	Year-to-Year Change in Fatal Crashes
2016-2015	0.09%	6.40%	3.23%	5.57%	-2.71%	11.95%	0.91%	6.55%	1.69%	6.56%
2015-2014	-0.91%	10.70%	3.11%	9.96%	1.43%	8.70%	2.18%	9.05%	1.23%	10.06%
2014-2013	0.20%	-0.35%	3.45%	1.37%	7.11%	-4.39%	0.16%	-1.98%	1.86%	-0.22%
2013-2012	2.14%	-1.71%	-0.27%	-2.43%	-5.34%	2.51%	-0.59%	-6.12%	0.77%	-2.13%
2012-2011	-11.43%	4.35%	14.47%	3.24%	6.61%	5.28%	0.21%	7.21%	0.45%	4.31%
2011-2010	-4.00%	-1.66%	2.79%	-3.92%	28.17%	3.98%	5.34%	2.54%	-0.58%	-1.67%
2010-2009	-2.96%	-3.31%	2.54%	-2.60%	3.84%	8.81%	1.01%	1.04%	-0.53%	-1.69%
2009-2008	-1.61%	-10.07%	0.59%	-6.37%	-5.75%	-21.47%	2.28%	-14.90%	-0.63%	-10.10%
2008-2007	0.84%	-10.42%	0.98%	-12.06%	-2.57%	-11.74%	8.61%	1.94%	1.10%	-9.99%
2007-2006	0.39%	-5.79%	4.15%	-2.68%	0.76%	-2.79%	6.88%	6.91%	2.07%	-3.18%
2006-2005	-0.86%	-3.61%	0.55%	-2.41%	5.04%	-3.74%	7.26%	6.00%	-0.04%	-2.36%
2005-2004	0.10%	-2.00%	4.18%	2.13%	-0.22%	1.00%	7.72%	13.61%	1.86%	1.01%
2004-2003	0.56%	-3.31%	5.34%	0.84%	6.76%	3.83%	7.65%	8.39%	2.57%	-0.34%
2003-2002	-0.18%	-2.97%	2.41%	2.91%	-1.85%	2.92%	7.31%	12.99%	0.93%	0.68%
2002-2001	-1.24%	-0.77%	1.01%	4.02%	7.63%	-4.89%	2.06%	3.06%	-0.29%	0.87%
2001-2000	3.00%	-0.78%	6.62%	1.62%	4.78%	-3.44%	12.82%	9.75%	4.51%	0.42%

*NOTE: Only registrations and fatal crashes including passenger cars, light trucks, large trucks, and motorcycles shown

**NOTE: Pink cells denote year-on-year decreases, and white cells denote year-on-year increases. All data was analyzed by pairing consecutive years. Multiple consecutive periods of similar activity (growth or contraction) were indicative of trends.

Table 17. Rates of Fatal Crashes per Registered Vehicles

Year	Passenger Cars Fatal Crash/Registered Vehicle	Light Trucks Fatal Crash/Registered Vehicle	Large Trucks Fatal Crash/Registered Vehicle	Motorcycles Fatal Crash/Registered Vehicle	All Vehicles* Fatal Crash/Registered Vehicle
2016	1 per 5,359	1 per 6,662	1 per 566	1 per 1,588	1 per 5,035
2015	1 per 5,697	1 per 6,813	1 per 651	1 per 1,676	1 per 5,277
2014	1 per 6,365	1 per 7,266	1 per 698	1 per 1,789	1 per 5,737
2013	1 per 6,330	1 per 7,120	1 per 623	1 per 1,751	1 per 5,620
2012	1 per 6,092	1 per 6,965	1 per 675	1 per 1,654	1 per 5,458
2011	1 per 7,177	1 per 6,282	1 per 666	1 per 1,769	1 per 5,667
2010	1 per 7,352	1 per 5,872	1 per 541	1 per 1,722	1 per 5,605
2009	1 per 7,325	1 per 5,577	1 per 567	1 per 1,723	1 per 5,540
2008	1 per 6,695	1 per 5,192	1 per 472	1 per 1,433	1 per 5,012
2007	1 per 5,947	1 per 4,521	1 per 428	1 per 1,345	1 per 4,462
2006	1 per 5,581	1 per 4,224	1 per 413	1 per 1,346	1 per 4,233
2005	1 per 5,426	1 per 4,100	1 per 378	1 per 1,330	1 per 4,134
2004	1 per 5,312	1 per 4,020	1 per 383	1 per 1,403	1 per 4,100
2003	1 per 5,108	1 per 3,848	1 per 372	1 per 1,412	1 per 3,984
2002	1 per 4,965	1 per 3,867	1 per 390	1 per 1,487	1 per 3,974
2001	1 per 4,989	1 per 3,982	1 per 345	1 per 1,502	1 per 4,020
2000	1 per 4,806	1 per 3,795	1 per 318	1 per 1,461	1 per 3,863
MEAN	**1 fatal crash per 5,913 registered vehicles**	**1 fatal crash per 5,300 registered vehicles**	**1 fatal crash per 499 registered vehicles**	**1 fatal crash per 1,552 registered vehicles**	**1 fatal crash per 4,807 registered vehicles**

*NOTE: Only registrations and fatal crashes including passenger cars, light trucks, large trucks, and motorcycles shown

Available registrations were graphically compared to fatally crashed vehicles to observe trends between the two datasets. The number of passenger cars registered decreased from 133,621,420 in 2000 to 112,961,266 in 2016 [24]. The number of passenger cars involved in fatal crashes decreased from 27,802 to 21,031 [26]. Shares of passenger cars registered and involved in fatal crashes are shown in Figure 25. In 2000, 59.2% of all registered vehicles were passenger cars and 49.4% of all vehicles involved in fatal crashes were passenger cars. In comparison, 42.0% of all registered vehicles were passenger cars in 2017, and 41.2% of all vehicles in fatal crashes were passenger cars.

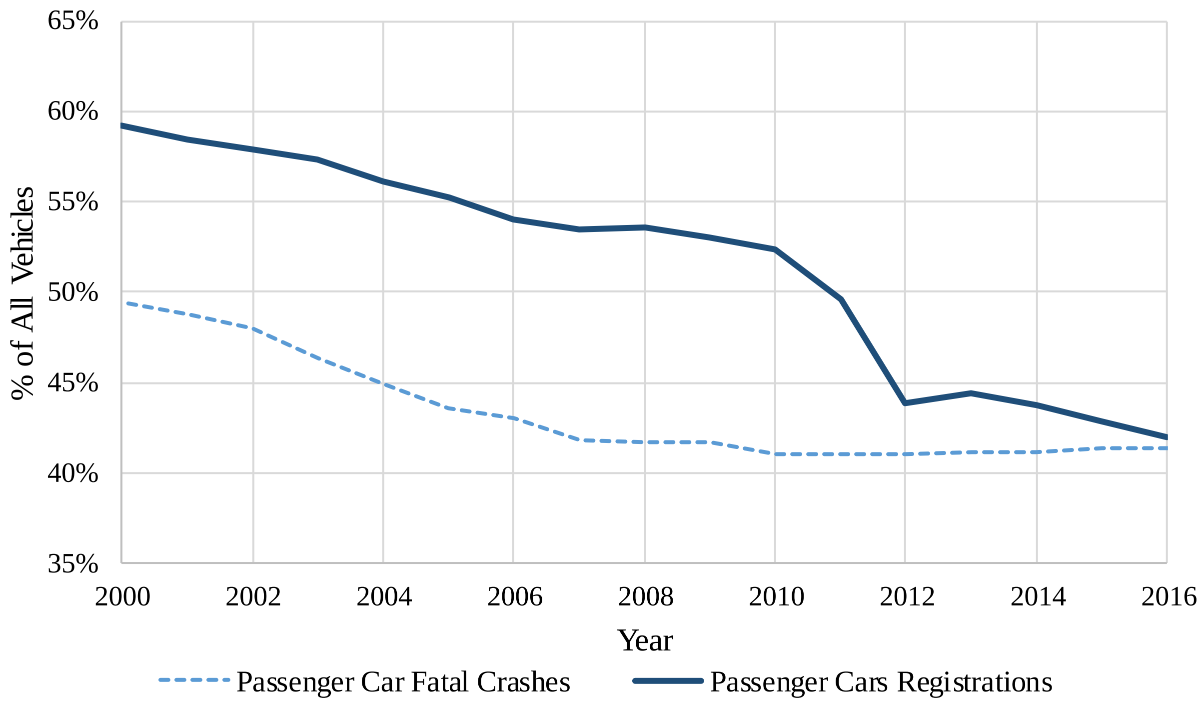


Figure 25. Percentage of Passenger Car Registrations Compared to Fatal Crashes [24, 25]

The number of light trucks registered increased from 77,796,827 in 2000 to 146,182,276 in 2016 [24]. The number of light trucks involved in fatal crashes decreased from 20,498 to 19,986 over that same period [26]. Shares of light trucks registered and fatally crashed are compared in Figure 26. There have been increases in both the share of light trucks registered and fatally crashed over the last 17 years; however, the number of light trucks involved in fatal crashes decreased. Light trucks comprised 34.5% of all registered vehicles in 2000 and 49.4% of all registered vehicles in 2016. The percent of light trucks involved in fatal crashes and percent of registrations that were light trucks were very similar until 2011. As noted in the crash data analysis, fatal crashes were considerably more common with vehicles which were five to 10 years old than new vehicles. Results suggest that in 2018 and 2019 as well as the early 2020s, there will be a large increase in light truck crashes, driven primarily by an increase in SUV and CUV crashes.

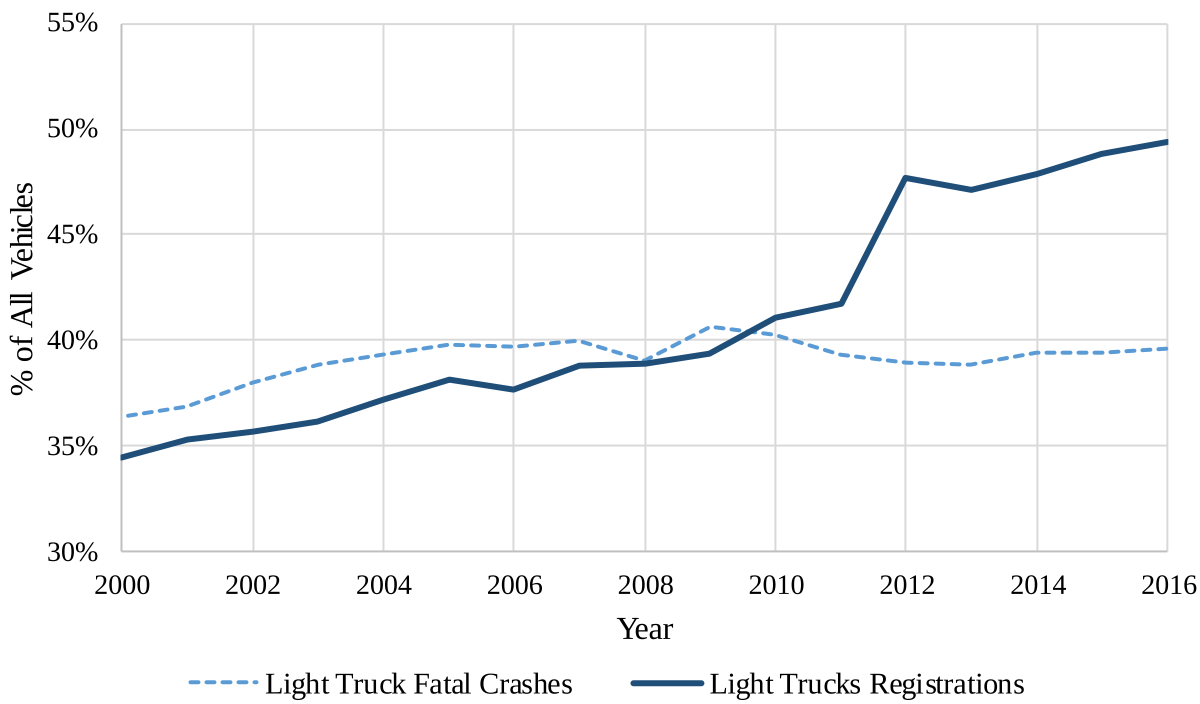


Figure 26. Light Truck Registrations Compared to Fatal Crashes [24, 25]

The number of motorcycles registered increased from 4,346,068 in 2000 to 8,679,380 in 2016. The number of motorcycles involved in fatal crashes increased from 2,975 to 5,236. This significant increase in fatal motorcycle crashes has led to alarm in the roadside safety community. A comparison of motorcycle registrations and crashes is shown in Figure 27.

The number of large trucks registered increased from 1,587,611 in 2000 to 2,582,751 in 2016 [24], and the number of large trucks involved in fatal crashes decreased slightly from 4,995 to 4,657 [26]. A comparison of large truck registrations and fatal crashes is shown in Figure 27.

Large trucks and motorcycles were each disproportionately represented in fatal crash data from what registration shares would suggest. Since 2007, motorcycles have comprised a three times greater proportional share of fatally crashed vehicles than their registrations share would suggest.

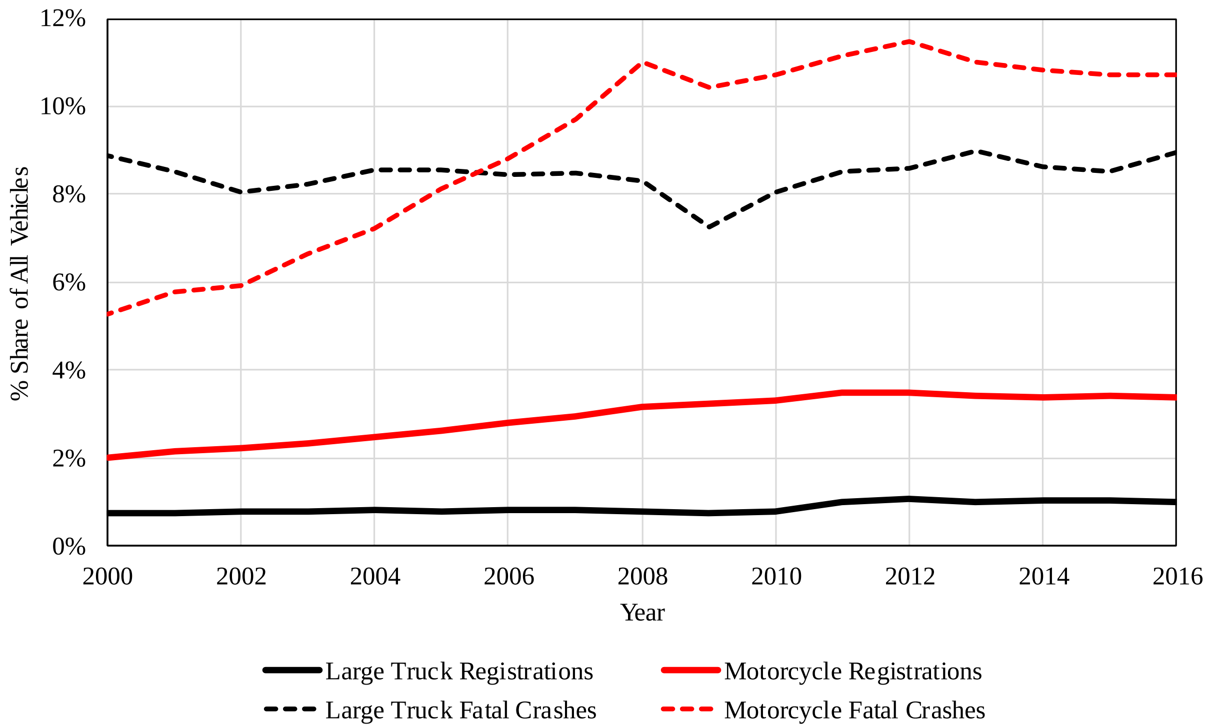


Figure 27. Motorcycle and Large Truck Registrations Compared to Fatal Crashes [24-26]

From 2010 to 2016, registrations were also compared with crashed vehicles resulting in injuries, shown in Figure 28. Passenger cars comprised a larger proportion of injury inducing crashes than registrations. Contrarily, light truck comprised a smaller portion of injury inducing crashes than registrations. Injury crashes for large trucks and motorcycles were both less than their registration shares.

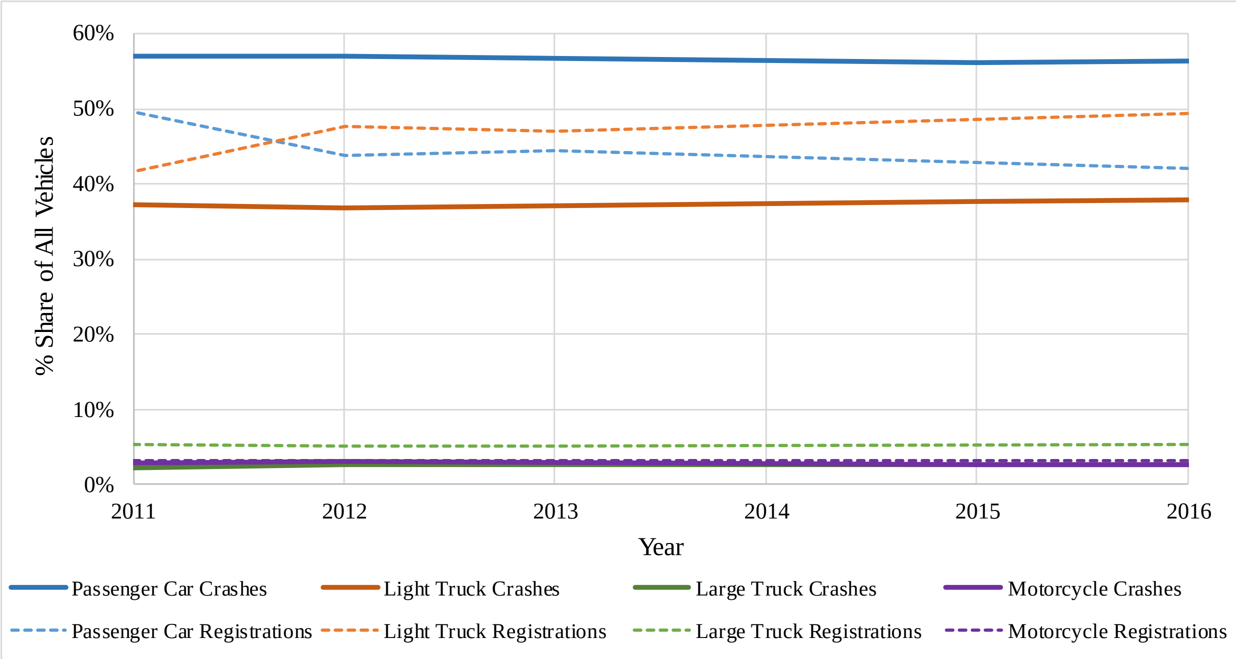


Figure 28. Vehicles Involved in Injury-Inducing Crashes Compared to Registrations [24]

6.3 State Registrations and Crash Data

National registrations and crashes provide insight on the nation as a whole; however, vehicle registrations greatly differ from state to state. Nationally from 2014 – 2015, 48.3% of all registered vehicles were light trucks and about 43.3% were cars [25]. In contrast, approximately 66.8% of all registered vehicles in Wyoming are light trucks and about 27.4% are cars. Some states, like Ohio, are more consistent with national registrations. From 2014 to 2015, nearly 47.5% of all registered vehicles were light trucks and about 47.1% were cars. Additional state registration data is shown in Table C-4.

Available crash data were compared to registrations on a state-by-state basis. Although the dataset was limited, it was desired to generate a comparison of the distribution of crashed passenger cars and light trucks to the distribution of vehicle registrations, to determine if there were risk factors specifically associated with vehicle types. Crash records from Wyoming, Ohio, and Utah were reviewed. In Wyoming, approximately 58.2% of all crashed vehicles were light trucks, and nearly 30.3% were passenger cars; 56.6% of vehicles crashed in Ohio were passenger cars and 41.8% were light trucks; and in Utah, 49.1% of crashed vehicles were passenger cars and 42.6% were light trucks. In each state, it was found that a smaller portion of light trucks and greater portion of cars were crashed than registered. Additional details of each state's registered and crashed vehicles are shown in Figures 29 through 31.

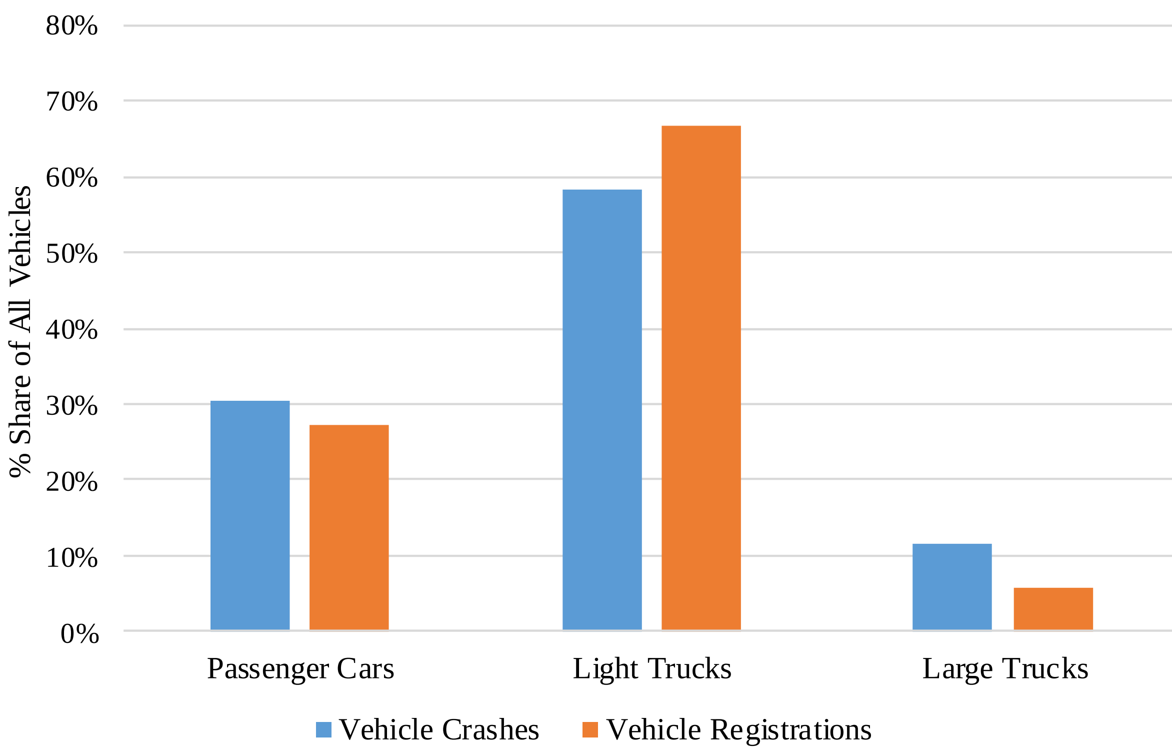


Figure 29. Comparison of Crashed and Registered Vehicles in Wyoming

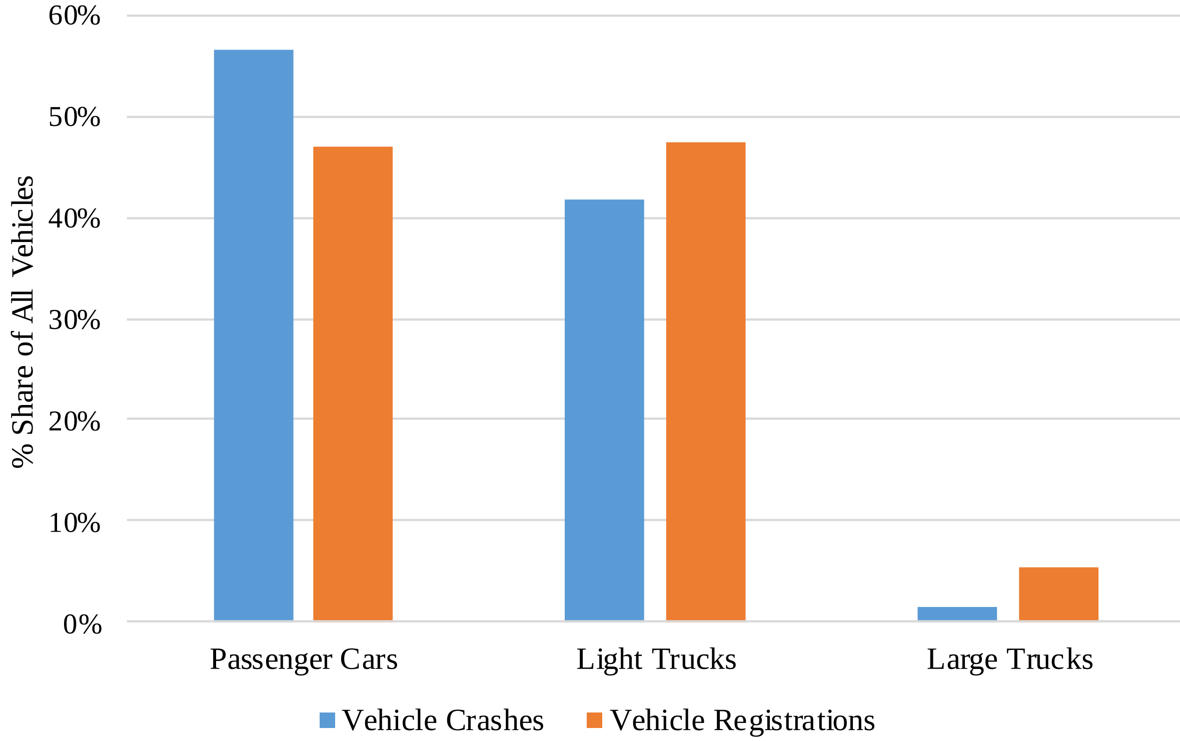


Figure 30. Comparison of Crashed and Registered Vehicles in Ohio

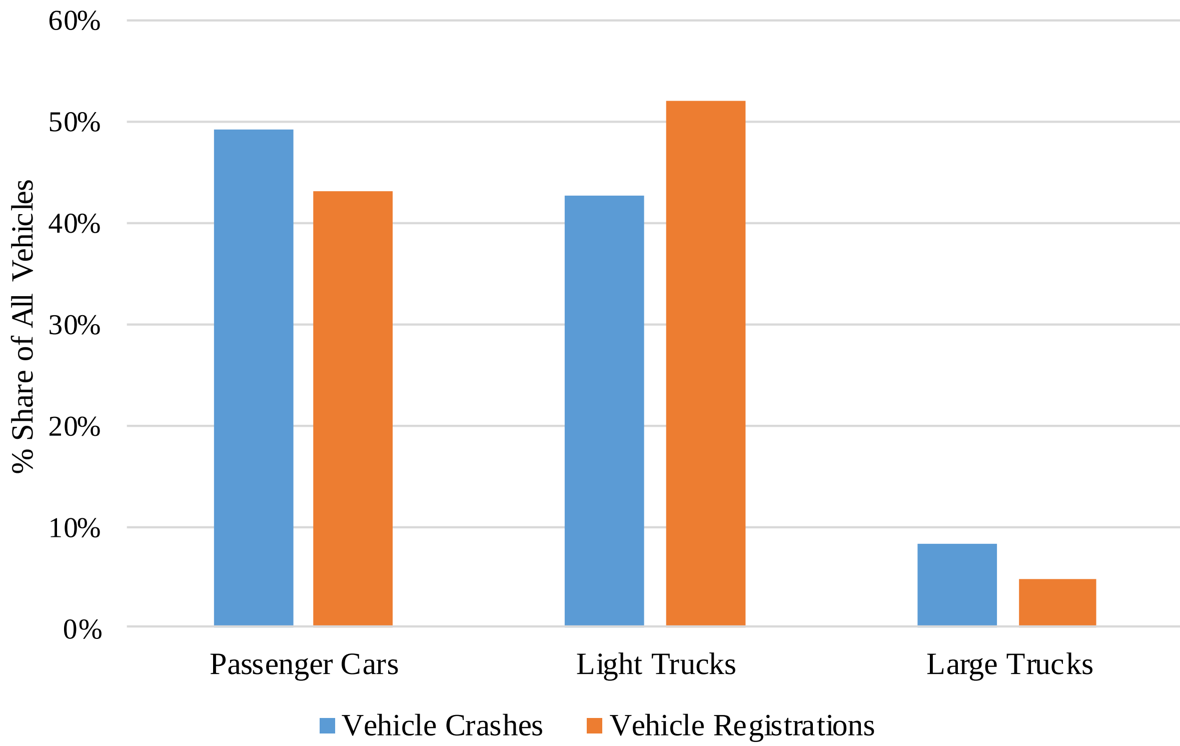


Figure 31. Comparison of Crashed and Registered Vehicles in Utah

6.4 Analysis Considerations

Results of the registration data analysis indicated a significant growth of light truck volume in the passenger vehicle market, primarily driven by increases in SUV and CUV registrations. Of the registered passenger vehicles, sedans were the most common, and about five sedans are registered for every one of all other combined car body styles (hatchback, coupe, wagon, and convertible). Hatchback vehicles were involved in an increasing number of fatal crashes between 2010 and 2017, but total registrations and overall share of passenger vehicles were not significantly changed. Some discrepancies may be attributed to vehicle classification differences between data sources, who may consider different criteria for segmenting hatchbacks and wagons.

Light truck registrations surpassed cars in 2012, and the margin between light truck and passenger car registrations increased each year thereafter. State data indicated that national trends may not be representative of local trends because passenger cars were the most common vehicle involved in fatal crashes in Ohio and Utah.

Motorcycles were found to be nearly three times more likely to be involved in fatal crashes than registration share would suggest, and likewise, a greater percentage of motorcycle crashes are severe (fatality and serious injury) than other vehicle types. Nearly 80% of motorcycle crashes result in fatalities or injuries, and approximately 19% to 33% of all other crashed vehicles resulted in fatalities or injuries. Motorcycle involvement in fatal and injury crashes is likely more common than that of other vehicle types because motorcycles lack restraint systems, and their occupants are directly exposed to their surroundings. Additional details on distribution of crash severity by vehicle type are shown in APPENDIX B .

Although crash trends suggest that passenger cars are more likely to be involved in both fatal crashes and all crashes compared to light trucks, it is important to acknowledge the effect of vehicle age on crash likelihood. As shown in Chapter 4, the average vehicle age at the time of the crash was between 11 and 12 years old, declining steadily after 16 years of vehicle age, whereas the average age in fatal crashes was 4 to 6 years old. A significant number of light truck vehicles were purchased in the years after 2012 and 2013, which would suggest that a significant volume of light truck crashes involving light trucks, specifically CUVs, is expected soon. Thus, although fatal crash rates for light trucks, SUVs, and CUVs was relatively low between 2013 and 2016 compared to registered vehicle data, there is significant concern that this only represents a lag between sales and registrations compared to crash data.

Additionally, FARS identifies each fatal crash using a singular, specific vehicle type. It is not clear what vehicle type is selected when severe crash results involve more than one vehicle type (e.g., large truck to car crash). Analyzing all crash data to evaluate vehicle for only run-off-road (ROR) crashes was beyond the scope of this research study, and would itself pose challenges when more than one vehicle was involved in a ROR crash. Results may be affected by the methods chosen to tabulate vehicle type per fatal crash outcome.

CHAPTER 7 Vehicle Sales Analysis

7.1 Method

Vehicle sales data was obtained from 2005 to 2018 and included unit sales by vehicle make, model, and year for domestic and import vehicle models (specific model trim level and motorcycle sales were not included). The sales were analyzed to approximate modern U.S. vehicle fleet composition. Emphasis was placed on 2017 sales data because the dataset was complete and available throughout this study. Note that 2018 data became available after preliminary results were presented for 2017. Some 2018 data was utilized and compared to 2017, but full utilization of 2018 data would require a complete replication of the 2017 data analysis effort and was therefore not within the scope of this project.

7.2 Passenger Vehicle Sales Trends

In 1980, passenger cars comprised nearly 80% new passenger vehicle sales, and light trucks comprised the majority of the remaining sales (20%) [29]. Passenger cars include body styles such as sedans, coupes, convertibles, and hatchbacks, while light trucks consist of CUVs, SUVs, pickup trucks, and vans. A significant shift in passenger vehicle sales trends has occurred since 1980. Recently, new light truck sales outnumbered passenger car sales by a factor of two. In 2018, nearly 69% of new passenger vehicle sales involved light trucks, whereas 31% were passenger cars. The sales trend from 1980 to 2018 is shown in Figure 32.

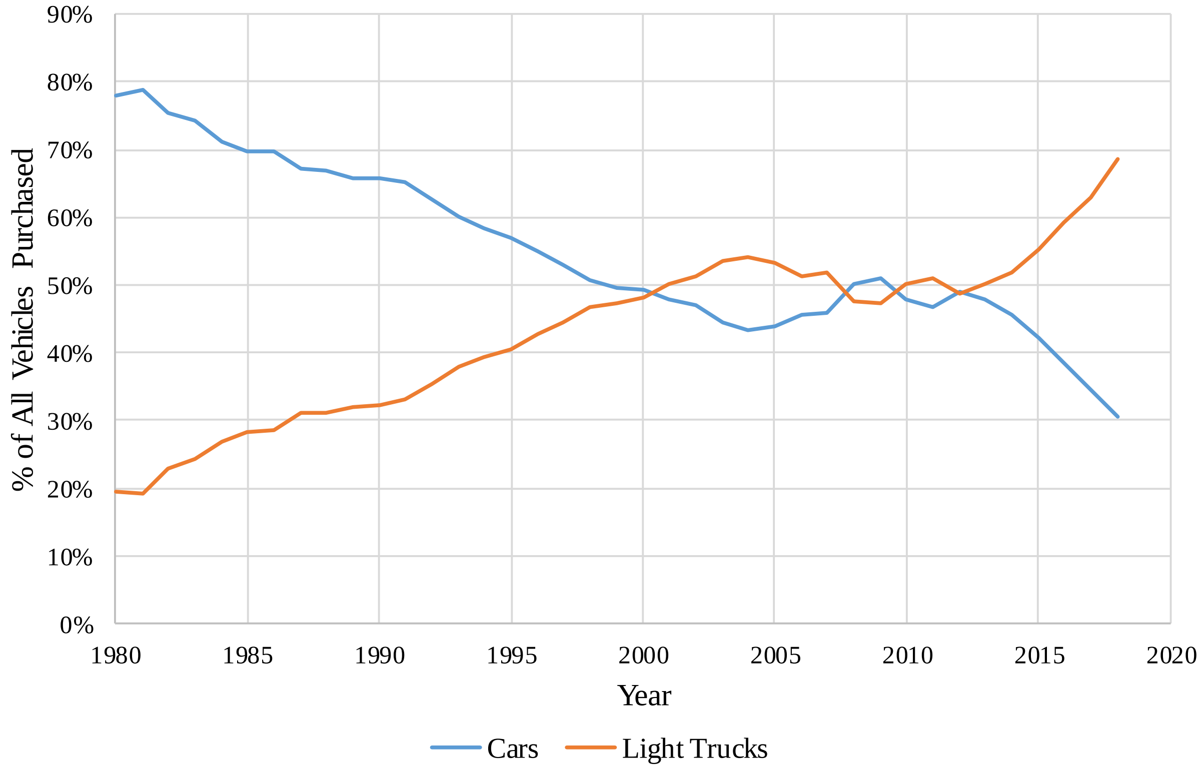


Figure 32. U.S. Passenger Vehicle Sales by Car and Light Trucks [29]

Trends in light truck sales were strongly affected by U.S. economic events. During periods of economic growth, overall sales increased, and light truck sales had a disproportionate increase. During economic recessions and corrections, overall sales declined, as shown in Figure 33. It is known that economic uncertainties, particularly recessions, coincide with decreased consumer purchasing. Passenger vehicle sales decreased with periods of economic uncertainty such as the recessions of 1990 [35] and 2007 [36].

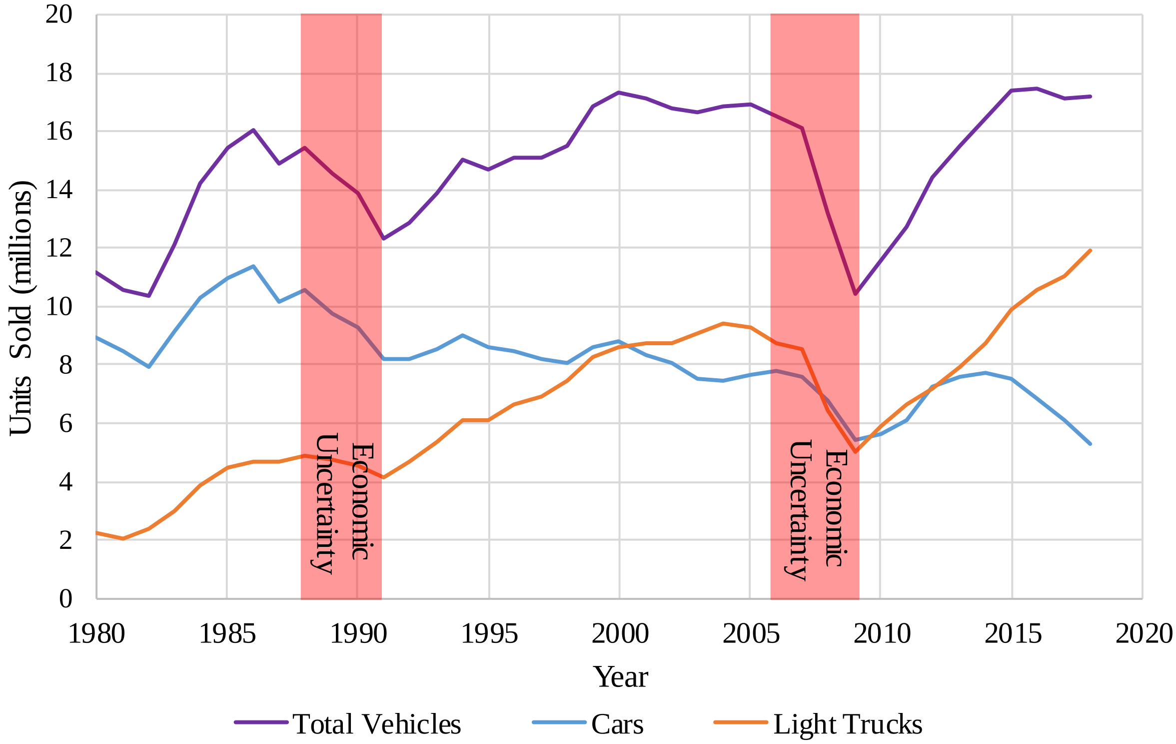


Figure 33. Passenger Vehicle Sales and Periods of Economic Uncertainty

Sales data [29] for years 2005 to 2018 were analyzed by assigning a classification for each vehicle model based on Wards Intelligence "vehicle type" segmentation criteria [23]. The distribution of new vehicle sales by vehicle type were plotted for years 2005 through 2018, as shown in Figure 34 and Table 18. Since 2005, CUVs have seen a significant increase in their share of total vehicles sold, rising 26.7% from 12.0% to 38.7%. In contrast, pickup truck, SUV, van, and all passenger car sales declined as a percentage of sales between 2005 and 2018. Therefore, the increase in new light truck sales over the last decade has been primarily driven by CUV sales. For comparison, in 2005, there were 41 CUV and 164 car vehicle models available for purchase, and in 2018 there were 97 CUV and 160 car models available for purchase.

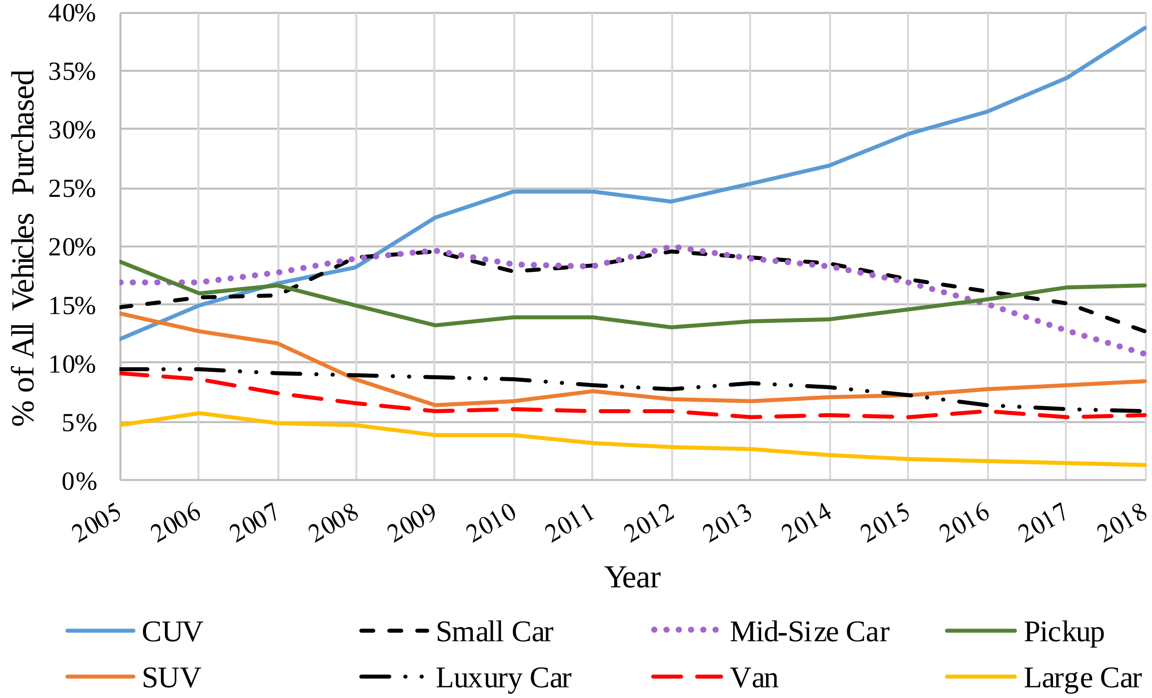


Figure 34. U.S. Passenger Vehicle Sales by Vehicle Type

Table 18. Share Change in U.S. Passenger Vehicle Sales by Vehicle Type

Passenger Vehicle Sales Shares				
Vehicle Type	**2005**	**2017**	**2018**	**2005 to 2018 Share Change**
CUV	12.0%	34.5%	38.7%	26.7%
Small Car	14.7%	15.1%	12.8%	-2.0%
Mid-Size Car	16.9%	12.8%	10.8%	-6.1%
Pickup Truck	18.8%	16.5%	16.7%	-2.1%
SUV	14.3%	8.1%	8.4%	-5.9%
Luxury Car	9.4%	6.1%	6.0%	-3.5%
Van	9.2%	5.4%	5.5%	-3.7%
Large Car	4.7%	1.5%	1.3%	-3.4%

7.2.1 Future Passenger Vehicle Sales

Supply and demand models suggest that manufacturers are reacting to changes in consumer preferences. Utility vehicles typically have more seating space and cargo areas, and drivers of these vehicles sit higher off the ground compared to cars. Moreover, due to increases in weight and size, light truck vehicles are generally considered safer for vehicle occupants than passenger cars. These factors may contribute to higher consumer preference for utility vehicles over cars [37]. Recently, General Motors and Ford have phased out car models in favor of producing more CUVs and SUVs [38].

Since the 1980s, light truck sales have grown consistently, with a sharp increase observed since 2014. The increasing trend is likely to flatten as the market share is steadily approaching three out of four new vehicle sales; however, with tremendous improvements in CUV fuel economy combined with relatively low fuel prices and greater CUV reliability [37], it is uncertain when the light truck sales will stagnate as a percentage of all new vehicle sales.

7.2.2 Trim Levels and Pickup Truck Sales

Sales data were not differentiated among model trim levels for any passenger vehicles in the available Wards Intelligence data. Most vehicle models may be produced with external trim, structure, optional features, or size variations. These customizations may be minor and include features such as heated seats, sunroof or moon roof, in-vehicle navigation, or entertainment systems. Structural differences such as wheelbase, engine size, towing or cargo capacity, and increased occupant compartment volume may also vary among trims.

For example, the 2017 Honda Civic has five trim level curb weights among three vehicle body styles (sedan, coupe, and hatchback) [39]:

- The “LX” trim consists of standard vehicle features. It includes a 174-hp 1.5L turbocharged engine, 6-speed transmission, rear-view camera, and an available continuously-variable transmission (CVT).
- The “Sport” includes most features of the LX but has a 189-hp 4-cylider engine. Underbody spoilers, 19-inch alloy wheels, and fog lights are all included with available CVT.

- The “EX” includes all available LX features as well as power moonroof, audio-display touch screen, Honda LaneWatch, remote start, and comes with CVT as a standard feature.
- The “EX-L” has all EX features. Leather-trimmed interior, satellite linked-navigation, heated front seats, and 8-way power driver’s seats have also been implemented.
- The “Touring” is the premier vehicle trim and consists of all the EX-L features as well as automatic LED headlights, Honda Sensing, upgraded audio system, and heated rear outboard seats.

Images and further specification differences of the civic models are readily available using online search engines, such as cars.com [39].

Sales data were not differentiated by trim level or optional features. For example, a total of 117,596 new Kia Forte small cars were sold in 2017 [40]. Those 117,596 sales were distributed among six trim levels: two coupes, two hatchbacks, and two sedans. The lightest of the vehicle models was the Forte LX 4-Door Sedan, and the heaviest was the Forte SX Luxury 5-Door Hatchback. Unfortunately, no information was available to determine how sales were distributed among the six trim options. Techniques for distributing total vehicle model sales among model trim levels are further discussed in Chapter CHAPTER 9.

Pickup truck model sales were differentiated less than passenger cars with respect to trim levels and payload capacities. For example, Ford F-series pickup trucks sold 834,445 units in 2017 [40]; however, data were unavailable for the proportion of ½-ton (F-150), ¾-ton (F-250), and one-ton (F-350) payload pickup trucks, as well as trim variations for each suspension class.

To accommodate the low resolution of available data, regional sales aggregates from commercial and individual sales were acquired from Dominion Cross-Sell, which contained data collected from car dealerships in 23 states [41]. The state data provided by the Cross-Sell are denoted in Figure 35.

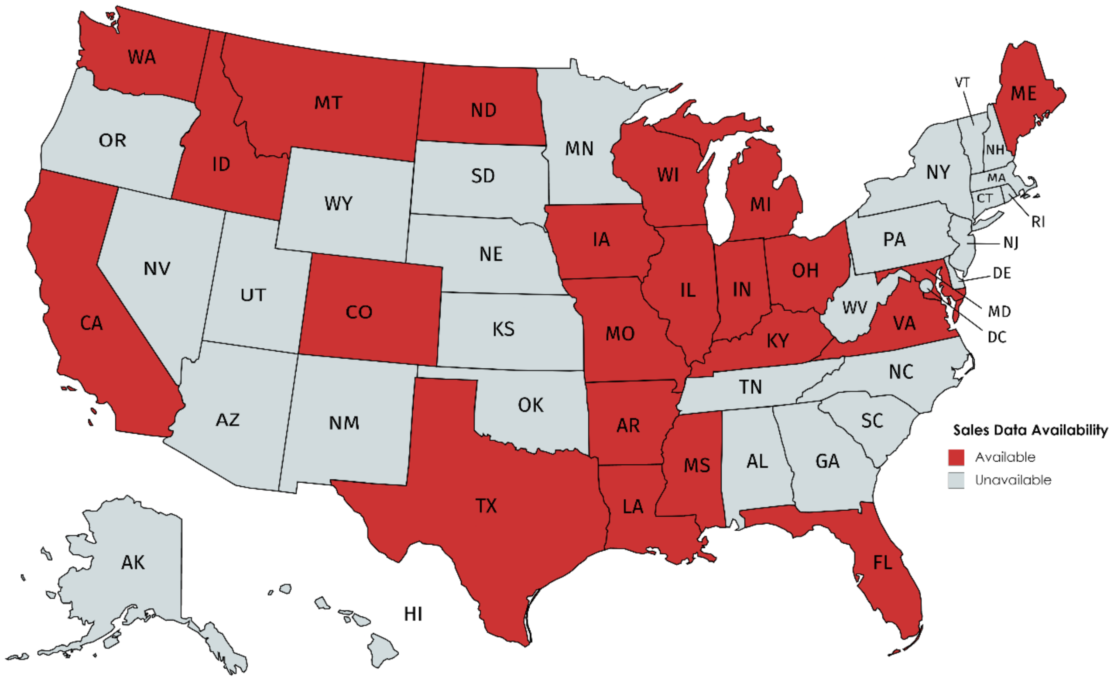


Figure 35. State Data Contributors for Pickup Truck Payload Capacity Analysis [41,42]

The Cross-Sell data denoted the number of pickup truck model units sold by payload capacity in each state. Then, the proportion of sales attributed to ½-ton, ¾-quarter ton, and one-ton pickup trucks were extrapolated to estimate the national sales average estimates. For example, within the Cross-Sell market area, 483,605 Ford F-series pickup trucks were sold. Of these, 332,165 (68.7%) were Ford F-150s, 102,828 (21.3%) were F-250s, and 48,612 (10.1%) were F-350s.

Next, researchers extrapolated the percent shares of pickup trucks in the Dominion Cross-Sell data to the national sales data. The market area percent share of models sold was multiplied by the total national sales number to obtain estimated national units sold by payload capacity, shown in Table 19. These approximate sales values and distribution of total model sales among trim levels are further discussed in Chapter CHAPTER 9.

Table 19. National Sales Estimates of Pickup Trucks by Payload Capacity

Make	Model and Payload	Market Area Units Sold	% Share of Models Sold	Total Units Sold Nationally	Estimated Units Sold Nationally
Chevrolet	Silverado 1500	364,430	75.8%	585,864	**444,085**
	Silverado 2500	84,740	17.6%		**103,112**
	Silverado 3500	31,796	6.6%		**38,667**
Ford	F-150	332,165	68.7%	834,445	**573,264**
	F-250	102,828	21.3%		**177,737**
	F-350	48,612	10.0%		**83,445**
GMC	Sierra 1500	94,402	73.7%	217,943	**160,624**
	Sierra 2500	25,788	20.1%		**43,807**
	Sierra 3500	7,867	6.1%		**13,295**
Ram	1500	204,677	72.0%	483,520	**348,134**
	2500	52,845	18.6%		**89,935**
	3500	26,864	9.4%		**45,451**

7.3 High-Sales Volume Vehicles

Researchers also reviewed the vehicle makes and models with the highest sales volumes to ensure an adequate number of models to be a valid, standard passenger vehicle. MASH requires that models used for crash testing must have a minimum of 50,000 units sold nationally, and a recommended 100,000 units sold each year in the target weight range [1]. Passenger vehicles yielding greater than 100,000 sales in 2017 and 2018 are shown in Figures 36 and 37.

2017					2018				
Make/Model	**Vehicle Type**	**Units Sold**	**% of Total Cars Sold in 2017**	**% of Total Vehicles sold in 2017**	**Make/Model**	**Vehicle Type**	**Units Sold**	**% of Total Cars sold in 2018**	**% of Total Vehicles sold in 2018**
Toyota Camry	Mid-Size Car	387,081	6.4%	2.3%	**Tesla Model 3**	Luxury Car	115,102	2.2%	0.7%
Honda Accord	Mid-Size Car	322,655	5.3%	1.9%	**Toyota Camry**	Mid-Size Car	343,439	6.5%	2.0%
Nissan Altima	Mid-Size Car	254,996	4.2%	1.5%	**Honda Accord**	Mid-Size Car	291,071	5.5%	1.7%
Ford Fusion	Mid-Size Car	209,623	3.4%	1.2%	**Nissan Altima**	Mid-Size Car	209,146	3.9%	1.2%
Chevy Malibu	Mid-Size Car	185,857	3.1%	1.1%	**Ford Fusion**	Mid-Size Car	173,600	3.3%	1.0%
Hyundai Sonata	Mid-Size Car	131,803	2.2%	0.8%	**Chevy Malibu**	Mid-Size Car	144,542	2.7%	0.8%
Kia Optima	Mid-Size Car	107,493	1.8%	0.6%	**Hyundai Sonata**	Mid-Size Car	105,118	2.0%	0.6%
Honda Civic	Small Car	377,586	6.2%	2.2%	**Kia Optima**	Mid-Size Car	101,603	1.9%	0.6%
Toyota Corolla	Small Car	308,695	5.1%	1.8%	**Honda Civic**	Small Car	325,760	6.1%	1.9%
Nissan Sentra	Small Car	218,451	3.6%	1.3%	**Toyota Corolla**	Small Car	285,865	5.4%	1.7%
Hyundai Elantra	Small Car	198,210	3.3%	1.2%	**Nissan Sentra**	Small Car	213,046	4.0%	1.2%
Chevy Cruze	Small Car	184,751	3.0%	1.1%	**Hyundai Elantra**	Small Car	200,415	3.8%	1.2%
Ford Focus	Small Car	158,385	2.6%	0.9%	**Chevy Cruze**	Small Car	142,617	2.7%	0.8%
Kia Forte	Small Car	117,596	1.9%	0.7%	**Ford Focus**	Small Car	113,345	2.1%	0.7%
Volkswagen Jetta	Small Car	115,807	1.9%	0.7%	**Kia Soul**	Small Car	104,709	2.0%	0.6%
Kia Soul	Small Car	115,712	1.9%	0.7%	**Kia Forte**	Small Car	101,890	1.9%	0.6%
Nissan Versa Note	Small Car	106,772	1.8%	0.6%					

Figure 36. Passenger Cars with Greater than 100,000 Sales in 2017 and 2018

2017					2018				
Make/Model	**Vehicle Type**	**Units Sold**	**% of Total Light Trucks sold in 2017**	**% of Total Vehicles sold in 2017**	**Make/Model**	**Vehicle Type**	**Units Sold**	**% of Total Light Trucks sold in 2018**	**% of Total Vehicles sold in 2018**
Toyota RAV4	CUV	407,594	3.7%	2.4%	**Toyota RAV4**	CUV	427,170	3.6%	2.5%
Honda CR-V	CUV	377,895	3.4%	2.2%	**Honda CR-V**	CUV	379,013	3.2%	2.2%
Nissan Rogue	CUV	365,972	3.3%	2.1%	**Chevy Equinox**	CUV	332,618	2.8%	1.9%
Ford Escape	CUV	308,296	2.8%	1.8%	**Nissan Rogue**	CUV	322,315	2.7%	1.9%
Chevy Equinox	CUV	290,458	2.6%	1.7%	**Ford Escape**	CUV	272,228	2.3%	1.6%
Toyota Highlander	CUV	215,775	2.0%	1.3%	**Toyota Highlander**	CUV	244,511	2.1%	1.4%
Subaru Outback	CUV	188,886	1.7%	1.1%	**Jeep Cherokee**	CUV	239,437	2.0%	1.4%
Subaru Forester	CUV	177,563	1.6%	1.0%	**Subaru Outback**	CUV	178,854	1.5%	1.0%
Jeep Cherokee	CUV	169,882	1.5%	1.0%	**Subaru Forester**	CUV	171,613	1.4%	1.0%
Ford Edge	CUV	142,603	1.3%	0.8%	**Jeep Compass**	CUV	171,167	1.4%	1.0%
Hyundai Santa Fe	CUV	133,171	1.2%	0.8%	**Hyundai Santa Fe**	CUV	164,128	1.4%	1.0%
Mazda CX-5	CUV	127,563	1.2%	0.7%	**Honda Pilot**	CUV	159,615	1.3%	0.9%
Honda Pilot	CUV	127,279	1.2%	0.7%	**Mazda CX-5**	CUV	150,622	1.3%	0.9%
Chevy Traverse	CUV	123,506	1.1%	0.7%	**Chevy Traverse**	CUV	146,534	1.2%	0.9%
Hyundai Tucson	CUV	114,735	1.0%	0.7%	**Subaru Crosstrek**	CUV	144,384	1.2%	0.8%
GMC Acadia	CUV	111,276	1.0%	0.6%	**Hyundai Tucson**	CUV	142,299	1.2%	0.8%
Subaru XV	CUV	110,138	1.0%	0.6%	**Ford Edge**	CUV	134,122	1.1%	0.8%
Lexus RX	CUV	108,307	1.0%	0.6%	**GMC Terrain**	CUV	114,314	1.0%	0.7%
Jeep Renegade	CUV	103,434	0.9%	0.6%	**Lexus RX**	CUV	111,641	0.9%	0.6%
F-Series Trucks	Pickup	834,445	7.5%	4.9%	**Kia Sorento**	CUV	107,846	0.9%	0.6%
Chevy Silverado	Pickup	585,864	5.3%	3.4%	**Volkswagen Atlas**	CUV	103,022	0.9%	0.6%
Ram Pickup Light-Duty	Pickup	483,520	4.4%	2.8%	**F-Series Trucks**	Pickup	844,448	7.1%	4.9%
GMC Sierra	Pickup	217,943	2.0%	1.3%	**Chevy Silverado**	Pickup	585,575	4.9%	3.4%
Toyota Tacoma	Pickup	198,124	1.8%	1.2%	**Ram Pickup Light-Duty**	Pickup	521,046	4.4%	3.0%
Toyota Tundra	Pickup	116,285	1.1%	0.7%	**Toyota Tacoma**	Pickup	245,659	2.1%	1.4%
Chevy Colorado	Pickup	112,996	1.0%	0.7%	**GMC Sierra**	Pickup	219,554	1.8%	1.3%
Ford Explorer	SUV	271,131	2.5%	1.6%	**Chevy Colorado**	Pickup	134,842	1.1%	0.8%
Jeep Grand Cherokee	SUV	240,696	2.2%	1.4%	**Toyota Tundra**	Pickup	118,258	1.0%	0.7%
Jeep Wrangler	SUV	190,522	1.7%	1.1%	**Ford Explorer**	SUV	261,571	2.2%	1.5%
Toyota 4Runner	SUV	128,296	1.2%	0.7%	**Jeep Wrangler**	SUV	240,032	2.0%	1.4%
Dodge Caravan	Van	125,196	1.1%	0.7%	**Jeep Grand Cherokee**	SUV	224,908	1.9%	1.3%
Chrysler Pacifica	Van	118,274	1.1%	0.7%	**Toyota 4Runner**	SUV	139,694	1.2%	0.8%
Toyota Sienna	Van	111,489	1.0%	0.7%	**Chevy Tahoe**	SUV	104,153	0.9%	0.6%
Honda Odyssey	Van	100,307	0.9%	0.6%	**Dodge Caravan**	Van	151,927	1.3%	0.9%
					Chrysler Pacifica	Van	118,322	1.0%	0.7%
					Honda Odyssey	Van	106,327	0.9%	0.6%
					Ford Transit	Van	101,474	0.9%	0.6%

Figure 37. Light Trucks with Greater than 100,000 Sales in 2017 and 2018

High-sales volume vehicle model statistics for 2017 and 2018 (models with greater than 100,000 unit sales) are shown in Table 20. High-sales volume passenger cars accounted for 57.6% and 56.0% of all U.S. car sales in 2017 and 2018, respectively, and represented nearly 20% of all U.S. passenger vehicles sold. High-sales volume light trucks had greater than 7.5 million unit sales each year. High-sales volume light trucks accounted for 68.2% and 70% of all light truck sales in 2017 and 2018, respectively, and accounted for 44.0% and 48.4% of all vehicle sales in 2017 and 2018, respectively. As a result, the 51 high-sales vehicle models accounted for nearly two-thirds of all sales of the 317 new vehicle models in 2017. Similar results were observed in 2018.

Table 20. High-Sales Volume Vehicle Models

Vehicle Group	2017				2018			
	Total Available Models	Total Unit Sales	High-Sales Volume Models	High-Sales Volume Unit Sales	Total Available Models	Total Unit Sales	High-Sales Volume Models	High-Sales Volume Unit Sales
Cars	164	6,080,229	17	3,501,473	160	5,303,580	15	2,856,166
Light Trucks	153	11,055,250	34	7,539,421	158	11,909,966	37	8,335,243

7.4 Alternative-Power Source Vehicles

Traditionally, passenger vehicles in the U.S. were powered by gasoline internal combustion engines (ICEs). Alternative power source (APS) vehicles have become more common as a means of reducing carbon emissions and improving fuel efficiency. These vehicles have unique engines, structures, chasses, and weights compared to similar models with conventional ICEs, and the market share is expected to increase in the future [43-48]. Wards Intelligence documents vehicle sales based on power-source, thus, the proportion of these vehicles as a percentage of all sales was investigated. The most common APS vehicles include Battery Electric Vehicles (BEVs), gasoline/electric Hybrids, Plug-in Hybrid Electric Vehicles (PHEVs), and Fuel Cell Electric Vehicles (FCEV).

APS vehicles comprised 1.2% to 3.9% of all vehicles sold from 2005 to 2018, respectively [43]. The remaining vehicles sold each year were ICEs. It was observed that APS cars made up 7.3% of all new passenger car sales in 2017.

In 2017, 31 different vehicle models had at least one gas-powered and one APS trim. The average weight difference among all 2017 models in each vehicle group was calculated to determine the approximate weight difference between gas-powered and APS vehicles. APS CUVs weighed approximately 300 lb more than their gas-powered counterparts. Hybrid mid-size cars weigh on average 213 lb more than similar gas-powered mid-size cars, and mid-size car PHEVs weigh nearly 280 lb more than gas-powered mid-size cars. An example of weight comparison by power source, the Ford Fusion had three available trims in 2017, each using a different power source. The gas-powered trim curb weight was 3,435 lb, the hybrid trim curb weight 3,660 lb, and the PHEV trim curb weight 3,962 lb. Results of weight comparisons for similar makes and models are shown in Table 21.

Table 21. APS Vehicle Weight Comparison to Gas-Powered

Vehicle Group	No. of Models	Total Model Sales	Alternative Model Sales	Alternative Share of Model Sales	Avgerage Weight Difference, lb	Percent Weight Change
Hybrids						
CUV	5	833,292	70,842	8.5%	310.4	7.4%
Luxury Car	4	75,041	6,442	8.6%	272.8	7.1%
Mid-size Car	5	1,158,655	115,060	9.9%	213.0	6.1%
Small Car	1	115,807	70	0.1%	304.2	11.4%
SUV	1	108,307	8,568	7.9%	286.6	6.4%
PHEVs						
CUV	6	207,469	10,093	4.9%	284.8	6.8%
Luxury Car	4	125,271	8,681	6.9%	157.6	3.8%
Mid-size Car	5	480,335	15,070	3.1%	280.0	8.0%
Van	1	118,274	4,401	3.7%	612.9	14.2%
BEVs						
Small Car	2	274,097	3,884	1.4%	616.2	21.2%

While APS vehicle options are available for most vehicle groups, cars have traditionally comprised the largest share of APS vehicles. Cars accounted for at least 70% of all APS vehicle sales over the last 13 years, as shown in Table 22. Additionally, APS cars as a share of all cars sold steadily increased from 2.0% in 2005 to 5.8% in 2016. The percentage of new car sales with APS climbed dramatically in 2017 and 2018, resulting in 10.0% of all new cars sold in 2018 with APS.

Table 22. APS Cars as a Share of Vehicle Sales

Year	APS Vehicles Sold	APS Cars Sold	Car Share of All APS Vehicles	Total Cars Sold (All Power Sources)	APS Car Share of All Cars Sold
2018	672,390	530,696	78.93%	5,303,580	10.01%
2017	555,834	440,517	79.25%	6,080,229	7.25%
2016	490,672	398,693	81.25%	6,872,729	5.80%
2015	492,757	468,353	95.05%	7,516,826	6.23%
2014	572,722	544,226	95.02%	7,689,100	7.08%
2013	585,975	564,887	96.40%	7,585,341	7.45%
2012	478,431	454,047	94.90%	7,243,654	6.27%
2011	280,620	250,167	89.15%	6,089,403	4.11%
2010	274,376	232,163	84.61%	5,635,433	4.12%
2009	290,232	236,755	81.57%	5,400,890	4.38%
2008	315,688	250,462	79.34%	6,813,369	3.68%
2007	352,735	282,386	80.06%	7,618,413	3.71%
2006	251,867	177,672	70.54%	7,820,854	2.27%
2005	205,828	151,253	73.49%	7,667,066	1.97%

State legislation, improvements to commercially available electric vehicle infrastructure, and vehicle manufacturers' intent to increase the number of APS vehicles indicate the fleet share of APS vehicles is expected to increase [44]. Audi anticipates that by 2025, one-third of their vehicles will be powered by APS [45], and Ford has an $11 billion program investment to develop new APS vehicles such as the BEV F-150, Mach 1, and PHEV Escape hybrid, all of which have an expected rollout date of 2020 [46]. GM and Honda each have stated their intent to manufacture new APS vehicles citing both consumer demand and stringent fuel economy restrictions in the U.S. and overseas [47, 48].

Although the current proportion of passenger vehicles which have APS engines do not warrant consideration for implementation as MASH passenger vehicles, there is evidence to support consideration for APS vehicles in future iterations for selecting standardized passenger vehicles. Differentiating vehicles by power source may also be important when observing impact behavior for ISPE studies, specifically for BEVs because of heavy batteries housed under the occupant compartment. Little to no research exists on the impact behavior of BEVs, and the presence of batteries may alter vehicle impact loading of barriers and guardrails by effectively lowering c.g. height and increasing vehicle weight. Additionally, lithium-ion batteries present other risks such as combustibility or explosion which can result of chemical leakages, overcharging, and external heating [49]; however, it is unknown how these risks factor into vehicle crashworthiness.

7.5 Sales Data Considerations and Discussion

Projection of future vehicle sales is a challenging endeavor. Economic factors, vehicle availability, and consumer demand are just a few factors in the nexus of passenger vehicle sales. One difficulty in using a sales data approach to vehicle selection is that some sales data do not differentiate among different vehicle model trim levels. For example, pickup trucks were not differentiated by payload capacity in Wards Intelligence dataset, so a third-party data source was used to approximate distribution of pickup truck sales. Different approaches for approximating vehicle sales by trim level are expanded upon in Chapter CHAPTER 9 where the 5th and 95th percentile passenger vehicle weights were identified to target MASH passenger vehicle candidates.

Sales trends show light trucks have consistently increased their proportional share of vehicle sales since 2012, and in 2017, light trucks accounted for more than two-thirds of passenger vehicle sales. Increase in the light truck's share of sales has been primarily driven by increase of CUV sales, and in addition to CUVs, small cars, mid-size cars, and pickup trucks comprised the most significant portions of passenger vehicle sales.

While APS vehicles do not make up a significant fleet portion to warrant use in crash testing, they should be monitored in the future to determine whether their inclusion in crash testing is necessary. If the time comes that APS vehicles comprise a significant portion of vehicle sales, the crashworthiness of APS vehicles may need to be observed and compared to ICE vehicle counterparts.

CHAPTER 8 Crash, Registration, and Sales Data Comparison

8.1 Sales and Crash Data Comparison

Comparison of sales and crash data were desired to observe whether trends existed between datasets. Wards Intelligence sales data was compared to vehicles involved in fatal crashes, as shown in Figure 38. Motorcycle and large truck sales and crash data were not considered in this analysis. Crash data indicated that although light truck sales were eclipsed passenger car sales in 2013, passenger cars were more commonly involved in fatal crashes than light trucks through 2017. Note that passenger cars were denoted as “Automobile” in sales and crash data.

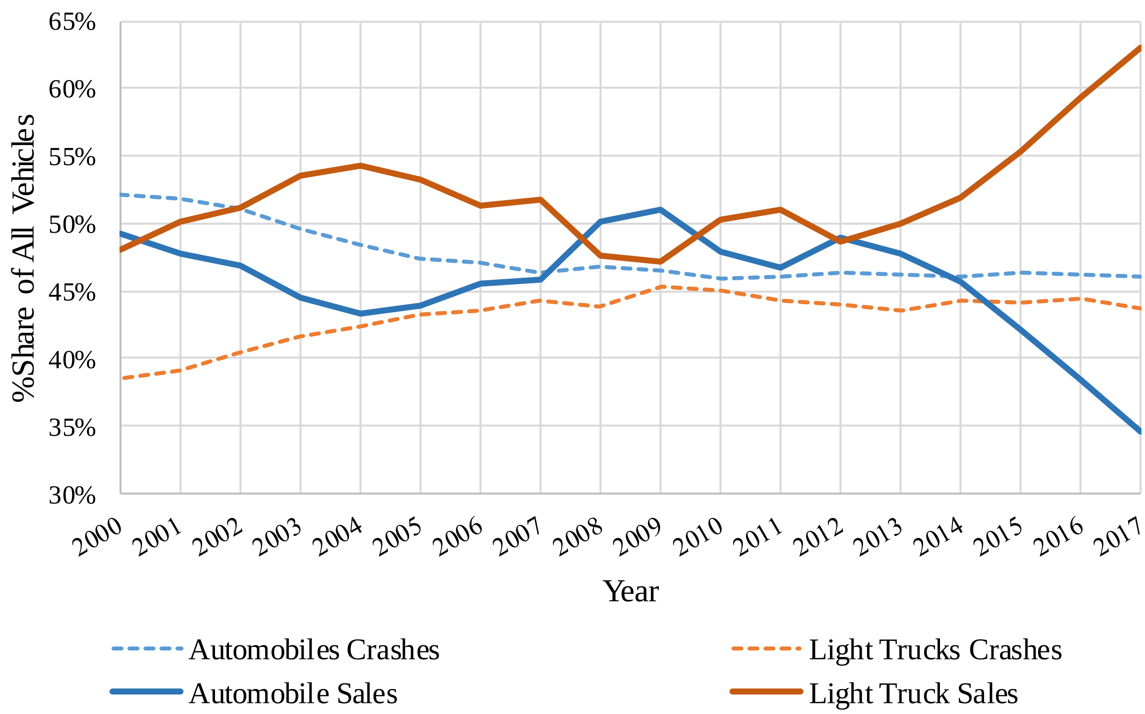


Figure 38. Vehicles Involved in Fatal Crashes Compared to Sales

Sales data was compared with fatal crash data to determine if sales data could be a viable predictor of future fatal crash distributions by vehicle type. A sum of squared error (SSE) technique was used to estimate the time offset between sales data proportions and fatal crash vehicle distributions. The formula used to calculate correlation is shown in Equation 2, where x_a and y_a are average sales and crashes, respectively.

$$\frac{\Sigma(x-x_a)(y-y_a)}{\sqrt{\Sigma(x-x_a)^2\Sigma(y-y_a)^2}} \quad (2)$$

Correlation optimization was desired by finding the time delay between new sales data and crash data corresponding to a minimization of error in a predictive model. That time delay was referred to as "sales lag." Correlations between sales and crash data of passenger cars and light trucks are shown in Table 23. The correlation was strongest, indicating minimum error, with a sales lag of nine years for passenger cars and six years for light truck vehicles. The composite error was minimized for between three and four years of sales lag.

Table 23. Correlations among Vehicle Sales and Vehicles in Fatal Crashes

Sales Lag, No. of Years	Passenger Cars	Light Trucks	All Passenger Vehicles
2	0.412	0.442	0.733
3	0.595	0.674	**0.762**
4	0.725	0.826	**0.762**
5	0.823	0.914	0.734
6	0.901	**0.928**	0.698
7	0.920	0.905	0.649
8	0.918	0.886	0.595
9	**0.927**	0.876	0.446
10	0.919	0.846	0.229
11	0.891	0.820	0.018

Researchers also compared vehicle model sales and crash volumes. Nationally high-sales volume vehicle models were compared to models involved in the most crashes in Ohio, and are shown in Table 24. The twenty nationally highest-sales passenger vehicle models from 2014 to 2015 are listed in descending rank, and the number of crashed units in Ohio from 2014 to 2015 are listed along with their frequency rank. The twenty most frequently crashed units in Ohio in 2014 and 2015 are also displayed. Fourteen of the most frequently crashed vehicle models in Ohio were included in the top twenty nationally highest-selling models. Six of the twenty vehicle models commonly crashed in Ohio are no longer in production. It should be noted that the Chevrolet Cavalier (later model, Cobalt), Ford Ranger, Ford Fusion, and Ford Focus were historically very high-selling vehicle models produced over many years before being discontinued, which are highlighted in the table.

Table 24. Vehicle Model Involvement in Ohio Crashes for 2014 and 2015

Make/Model	National		Ohio	
	Units Sold	Sales Rank	Units Crashed	Crash Rank
Ford F-Series Pickups	1,426,828	1	26,111	2
Chevrolet Silverado Pickups	1,130,299	2	16,305	8
Ram Pickups	859,823	3	4,920	40
Toyota Camry	857,961	4	22,206	4
Honda Accord	743,931	5	26,569	1
Toyota Corolla	702,830	6	15,426	9
Honda CR-V	680,666	7	10,158	17
Nissan Altima	669,042	8	10,940	14
Honda Civic	661,365	9	25,979	3
Ford Escape	612,704	10	12,714	11
Ford Fusion	*607,030*	*11*	*12,006*	*13*
Toyota RAV4	583,110	12	5,423	34
Chevrolet Equinox	519,831	13	7,499	22
Chevrolet Cruze	499,662	14	7,532	21
Nissan Rogue	486,389	15	2,542	74
Hyundai Elantra	463,729	16	9,104	19
Ford Explorer	459,245	17	12,068	12
GMC Sierra Pickups	435,972	18	5,018	39
Hyundai Sonata	430,239	19	9,320	18
Ford Focus	*422,112*	*20*	*18,118*	*7*
Chevrolet Impala	257,105	37	19,626	5
Chevrolet Malibu	383,373	23	18,428	6
Ford Taurus	*111,445*	*84*	*15,129*	*10*
Chevrolet Cavalier	-	-	*10,464*	*15*
Ford Ranger	-	-	*10,229*	*16*
Chevrolet Cobalt	-	-	*8,870*	*20*

*Gray and italic cells denote vehicle model is no longer in production

Vehicle model sales and crash volumes were also observed in Wyoming. Nationally high-sales volume vehicle models were compared to models most crashed in Wyoming and are shown in Table 25. The twenty nationally highest-sales passenger vehicle models from 2013 to 2017 are listed in descending rank, and the number of crashed units in Wyoming from 2013 to 2017 are listed along with their frequency rank. The twenty most frequently crashed units in Wyoming from 2013 to 2017 are also displayed. Nine of the most frequently crashed vehicle models in Wyoming were a part of the top twenty highest-selling models. Six of the most commonly crashed models in Wyoming were passenger cars, and three of the twenty vehicle models commonly crashed in Wyoming are no longer in production.

Table 25. Vehicle Model Involvement in Wyoming Crashes

Make/Model	National		Wyoming	
	Units Sold	Sales Rank	Units Crashed	Crash Rank
Ford F-Series Pickups	3,739,120	1	10,773	1
Chevrolet Silverado Pickups	2,771,453	2	6,311	3
Ram Pickups	2,161,796	3	8,165	2
Toyota Camry	2,042,144	4	1,681	8
Honda Accord	1,778,489	5	1,773	7
Honda Civic	1,741,758	6	1,330	19
Honda CR-V	1,719,800	7	818	33
Toyota Corolla	1,674,188	8	1,113	23
Toyota RAV4	1,561,107	9	763	35
Nissan Altima	1,552,141	10	872	30
Ford Escape	1,524,062	11	1,037	26
Ford Fusion	1,377,773	12	725	39
Nissan Rogue	1,345,016	13	268	86
Chevrolet Equinox	1,290,676	14	499	51
Ford Explorer	1,171,280	15	2,281	5
Chevrolet Cruze	1,121,513	16	517	47
Hyundai Elantra	1,118,170	17	441	59
GMC Sierra Pickups	1,059,984	18	3,297	4
Jeep Grand Cherokee	1,007,342	19	1,556	12
Chevrolet Malibu	997,705	20	1,226	21
Toyota Tacoma	883,843	25	1,621	10
Chevrolet Impala	586,785	39	1,562	11
Chevrolet Suburban	273,733	87	1,496	14
Toyota Tundra	581,879	40	1,425	15
Dodge Durango	327,083	69	1,373	16
Subaru Legacy	270,151	90	1,372	17
GMC Yukon	215,233	100	1,339	18
Chevrolet CK Pickups	-	-	*1,796*	*6*
Ford Ranger	-	-	*1,665*	*9*
Ford Taurus			*1,533*	*13*

*Gray and italic cells denote vehicle model is no longer in production

8.2 Sales and Registrations Data Comparison

Registrations and sales were also analyzed to determine whether trends existed. Sales are indicative of only new vehicle purchases while registrations include vehicles legally allowed to travel roadways (combination of recently purchased vehicles and vehicles purchased in previous years).

Shares of vehicle registrations and sales by vehicle type are shown in Figure 39. Passenger cars were combined into one category because no differentiation by body style (e.g., sedan, coupe, convertible, etc) was available among sales data. Light trucks were differentiated by type, including SUVs/CUVs, pickup trucks, and vans because available data differentiated between light truck types. Passenger car registration share decreased by over 25% from 1994 to 2016. SUVs/CUVs accounted for an approximate 28% increase registration share, and pickup truck and van registrations were relatively constant over the same span. Sales data by vehicle type was available after 2005 and were graphically compared to registrations. Registration and sale data followed similar overall trends.

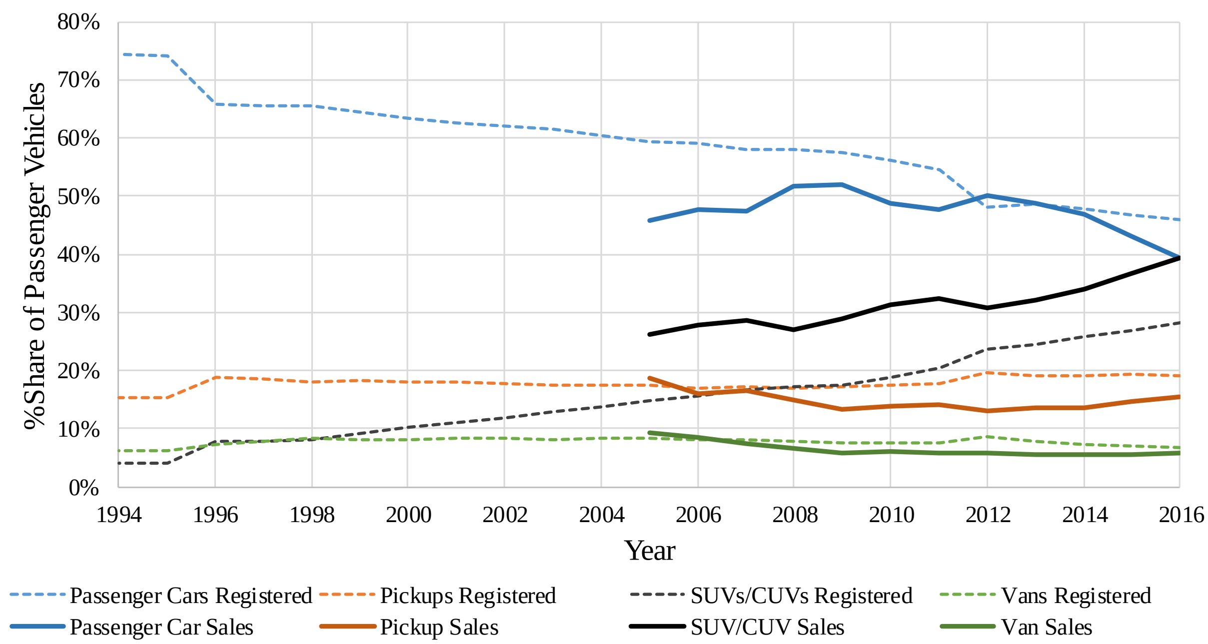


Figure 39. Share of Registered and Sold Vehicles by Type

Vehicle registrations were compared with vehicle sales, as shown in Figure 40. Researchers investigated whether a deterministic time lag relationship could be developed between registered vehicle age and new sales data, and results of the analysis are plotted in Figure 41. Correlation coefficients were calculated using available registration and 2017 sales numbers to quantitatively evaluate the extent to which registration data mimicked sales data. When sales data were shifted twelve years to the future (e.g. 1982 sales shifted to 1994), the maximum correlation coefficient of 0.97 was obtained between registrations and sales data, indicating minimum error between the datasets. Findings may suggest U.S. passenger vehicle registrations in 2029 could be proportionally similar to 2017 sales data (twelve-year offset).

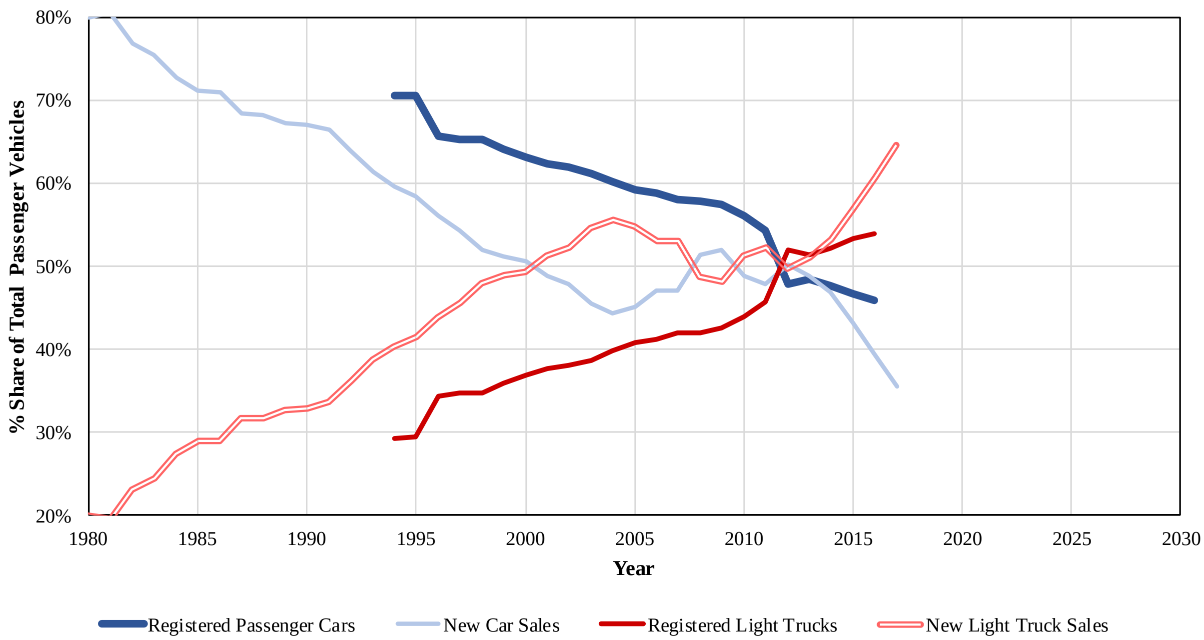


Figure 40. Registered Vehicle Relationship to Vehicle Sales

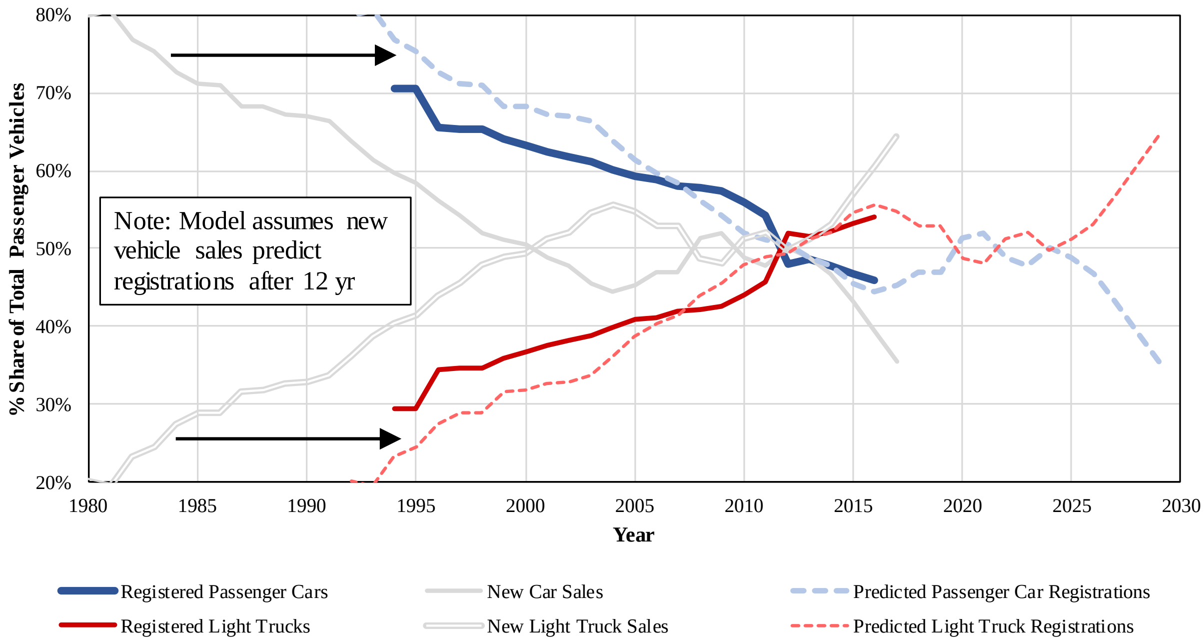


Figure 41. Registered Vehicle Relationship to Shifted Vehicle Sales

Registration data was also evaluated based on historical average vehicle ages [28]. Average registered vehicle age with trend lines is shown in Figure 42. Data from 1995 to 2014 were available, and the average age of all light vehicles increased from 8.4 to 11.4 years on average during this time. Linear regression was used to approximate average vehicle age in 2017, and was calculated to be approximately twelve years. The average ages of cars and trucks were very similar and followed similar trends. Thus, researchers concluded that the average vehicle age in 2017 was approximately twelve years old.

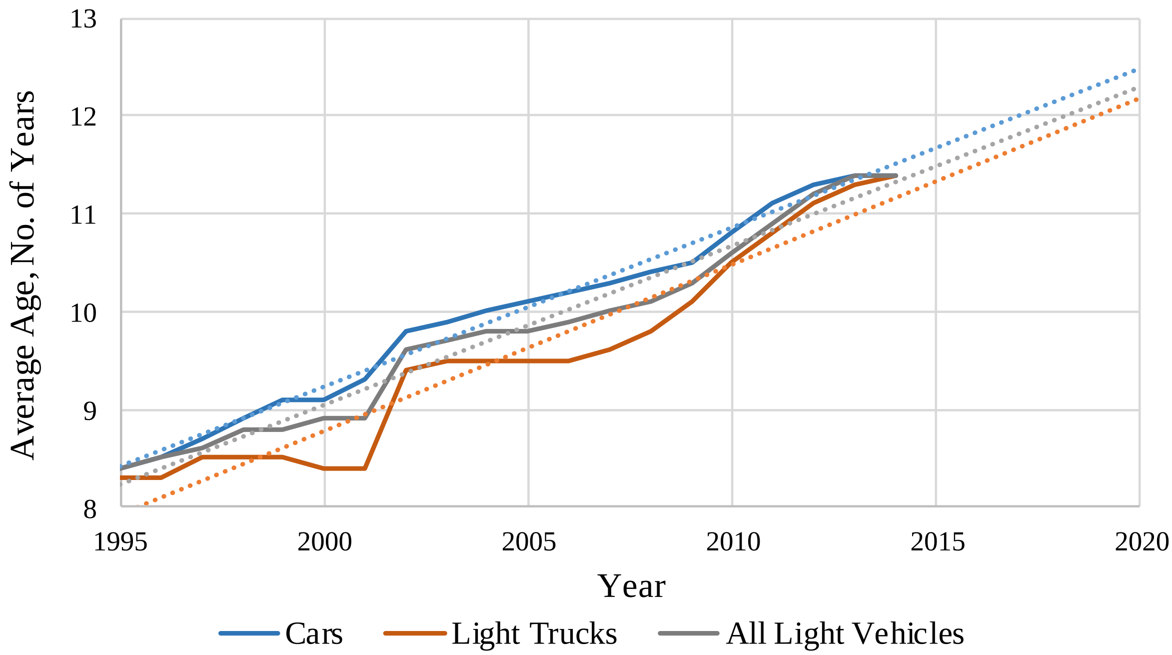


Figure 42. Average Registered Vehicle Ages with Trend Lines

Results indicated that sales data was a suitable predictor of the future distribution of vehicle registrations. Based on these results and findings and the significant increase in SUV and CUV sales in 2015 through 2018, researchers believe that by the late 2020s, the majority of passenger vehicle owned and registered are likely to be SUVs and CUVs.

8.3 Discussion

Fatal crash data indicated that cars were, on average, about nine years old and light trucks were about six years old when fatal crashes occurred. This result was determined to be consistent and repeatable. Surprisingly, vehicles involved in fatal crashes were newer, on average, than the average age of registered vehicles in the U.S. Recent significant increases in fatal crash numbers suggest that even with the implementation of Advanced Driver Assistance Systems (ADAS) and Autonomous Driving Systems (ADS), significant safety improvements are still needed.

Sales data were shown to be indicative of future vehicle registrations. Registered passenger cars and light truck types exhibited similarly shaped curves in comparison with sales. Additionally, average registered passenger vehicle age was found to be approximately twelve years, and registrations were found to be proportionally reflective to sales twelve years after a given sales year. Findings suggests sales data is a suitable measure for estimating the composition of future vehicle registrations and crashes. Thus, sales data was chosen for analysis of MASH vehicle updates in the remainder of the research effort. Additionally, because sales data is generally more complete and easier to acquire than either registration or crash data, and requires less distillation and revision, it is recommended that future iterations of standardized passenger vehicle selection primarily utilize new vehicle sales data for discussion, analysis, and conclusions.

CHAPTER 9 Vehicle Weight Distribution and Vehicle Selection Criteria

9.1 Objective and Background

Using vehicle sales data for 2017, researchers identified the weight distribution of new vehicle sales to identify the 5th and 95th percentile weights for new vehicle sales, and to determine how existing MASH vehicle specifications aligned with new vehicle sales data. Weight data for each vehicle model and trim level were paired with sales data to develop the weight distribution. Subsequently, geometrical and inertial parameters associated each vehicle model were reviewed to standardize MASH passenger vehicle parameter selection requirements.

Canadian Vehicle Specifications [33] were used to obtain vehicle dimensional properties; note, NHTSA also uses this as reference for vehicle measurements. Additionally, Expert AutoStats [34] was used to obtain vehicle dimensions such as hood height and front bumper height which were not documented in Canadian Vehicle Specifications.

9.2 Passenger Vehicle Weight Distributions

9.2.1 High- and Low-Weight Distributions

Researchers utilized the same assumptions and distributions previously discussed in Chapter 7 to allocate sales by trim levels. To evaluate the tolerances on possible new vehicle weight distributions, researchers also generated boundary curves corresponding to the lightest and heaviest possible distributions of new vehicle sales:

- a “High-Weight” estimate, in which the trim option associated with the heaviest vehicle weight was allocated all vehicle sales, and the smaller-weight trim levels were assumed to have zero sales; and
- a “Low-Weight” estimate, in which the lowest weight trim level was allocated all vehicle sales, and the heavier-weight trim levels were assumed to have zero sales.

APS vehicles had sales explicitly noted; most APS vehicles only had a single trim level noted. As a result, all APS vehicle sales were annotated by trim level and only the ICE vehicle sales were distributed by trim levels. Note an example of the high- and low-weight distribution sales allocation for a vehicle model with multiple trim levels and an APS trim option is shown in Table 26. The high- and low-value sales estimate method was applied to other vehicle measurements in Chapter CHAPTER 11 to observe ranges for additional 2017 passenger vehicle dimensions.

The high- and low-weight distributions for 2017 passenger vehicle sales are shown in Figure 43. Additionally, current MASH passenger vehicle weights were compared to the high- and low-weight estimated distributions, as shown in Figure 43. It is known that the actual 2017 weight distribution must fall between the bounds of the high- and low-weight distributions. It was discovered that the 5^{th} percentile weight was between 2,743 lb and 2,855 lb, and the 95^{th} percentile weight was between 5,631 lb and 5,981 lb.

The high- and low-vehicle weight distributions were more similar for passenger cars and light vehicles than for heavier vehicles. The primary reason for this was large weight deviation associated with variations in trim levels for larger vehicles. For example, the Honda Civic sold 377,286 units in 2017. The low-weight estimate attributed 377,286 unit sales to the lightest trim weight of 2,743 lb, and the high-weight estimate attributed the same number of sales to the heaviest trim weight of 2,919 lb; thus, the difference in average weight between low- and high-weight distributions was 176 lb. By comparison, the Ford F-150 sold an estimated 573,264 units in 2017. The low-weight estimate weighed 4,050 lb and the high-weight estimate of the heaviest trim weight was 5,697 lb, for a range of 1,647 lb between lowest- and highest-weight trim levels.

Table 26. High- and Low-Weight Sales Distributions of Honda Accord

300,647 Gas-Powered Units Sold in 2017				
Make/Model	**Trim Level**	**Curb Weight, lb**	**Low-Weight Sales Estimate**	**High-Weight Sales Estimate**
Honda Accord	2DR Coupe EX/EX-L Navi	3,263	300,647	--
Honda Accord	4DR Sedan LX/Sport/EX-L/Touring	3,298	--	--
Honda Accord	2DR Coupe EX-L V6	3,534	--	--
Honda Accord	4DR Sedan EX-L V6/Touring V6	3,560	--	300,647
Honda Accord	Hybrid 4DR Sedan	3,514	22,008	22,008

*Recall – Sales volume of APS vehicles are explicitly known

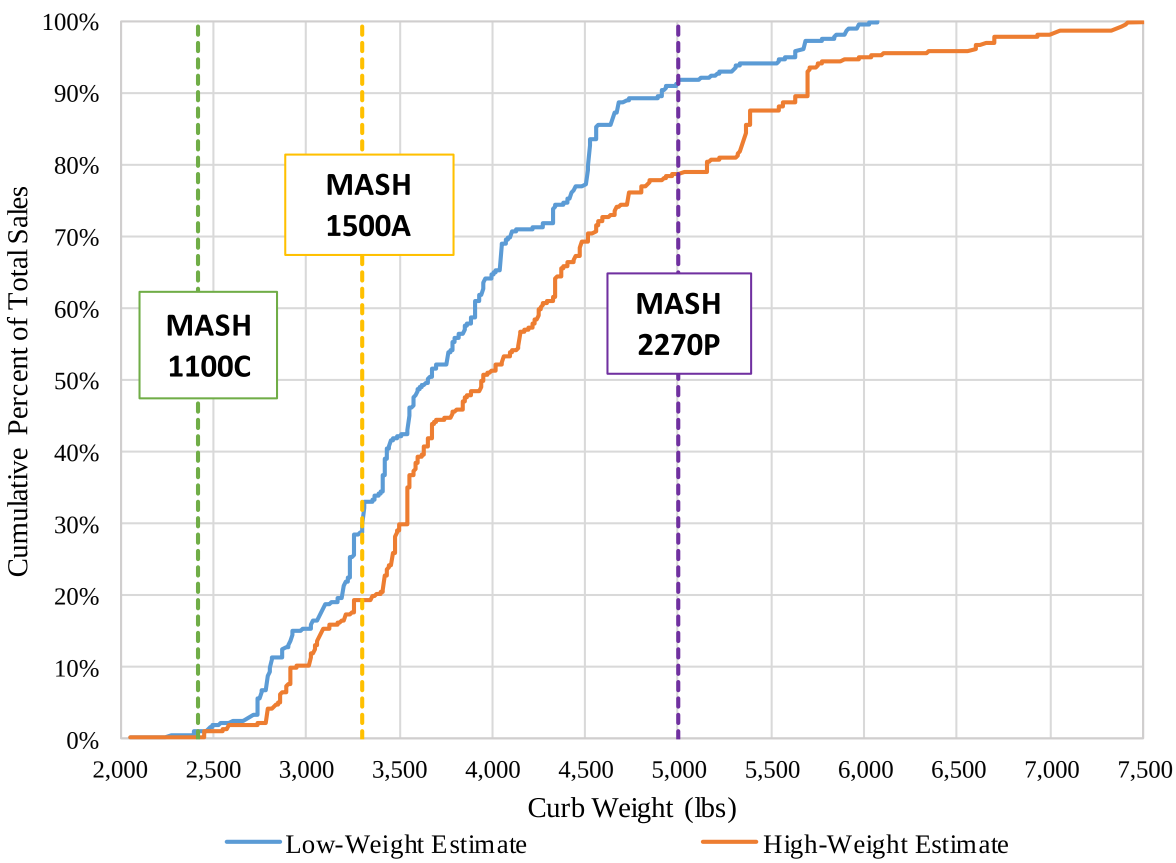


Figure 43. High- and Low-Weight Distributions and Existing MASH Passenger Vehicles

9.2.2 Median Sales Distribution

A single (discrete) weight distribution was desired to identify target weights for new MASH vehicle selection. A median-weight distribution was used to approximate the 5th and 95th percentiles for MASH vehicle selection. Median-value distributions were also used for other discrete measurement distributions found Chapter CHAPTER 11.

A median-weight distribution model was created by allocating all the vehicle model sales to the trim level with the median curb weight. Models with odd numbers of trim variations provided a single, median weight, whereas models with even numbers of trim levels were averaged between the two median curb weights. Additionally, sales volumes for APS vehicle trims were known and tabulated accordingly. Median-weight sales distributions examples for the Honda Civic (odd number of unknown trim sales) and Honda Accord (even number of unknown trim sales) are shown in Table 27. Recall that APS trim vehicle sales were explicitly known and not included in the calculation of ICE vehicle median weight.

Table 27. Median-Weight Sales Distribution Example

Make/Model	Trim Level	Curb Weight, lb	Median-Weight Sales Estimate
Honda Civic	DX/LX/EX 4DR Sedan	2,743	0
Honda Civic	LX 2DR Coupe	2,769	0
Honda Civic	EX-T/Touring 2DR Coupe	2,895	377,286
Honda Civic	5DR Hatch	2,917	0
Honda Civic	EX-T/Touring 4DR Sedan	2,919	0
Honda Accord	2DR Coupe EX/EX-L Navi	3,263	0
Honda Accord	4DR Sedan LX/Sport/EX-L/Touring	3,298	150,324
Honda Accord	2DR Coupe EX-L V6	3,534	150,324
Honda Accord	4DR Sedan EX-L V6/Touring V6	3,560	0
Honda Accord	Hybrid 4DR Sedan	3,514	22,008

9.2.3 Additional Sales Distribution Models

Available sales data did not differentiate sales by model trims so alternative sales distribution methods were also used to approximate discrete vehicle dimensional distributions. Other methods for allocating vehicle sales were also explored: (1) average high- and low-value sales distribution, and (2) sales average (mean weight) distribution.

The average high- and low-weight sales distribution was obtained by dividing vehicle model sales between the two trims with high and low weights. An example is shown in Table 28.

Table 28. Average High- and Low-Weight Distribution Example

377,286 Units Sold in 2017			
Make/Model	**Trim Level**	**Curb Weight, lb**	**Average High- and Low-Weight Sales Estimate**
Honda Civic	DX/LX/EX 4DR Sedan	2,743	188,643
Honda Civic	LX 2DR Coupe	2,769	0
Honda Civic	EX-T/Touring 2DR Coupe	2,895	0
Honda Civic	5DR Hatch	2,917	0
Honda Civic	EX-T/Touring 4DR Sedan	2,919	188,643

The mean weight sales distribution was accomplished by dividing a vehicle model's sales among all of its trim levels, as shown in Table 29.

Table 29. Mean Weight (Sales Average) Distribution Example

377,286 Units Sold in 2017			
Make/Model	**Trim Level**	**Curb Weight, lb**	**Sales Average (Mean Weight) Estimate**
Honda Civic	DX/LX/EX 4DR Sedan	2,743	75,457.2
Honda Civic	LX 2DR Coupe	2,769	75,457.2
Honda Civic	EX-T/Touring 2DR Coupe	2,895	75,457.2
Honda Civic	5DR Hatch	2,917	75,457.2
Honda Civic	EX-T/Touring 4DR Sedan	2,919	75,457.2

In determining which discrete weight distribution method to use, the average high- and low-weight distribution was ruled out because it was not representative of all vehicle model trim levels. Allocating half of the sales to the highest weight and half of the sales to the lowest weight disregarded intermediate trim models. In comparison, the sales average distribution equally allocated sales among every available trim and was very similar to the median weight distribution. However, researchers believe that the sales distributions for most vehicle models will follow a quasi-normal regression with peak sales in the intermediate trim levels and reduced sales at either extreme. In other words, the least-commonly purchased vehicles would be at either extreme, and the most-commonly purchased vehicles would have trim weights and options in between. As a result, the median weight distribution was believed to be the most representative for selecting a single, discrete weight distribution curve for selecting recommended test vehicles.

A comparison of all weight distribution methods and the reference to previously-collected data from 2002 is shown in Figure 44. Tabulated values for 5th and 95th percentile weights for the each of the 2017 distribution methods and the 2002 weight distribution are shown in Table 30. Vehicle weights have generally increased since 2002, especially at the smaller percentile weights. The 5th percentile median-estimate weight was 2,789 lb and the 95th percentile weight was 5,847 lb. Additional median weight distribution details can be found in APPENDIX B .

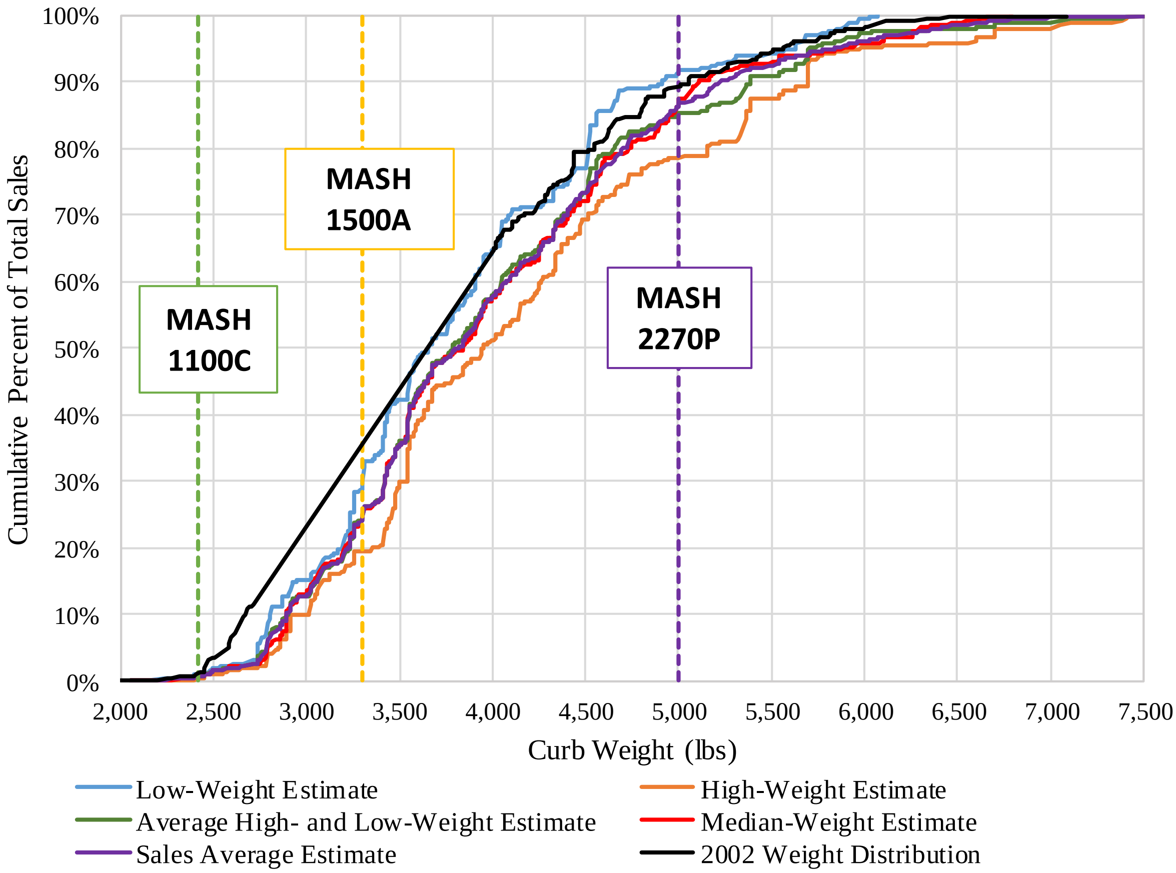


Figure 44. Additional Weight Distributions with Existing MASH Passenger Vehicles

Table 30. Tabulated 5th and 95th Values of Each Weight Distribution

Percentile Weight	Distribution Model	Weight, lb
5th	MASH 1100C	2,420
	Low Weight	2,743
	Average High and Low	2,789
	Median Weight	2,789
	Sales Average	2,789
	High Weight	2,855
95th	MASH 2270P	5,000
	Low Weight	5,631
	Average High and Low	5,697
	Median Weight	5,847
	Sales Average	5,816
	High Weight	5,981

9.3 MASH Small Passenger Vehicle

It is desired that the standardized small car weight for a compliant MASH small car vehicle would be approximately the 5th percentile weight, equal to 2,789 lb, in accordance with the principal of “practical worst-case” impact conditions. For simplification, the 5th percentile weight will be referred to as 2,800 lb. The range of vehicles within 2.2% of the nominal 5th percentile weight for 2017 vehicle sales distributions are demonstrated in Table 31, ranging from 2,735 to 2,865 lb. A 2.2% weight tolerance was selected to be consistent with current MASH guidelines. The current 1100C vehicle weight has an approximate 2.2% tolerance, 2,365 to 2,475 lb.

Given that sedans were the most common passenger car body style and more than twice as common as any other body style, sedan use was deemed appropriate and representative for MASH small vehicle use. Other body styles, including coupes, hatchbacks, wagons, or convertibles, were removed from further consideration. Note the sedan body style is consistent with existing MASH vehicle body style requirements. A refined selection of potential small car vehicle model candidates are shown in Table 32.

Table 31. Potential Small Passenger Vehicles in 5th Percentile Weight Range

Make	Model	Trim	Curb Weight, lb	Total Model Sales, No. of Units	Percentile Weight
HYUNDAI	VELOSTER	3DR HATCHBACK	2,740	12,658	2.62%
FORD	FIESTA	ST 4DR HATCHBACK	2,743	46,249	2.66%
HONDA	CIVIC	DX/LX/EX 4DR SEDAN	2,743	377,286	2.66%
BMW	COOPER	5DR HATCH FWD	2,749	32,232	2.66%
CHEVROLET	CRUZE	4DR SEDAN	2,756	184,751	3.21%
TOYOTA	86	2DR COUPE	2,758	6,846	3.25%
BMW	COOPER	3DR S HATCH FWD	2,760	32,232	3.25%
SUBARU	BRZ	2DR COUPE	2,765	4,131	3.28%
HONDA	CIVIC	LX 2DR COUPE	2,769	377,286	3.28%
CHEVROLET	SONIC	5DR HATCHBACK	2,784	30,290	3.37%
TOYOTA	**COROLLA**	**4DR SEDAN**	**2,789**	**308,695**	**5.21%**
KIA	FORTE	LX 4DR SEDAN	2,804	117,596	5.21%
VOLKSWAGEN	JETTA	4DR SEDAN 2.0L	2,804	115,737	5.21%
HYUNDAI	ELANTRA	4DR SEDAN	2,811	198,210	5.80%
MAZDA	CX-3	4DR SUV FWD	2,811	16,355	5.85%
KIA	SOUL	EX/SX	2,837	113,645	6.19%
BMW	COOPER	3DR JOHN WORKS HATCH FWD	2,844	32,232	6.19%
CHEVROLET	SONIC	4DR SEDAN	2,848	30,290	6.28%
BMW	COOPER	CONVERTIBLE 2DR FWD	2,855	32,232	6.28%
HYUNDAI	ELANTRA	GT 5DR HATCHBACK	2,855	198,210	6.87%

*Highlight demonstrates 5th percentile weight

Table 32. Potential Small Passenger Vehicles

Make/Model	Trim	Curb Weight, lb	Total Model Sales
HONDA CIVIC	DX/LX/EX 4DR SEDAN	2,743	377,286
CHEVROLET CRUZE*	4DR SEDAN	2,756	184,751
TOYOTA COROLLA	4DR SEDAN	2,789	308,695
KIA FORTE	LX 4DR SEDAN	2,804	117,596
VOLKSWAGEN JETTA	4DR SEDAN 2.0L	2,804	115,807
HYUNDAI ELANTRA	4DR SEDAN	2,811	198,210
CHEVROLET SONIC*	4DR SEDAN	2,848	30,290

*Production discontinued by manufacturer

9.4 MASH Large Passenger Vehicle

9.4.1 95th Percentile Weight

It is desired that the standardized light truck weight for a compliant MASH pickup vehicle would be approximately the 95th percentile weight, equal to 5,847 lb, in accordance with the principal of “practical worst-case” impact conditions. The 95th percentile weight based was rounded to 5,850 lb for simplification. MASH’s large passenger vehicle has historically been a pickup truck because of availability, cost, potential vehicle instability, and standardization and controllability of c.g. heights.

A 2.2% tolerance was applied to the 95th percentile vehicle weight selection in accordance with existing MASH techniques. The resulting range of potential vehicle curb weights therefore ranged between 5,600 and 6,100 lb. This was consistent with the existing MASH vehicle weight tolerance of 2.2%, which permitted test weights between 4,890 to 5,110 lb. Pickup trucks are the most common light truck vehicle found near the 95th percentile weight [27] and are consistent with existing MASH crash test vehicles; no changes were recommended from a pickup truck to an alternative vehicle (e.g., van, SUV, or CUV). The following criteria were used to obtain a suitable pickup truck class for crash testing:

- One-ton pickup trucks were removed from the potential large passenger vehicle list due to less availability and higher cost.
- Specialty and luxury trim levels were also removed due to lack of availability and high cost.

The remaining large passenger vehicle candidates consisted of half- and three quarter-ton pickup trucks, shown in Table 33.

Of the remaining fifteen pickup trucks shown in Table 33, ten were regular/single cab body style, and ten of the fifteen were two-wheel drive. As previously noted, there was no indication in the Wards Intelligence sales data regarding the distribution of vehicle trim and suspension packages and it was unclear if many trucks had been produced and sold which were consistent with these body styles. Researchers utilized used vehicle sales as a surrogate to estimate the availability of different body types. Analysis of available pickup trucks from model years 2013 to 2019 using Edmunds [30] and Cars.com [31] showed both regular cab and two-wheel drive pickup trucks in this weight range were underrepresented and there may not be enough vehicles to reliably conduct full-scale crash testing. Researchers therefore investigated alternatives to the 95th percentile weight which may have higher sales volumes, better availability, and reasonable cost.

Table 33. Potential Large Passenger Vehicles near 95th Percentile Weight

Make	Model	Trim	Curb Weight, lb	Total Model Sales, No. of Units	Percentile Weight Range
CHEVROLET	SILVERADO 2500	HD REG CAB L/BOX 2WD	5,631	103,112	94.13%
GMC	SIERRA 2500	HD REG CAB L/BOX 2WD	5,631	38,358	94.13%
NISSAN	TITAN	SINGLE CAB S/SV	5,668	52,924	94.13%
FORD	F-250	SD P/U REG CAB L/BOX	5,684	177,737	94.13%
NISSAN	TITAN	CREW CAB S/SV	5,688	52,924	94.13%
NISSAN	TITAN	XD SINGLE CAB 4X2	5,695	52,924	94.13%
NISSAN	**TITAN**	**CREW CAB PRO-4X**	**5,816**	**52,924**	**94.73%**
FORD	**F-250**	**SD P/U SUPERCAB S/BOX**	**5,933**	**177,737**	**95.37%**
NISSAN	TITAN	SD SINGLE CAB 4X4	5,957	52,924	95.69%
CHEVROLET	SILVERADO 2500	HD REG CAB L/BOX 4X4	5,961	103,112	95.69%
GMC	SIERRA 2500	HD REG CAB L/BOX 4X4	5,961	38,358	95.69%
RAM	RAM 2500	REG CAB L/BOX 2WD	5,966	89,935	95.69%
FORD	F-250	SD P/U SUPERCAB L/BOX	6,027	177,737	95.76%
FORD	F-250	SD P/U CREW CAB S/BOX	6,052	177,737	95.85%
FORD	F-250	SD P/U REG CAB L/BOX 4X4	6,107	177,737	96.76%

*Highlights demonstrate location of 95th percentile weight

9.4.2 Other Percentile Weights and Vehicle Availability

Researchers reviewed the sales distributions to find commonly-sold vehicles near the 95th percentile weights which were pickup truck body styles. It was observed that ¾-quarter ton, four-wheel drive, crew cab pickup trucks weighed over 6,300 lb (about 98th percentile weight) while their ½-ton counterparts generally weighed 5,300 lb to 5,400 lb (about 92nd percentile weight). Use of the 98th percentile weight was not desired; the 98th percentile pickup truck would increase large passenger vehicle weight by 1,300 lb compared to the 2270P. As well, the most common pickup truck suspension configuration was a ½-ton based on data from Dominion Cross-Sell [41], which suggests that the 98th percentile weight pickup truck with a full-ton suspension may not be representative of most vehicles in use on roadways.

The collected vehicle sales data was reanalyzed to investigate pickup truck weight and trim distributions. Distribution of ½-ton pickup trucks by cab style is shown in Figure 45. Sale listings for ½-ton pickup trucks (model years 2013-2019) on Cars.com for a national sample were reviewed to create a surrogate for body style distribution of pickup trucks. Note, Ram crew and quad cab sales were not listed independently. Of Chevy, GMC, Ram, and Ford, ½-ton, crew cab pickup trucks were found to be the significantly most available body style. Nearly 80% of pickup trucks for sale were crew cabs, 17% were extended cabs, and about 3% were regular cabs.

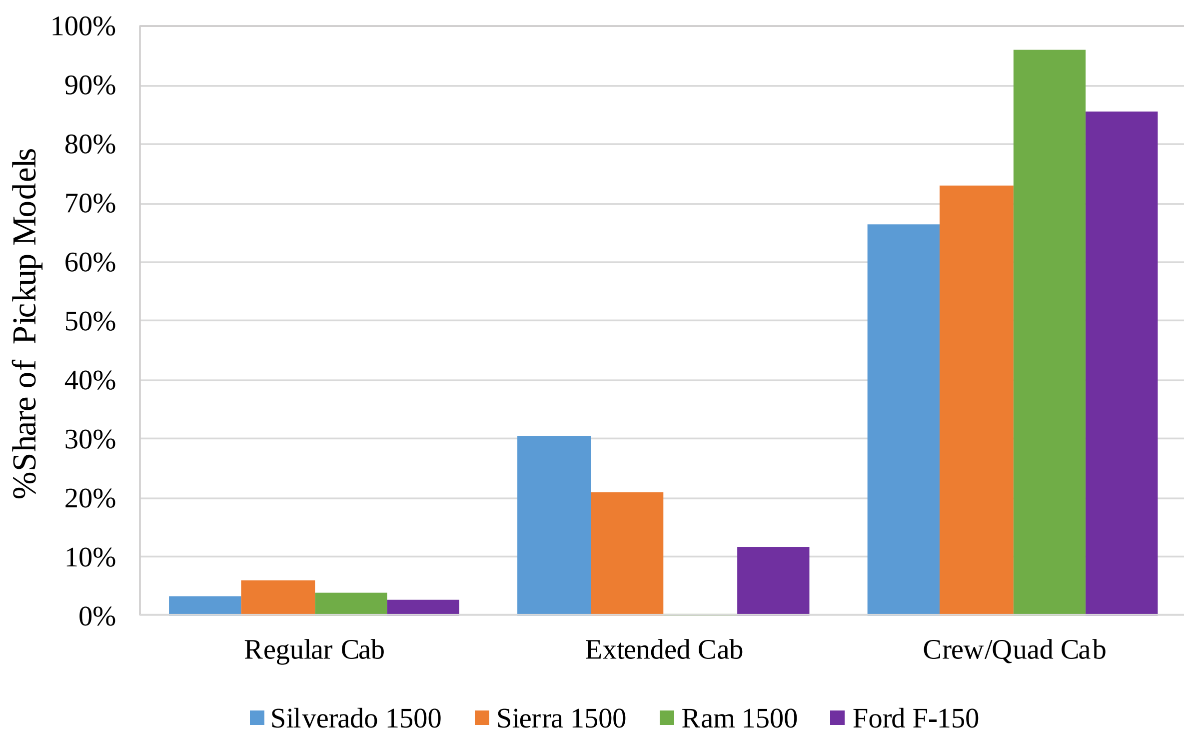


Figure 45. Cab Style Distributions of ½-ton Pickup Trucks [31]

Drivetrain distribution of crew/quad cab pickup trucks is shown in Figure 46. Drivetrain distribution was observed to evaluate how common four-wheel drive (4WD) and rear-wheel drive (RWD) configurations were for pickup trucks. 4WD pickup trucks outnumbered RWD pickup trucks by a magnitude of about 4:1. Therefore, the target test vehicle specification was to utilize a ½-ton suspension with a 4WD transmission.

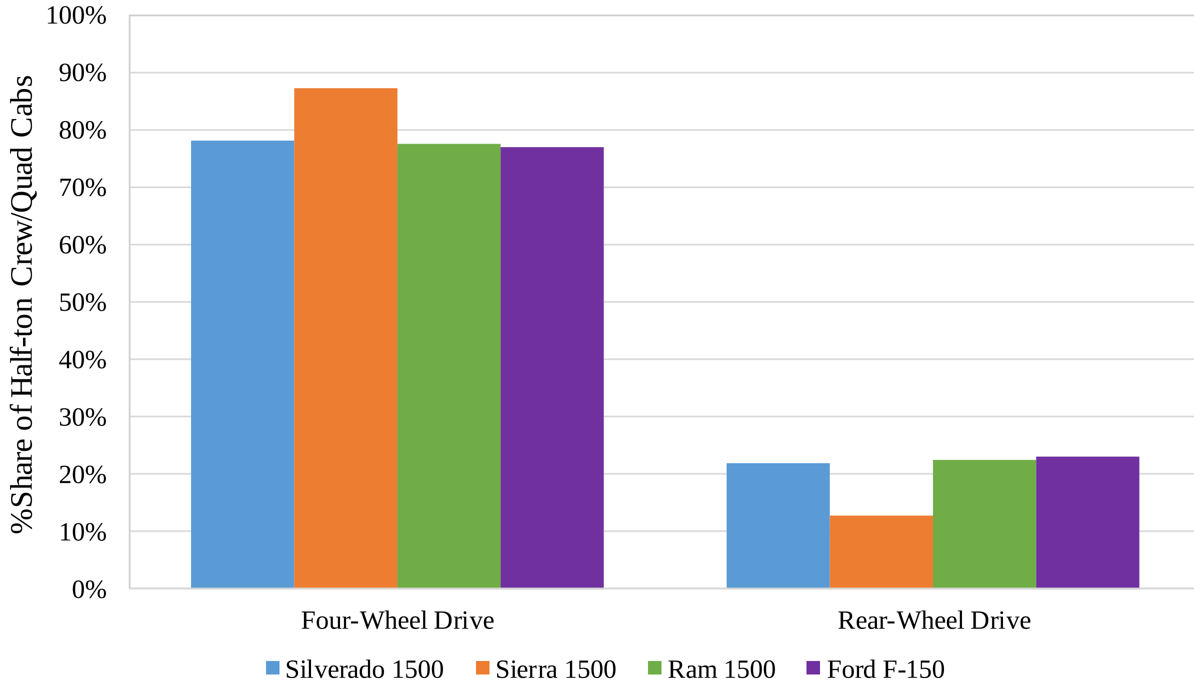


Figure 46. Drivetrain Distribution of ½-ton, Crew/Quad Cab Pickup Trucks [31]

Exploration of representative pickup truck test vehicle options near 5,850 lb indicated the ½-ton, crew cab, 4WD, medium-box pickup truck was a very common vehicle configuration sold in the U.S, and many baseline options for pickup trucks were available around the 92.5 percentile weight of 5,400 lb. By adopting a standard target weight of 5,400 lb, application of 2.2% nominal weight tolerance yielded a weight tolerance range from 5,280 lb to 5,520 lb. Several pickup trucks with suitable sales volumes, body styles, payload capacities, and vehicle dimensional properties were identified, but some of the half-ton pickup truck options fell below the minimum curb weight target, including Ford SuperCrew, Ram Quad Cab, Toyota Tundra, Toyota Tacoma, and Nissan Titan.

9.4.3 Light Truck Vehicle Discussion

A 95th-percentile target vehicle weight was deemed undesirable in this study due to difficulty acquiring high-sales volume vehicles with similar properties, so researchers selected the 92.5 percentile vehicle instead. Despite this compromise, the new target weight of the recommended vehicle adds 400 lb to the target weight of the current MASH truck. The additional weight is likely to increase barrier loading and may lead to more robust barrier designs. In addition, data for the performance of roadside barrier systems with 4WD pickup trucks is limited and has not been conducted according to MASH specifications. Supplementary crash testing before the new test vehicles are incorporated into the MASH specification is recommended to analyze whether adverse impact behavior exists due to the larger weight and four-wheel drivetrain.

Recent changes to model configurations of pickup trucks will require review, as they may affect future test vehicle selection and availability around the 92.5 percentile weight. Ford F-150 pickup trucks were deemed too light due to changes in body, chassis, and construction properties around 2015, such that the 2014 Ford F-150 SuperCrew 4WD configuration weighed 5,596 lb, and the 2015 overhauled edition of the same model weighed 4,930 lb. During the evaluation period of this study, neither the Chevrolet Silverado 1500 nor Dodge Ram 1500 had significant model revisions. However, review of 2019 specifications indicated significant weight reductions and model revisions in 2019. Early in 2019, it was projected that the 2019 Silverado would weigh approximately 450 lb lighter than the previous model year [50]. The finalized weight for the redesigned 2019 Silverado 1500 crew cab 4x4 was 5,090 lb, approximately 210 lb lighter than the 2018 model [51], and the Ram 2019 1500 Crew Cab 4WD (Big Horn/Lone Star) was also redesigned, such that the curb weight was reduced from 5,390 lb to 5,232 lb [52]. If future models of ½-ton, quad- or crew-cab pickup trucks have significantly reduced curb weights compared to 2017 distribution, the selection criteria for the light pickup truck vehicle may need to be reviewed to confirm it remains an adequate representation of heavy vehicle class for roadside hardware evaluation.

Pickup truck vehicles have also historically lagged safety improvements and performance of other vehicles due to the large masses and focus on other performance characteristics, but recent models have performed significantly better in standardized testing [53]. In 2016, the Ford F-150 became one of the first pickup trucks to receive an IIHS Top Safety Pick for the F-150 Crew Cab pickup truck [54], and in 2019, the Dodge Ram 1500 Crew Cab became the first ever pickup truck to receive the IIHS Top Safety Pick+ [55], the highest safety rating awarded to a production vehicle. Although it is believed that improved standardized test performance and safety ratings of vehicles will improve occupant survivability and injury risk during impacts with roadside hardware, it is not yet known whether newer vehicles will continue to interface well with existing roadside hardware.

9.5 MASH Intermediate Passenger Vehicle

MASH provides minimal guidance to aid in intermediate passenger vehicle selection and standardization. The intermediate vehicle was included in MASH to evaluate staged energy-absorbing terminals, crash cushions, truck-mounted attenuators, cable barrier penetrations.

Intermediate vehicle selection could be standardized based on the functional role it contributes to during full-scale crash testing. Researchers reviewed the discussion in MASH and full-scale crash tests involving mid-sized vehicles. Using these data, researchers recommended potential considerations for the selection of the intermediate vehicle:

- The intermediate vehicle should have a weight between the small car and pickup truck options. This approach is primarily useful for evaluating staged energy absorbers to ensure that vehicles with intermediate weights between the upper and lower limits are still safely captured with acceptable occupant risk.

- The intermediate vehicle should have significant sales volumes and represent a broad number of vehicles with similar attributes. While it has historically been assumed that vehicle performance with roadside barriers can be adequately represented using the 5th and 95th percentile vehicle weights, the mid-size vehicle may offer an opportunity to evaluate the continuity of roadside feature performance for intermediate vehicles.
- ISPE could be conducted to research potential heightened risk of barrier penetration through vaulting, spearing, or passing between cables; or increased rollover risk. It has been established that some vehicle-barrier impact configurations may lead to more critical barrier loading and risk of test failure by penetration or vehicle rollover. Several mid-size vehicles have been determined to amplify the risk of adverse barrier performance [1]. The vulnerabilities may be specific to vehicle types or barrier configurations. Evaluating the performance of roadside features with these critical vehicles may provide a conservative safety evaluation subject to ISPE review, crash testing, and vehicle model availability.

Based on these considerations, several intermediate passenger vehicle options were considered: (1) continue use of the 3,300-lb mid-size sedan; (2) continue use of the mid-size sedan with weight increase to 3,500 lb; (3) adopt a class of high-selling, compact CUVs; (4) adopt a 50th percentile weight mid-size vehicle.

9.5.1 3,300-lb Sedans

The current MASH criteria for 1,500-lb mid-size passenger car sedan models are reflective of a readily-available vehicle type. Use of mid-size sedans near 3,300 lb is possible with good availability. Non-luxury, gas-powered, four-door sedans within the current MASH mid-size weight tolerance of 3,225 to 3,375 lb were reviewed, and the 2017 total model sales of the vehicles in this class summed to 949,032 units. Intermediate passenger vehicle candidates are shown in Table 34.

Table 34. 2017 Mid-Size Sedans that Satisfy MASH Weight Criteria

Make	**Model**	**Trim Level**	**Curb Weight, lb**	**Total Model Sales**	**Percentile Weight Range**
KIA	OPTIMA	LX/LX+/EX/LX ECO TURBO 4DR SEDAN	3,225	107,493	20.39% - 20.69%
TOYOTA	CAMRY	4DR SEDAN	3,234	387,081	20.72% - 21.81%
HYUNDAI	SONATA	4DR SEDAN 2.4	3,252	131,803	22.31% - 22.67%
HONDA	ACCORD	4DR SEDAN LX/SPORT/EX-L/TOURING	3,298	322,655	23.39% - 24.29%

9.5.2 3,500-lb Sedans

Another intermediate passenger vehicle option is to increase mid-size sedan weight to be reflective of a middle-weight vehicle for model years around 2017. An adequately available sedan class near the 50th percentile weights of 3,850 lb was not identified, and the heaviest average weight of non-luxury, gas-powered, four-door mid-size sedans with enough sales volume to be viable as a standard passenger vehicle was approximately 3,500 lb, shown in Table 35. Mid-size sedan vehicle candidates near 3,500 lb accumulated 1,129,780 total model sales in 2017.

Table 35. Mid-Size Sedan Passenger Vehicle Options near 3,500 lb

Make	**Model**	**Trim Level**	**Curb Weight, lb**	**Total Model Sales**	**Percentile Weight Range**
FORD	FUSION	4DR SEDAN	3,435	209,623	30.75% - 31.60%
NISSAN	ALTIMA	3.5 4DR SEDAN	3,470	254,996	32.90% - 33.66%
HYUNDAI	SONATA	4DR SEDAN SPORT 2.0T	3,505	131,803	35.12% - 35.48%
TOYOTA	AVALON	4DR SEDAN	3,549	35,583	38.33% - 38.54%
HONDA	ACCORD	4DR SEDAN EX-L V6/TOURING V6	3,560	322,655	41.09%

9.5.3 Compact CUVs

Current MASH evaluation criteria primarily evaluates vehicle stability based on the performance of the 2270P pickup truck, but other vehicles with high c.g. heights, significant suspension travel, low weights, and narrow track widths may be more susceptible to rollover. In addition, CUVs are increasingly common passenger vehicles but have not yet been evaluated with impacts with roadside hardware. CUVs generally exhibit a 10-20% greater likelihood of rollover than mid-size sedans based on their static stability factor (SSF), which approximates vehicle stability [14], as discussed in Sections 3.2.2 and 3.3.

The Honda CR-V, Nissan Rogue, and Toyota RAV4 were three of the five top-selling passenger vehicles in 2017, demonstrating the popularity and availability of front-wheel drive, compact CUVs. The high-sales volume compact CUV class possessed curb weights within 150 lb of one another, as shown in Table 36. They accumulated 1,523,354 total model sales in 2017.

Table 36. Compact CUV Intermediate Passenger Vehicle Options

Make	Model	Trim	Curb Weight, lb	Total Model Sales, No. of Units	Estimated SSF and NHTSA Rollover Rating
HONDA	CR-V	4DR SUV FWD	3,311	377,895	1.20 ★★★
MAZDA	CX-5	GS 4DR SUV FWD (2016.5)	3,318	127,563	1.18 ★★★
VOLKSWAGEN	TIGUAN	2.0 FWD 4DR SUV	3,393	46,983	1.15 ★★★
NISSAN	ROGUE	4DR SUV FWD	3,417	365,972	1.16 ★★★
TOYOTA	RAV4	FWD 4DR SUV	3,428	357,035	1.15 ★★★
MAZDA	CX-5	GX 4DR SUV FWD (2016.5)	3,437	127,563	1.19 ★★★
HYUNDAI	TUCSON	4DR SUV FWD	3,439	114,735	1.22 ★★★
HYUNDAI	SANTA FE	SPORT FWD 4DR SUV	3,459	133,171	1.21 ★★★

9.5.4 50th Percentile Weight Passenger Vehicle

A percentile weight is not specified for the MASH intermediate passenger vehicle, and exploration of using a true mid-weight (50th percentile) vehicle may be worthwhile. The 50th percentile weight was approximately 3,850 lb, and a 2.2% tolerance, equal to 90 lb, suggests a vehicle class in the weight range of 3,760 lb to 3,940 lb. Mid-size, luxury, and sports cars in this weight range were deemed undesirable due to lower sales volumes, high cost, and large diversity of physical dimensions and attributes. One option in this weight range may be use of a large car. The distinguishing factor between large and mid-size cars is whether the vehicle's overall length is greater than 200 in. Large car availability was a primary concern, accounting for only 1.5% of all 2017 vehicle sales. The 3,785-lb Chevrolet Impala (75,887 model units sold) and 3,935-lb Dodge Charger (88,351 model units sold) may be of interest if crash testing of heavier sedans is desired. CUVs are another potential 50th percentile weight vehicle. They are more common on roadways than large cars and have lower SSF ratings, and thus may experience increased propensity for instability issues. The front-wheel drive CUVs near the 50th percentile weight accumulated 707,626 total model sales in 2017 and are shown in Table 37.

Table 37. Eligible 50th Percentile Weight CUVs

Make	Model	Trim	Curb Weight, lb	Total Model Sales, No. of Units	Estimated SSF and NHTSA Rollover Rating
CHEVROLET	EQUINOX	4DR SUV 2.4L FWD LS/LT/LTZ	3,761	290,458	1.16 ★★★
DODGE	JOURNEY	4DR SUV FWD I4	3,825	89,470	1.16 ★★★
GMC	TERRAIN	4DR SUV FWD	3,854	85,441	1.18 ★★★
KIA	SORENTO	EX/LIMITED FWD	3,878	99,684	1.20 ★★★
FORD	EDGE	4DR SUV FWD	3,911	142,603	1.18 ★★★
CHEVROLET	EQUINOX	4DR SUV 3.6L FWD LS/LT/LTZ	3,920	290,458	1.16 ★★★

The primary differences between the compact CUV and 50th percentile weight CUV are wheelbase and weight. The 50th percentile weight CUVs are generally 7 in. longer and 450 lb heavier than compact CUVs. The contribution of wheelbase to roadside hardware crashworthiness is not well understood; however, larger vehicle weight typically contributes to an increase in impact severity and barrier loading and decrease in occupant impact accelerations and velocities.

9.6 Intermediate Passenger Vehicle Discussion

The MASH intermediate passenger vehicle may remain a mid-size sedan weighing 3,300 lb or that an increase of mid-size sedan weight to 3,500 lb may could be best suited for the intermediate passenger vehicle. Mid-size sedans were originally chosen as the intermediate passenger vehicle because of their high availability and use in evaluation of cable barrier penetrations and staged energy absorbing terminals. The increase in CUV sales in recent years suggests that CUVs warrant consideration as a MASH intermediate passenger vehicle. Two CUV classes (near 3,400 lb and 3,850 lb) were adequately available for crash testing; however, barrier performance with CUV vehicles is not well known. Crash testing or ISPE of CUVs and mid-size sedans with existing roadside hardware could provide valuable insight on whether worst practical impact scenarios involve CUVs or mid-size sedans. Vehicle rollover, vaulting, and barrier penetration risk may be of interest when evaluating intermediate vehicle impact performance.

CHAPTER 10 Recommended MASH Passenger Vehicles and Dimensional Properties

10.1 Background

In addition to weight and body style, MASH specifies vehicle dimensional properties which must be met to serve as guide for passenger vehicle selection [1]. No method has previously been established for tabulation of vehicle dimensional properties. After determination of recommended vehicle classes, dimensional properties for recommended vehicles were identified and used as proposed MASH vehicle properties. Wheelbase, overall length, front overhang, overall width, track width, and hood height are specified measurements in MASH that were available for all passenger vehicle trim levels [33, 34]. Additionally, front bumper height may assist in determining how a vehicle initially interacts with roadside hardware, and front bumper height warrants consideration for inclusion in MASH as a specified dimensional property. Vehicle measurements are defined in Table 38 and shown in Figure 47. All measurements were obtained from Canadian Vehicle Specifications [33] except for hood height and front bumper height which were obtained individually using Expert AutoStats [34].

Table 38. Vehicle Measurement Definitions

Vehicle Measurement (Abbreviation)	**Definition**
Wheelbase (WB)	Distance measured between centers of front and rear wheels
Overall Length (OL)	Distance measured from foremost point on front vehicle surface to rearmost point on rear surface
Front Overhang (F)	Longitudinal distance between front bumper center and center of front wheel
Overall Width (OW)	Distance measured at widest point of vehicle, excluding exterior rearview mirrors
Track Width (TW)	Lateral distance measured between the wheel centers on each axle
Other Measurements	**Definition**
Center of Gravity Height (c.g. height)	Measured distance from ground to point where mass is equal on all sides of point (estimated 40% of overall height)
Static Stability Factor	Equals half of the average track width divided by c.g. height
Hood Height	Distance measured from ground to top of radiator mount
Front Bumper Height	Distance measured from ground to 'breakpoint' of the bumper or nose of the vehicle if no visible bumper

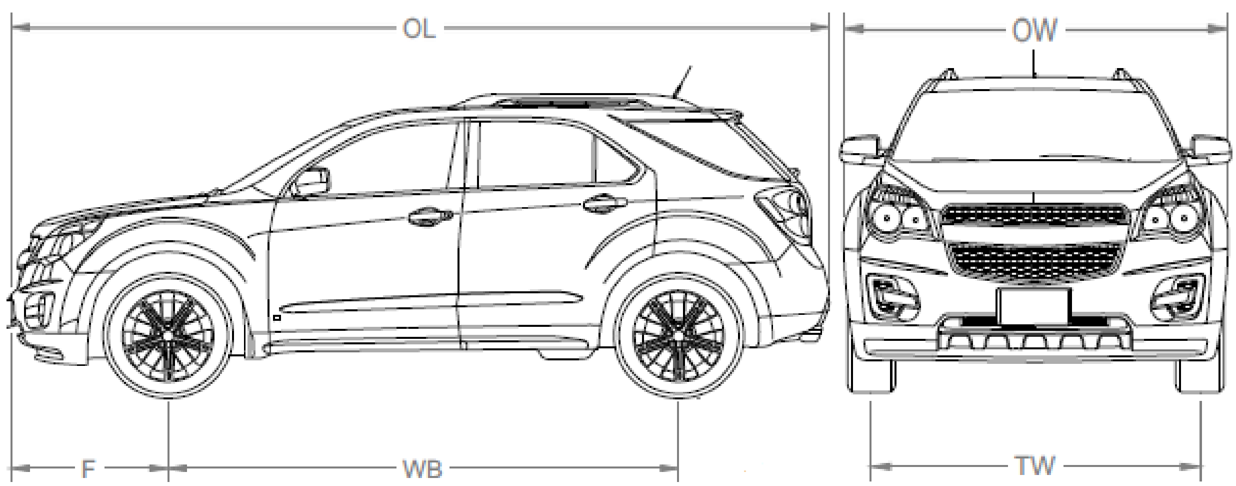


Figure 47. Vehicle Measurement Definitions [32]

10.2 Recommended Dimensional Properties Methodology

Researchers separately tabulated dimensional properties of small and large passenger vehicle candidates, as shown in Tables 39 through 43. The following steps were then taken to obtain recommended dimensional properties for MASH passenger vehicles:

- Identify the maximum and minimum value for the parameter for each viable vehicle trim option (Table 40)
- Identify the midpoint value (average) for each dimensional range (Table 40)
- Use midpoint-value as proposed vehicle property and apply same dimensional tolerance as currently used in MASH (tolerances can be seen in "Dimensions" section of Table 41).

10.3 Proposed Small Car Dimensional Properties

Dimensional properties of 2,800-lb small car candidates and high, low, and midpoint values for each dimensions are shown in Tables 39 and 40. Current MASH small car dimensional properties and proposed properties are shown in Table 41. The most notable recommended changes to the MASH small car are an increase in weight, wheelbase, overall length, hood height, and width. It is unclear exactly how these recommended property changes will affect impact behavior, but vehicle weight increase may result in increased barrier loading and penetrations and less severe occupant impact velocities and accelerations.

Of the potential small passenger vehicle candidates, only the Kia Forte and Hyundai Elantra have been used under MASH. Because it has nearly doubled sales of the Kia Forte every year since the Forte's inception in 2009, the Hyundai Elantra is recommended as the MASH small passenger vehicle.

Table 39. Dimensional Properties of Potential Small Car Passenger Vehicles [33-34]

Make/Model	Trim	Wheelbase, in.	Overall Length, in.	Overall Height, in.	Calculated C.G. Height, in.	Overall Width, in.	Front Overhang, in.	Rear Overhang, in.	Average Track Width, in.	Static Stability Factor	C.G. Behind Front Axle, in.	Hood Height, in.	Front Bumper Height, in.
HONDA CIVIC	DX/LX/EX 4DR SEDAN	106.3	182.3	55.9	22.4	74.0	35.0	40.9	61.2	1.37	41.3	25.0	17.0
CHEVROLET CRUZE**	4DR SEDAN	106.3	183.9	57.5	23.0	70.9	38.6	39.0	61.2	1.33	46.6	31.0	18.0
TOYOTA COROLLA	4DR SEDAN	106.3	182.7	57.5	23.0	70.1	38.2	38.6	59.8	1.30	46.6	26.0	20.0
KIA FORTE	LX 4DR SEDAN	106.3	179.5	56.3	22.5	70.1	34.6	38.6	61.6	1.37	40.3	26.0	19.0
VOLKSWAGEN JETTA	4DR SEDAN 2.0L	104.3	183.1	57.1	22.8	70.1	35.8	42.9	60.6	1.33	45.8	n/a	n/a
HYUNDAI ELANTRA*	4DR SEDAN	106.3	179.9	55.1	22.0	70.5	34.6	39.0	61.4	1.39	41.3	25.0	19.0
CHEVROLET SONIC**	4DR SEDAN	99.2	174.0	59.8	23.9	68.5	35.0	40.2	59.4	1.24	43.6	30.0	21.0

*Recommended MASH small passenger vehicle
**Model production ceased

Table 40. High, Low, and Midpoint Dimensional Property Values

High/Low	Curb Weight, lb	Wheelbase, in.	Overall Length, in.	Overall Height, in.	Calculated C.G. Height, in.	Overall Width, in.	Average Track Width, in.	Front Overhang, in.	Static Stability Factor (SSF)	C.G. Behind Front Axle, in.	Hood Height, in.	Front Bumper Height, in.
High	2,848	106.3	183.9	59.8	23.9	74.0	61.6	38.6	1.39	46.6	31.0	17.0
Midpoint	n/a	102.8	179.0	57.5	23.0	71.3	60.5	36.6	1.3	43.5	28.0	19.0
Low	2,743	99.2	174.0	55.1	22.0	68.5	59.4	34.6	1.24	40.3	25.0	21.0

Table 41. Recommended MASH Small Passenger Vehicle Properties

Property	Current MASH (1100C)	Proposed MASH	Change
Weight, lb			
Test Inertial	2,420 ± 55	2,800 ± 65	+380
Dummy	165	165	0
Max. Ballast	175	175	0
Gross Static	2,585 ± 55	2,965 ± 65	+380
Dimensions, in.			
Wheelbase	98 ± 5	103 ± 5	+5
Front Overhang	35 ± 4	36 ± 4	+1
Overall Length	169 ± 8	178 ± 8	+9
Overall Width	65 ± 3	71 ± 3	+6
Hood Height	24 ± 4	28 ± 4	+4
Track Width[a]	56 ± 2	60 ± 2	+4
Front Bumper Height[c]	n/a	19 ± 3	n/a
Center of Mass Location[b], in.			
Behind Front Axle	39 ± 4	43 ± 4	+4
Location of Engine	Front	Front	n/a
Location of Drive Axle	Front	Front	n/a
Transmission Type	Manual or Auto	Manual or Auto	n/a

a: Average of front and rear axles
b: For "test inertial" weight
c: Not currently specified in MASH

10.4 Proposed Pickup Truck Dimensional Properties

The same high- and low-value method for obtaining recommended small car vehicle properties was used to obtain proposed properties for ½-ton, 4WD, crew cab pickup trucks. The Ram, Chevy Silverado, and GMC Sierra models were large passenger vehicle candidates considered. The Ford ½-ton, 4WD, crew cab pickup truck weighed 4,930 lb in 2017, and with a maximum ballast of 440 lb, the pickup truck model fell short of the target large passenger vehicle weight of 5,400 lb. It should be noted that for consistency, a full cab (e.g., "Crew Cab") should be used for the standard light truck vehicle, which may eliminate some vehicles with condensed rear seating in the cab.

Dimensional properties of the three pickup truck candidates and high, low, and midpoint values for each dimension are shown in Tables 43 and 44. Recommended pickup truck cab style and proposed pickup truck dimensional properties are nearly identical to those currently used in MASH, as shown in Table 45.

Notable measurement differences between current and proposed MASH pickup trucks are a 400-lb weight increase, 3-in. increases to wheelbase and hood height, and four-wheel drivetrain. It is unknown how these may factor into impact severity and crashworthiness, but it is expected that the weight increase will increase barrier impact loading and impact severity. Estimated c.g. height was approximated at 40% of overall vehicle height [33], which indicates that the current MASH requirement that vehicle c.g. height be located no less than 28.0 in. above the ground [1] should be satisfied. Estimated c.g. heights of recommended pickup trucks range from 29.6 to 31.0 in.; however, it is unclear how these measurements compare with actual values because they were unavailable in both Canadian Vehicle Specifications [33] and Expert AutoStats [34]. Experimental determination of recommended pickup truck c.g. heights is suggested to ensure accuracy of the current MASH c.g. height specification. Until c.g. heights of pickup trucks have been experimentally determined, no change to large passenger vehicle c.g. height is recommended. It is also recommended that c.g. heights of high-selling, large SUVs be experimentally determined to verify that the 28.0 in. c.g. height MASH requirement is reflective of modern SUVs.

Additional consideration is needed to anticipate how pickup truck weights will vary soon. Immediately preceding this research study, Ford began sales of a much lighter variation of the ½-ton pickup, and recently GM and Ram have redesigned their vehicles to be lighter [50]. Researchers evaluated the continuity of the recommendations for the 92.5 percentile light truck vehicle using data from Edmunds [30] for ½-ton, crew cab, four-wheel drive, base-trim level pickup trucks from model years 2017 to 2020. Each pickup model saw decrease in curb weight during this span; however, other dimensional properties were mostly unchanged. Remarkably, the newer ½-ton suspension, 4WD, Crew Cab/Full Cab pickup truck curb weights for base trim models is very similar to the current MASH 2270P target weight of approximately 5,000 lb. It is recommended that the Ram 1500 ½-ton, crew cab, four-wheel drive pickup truck be used the MASH large passenger vehicle because Ram 1500 pickup trucks are currently tested under MASH, and the Ram 1500 will be closest to target test vehicle weight in the near future. With a large number of light pickup truck sales consisting of Ford F-150, Chevrolet Silverado 1500, Dodge Ram 1500, or Sierra 1500, it is likely that the reduced weight of the pickup trucks will shift the upper end of the mass distribution further to the left, modifying the actual 95th and 92.5 percentile weights accordingly. MASH should revisit a study evaluating the vehicle fleet every five years to adequately capture variance in vehicle model weights.

Table 42. ½-ton, Crew Cab, Four-Wheel Drive, Base Trim Level Pickups [33-34]

Pickup Manufacturer	**Curb Weight (lb)**			
	2017	**2018**	**2019**	**2020**
Ram	5,450	5,390	5,160	5,133
Chevrolet	5,460	5,461	4,965	4,990
GMC	5,460	5,461	4,965	4,990
Ford	4,895	4,913	4,913	4,913

Table 43. Dimensional Properties of Potential Pickup Truck Test Vehicles [33-34]

Make/Model	Trim	Curb Weight, lb	Wheelbase, in.	Overall Length, in.	Overall Height, in.	Calculated C.G. Height, in.	Overall Width, in.	Front Overhang, in.	Rear Overhang, in.	Average Track Width, in.	Static Stability Factor	C.G. Behind Front Axle, in.	Hood Height, in.	Front Bumper Height, in.
CHEVROLET SILVERADO 1500	CREW CAB M/BOX 4X4	5,359	153.1	235.4	74.0	29.6	79.9	39.4	42.5	68.3	1.15	61.2	45.0	25.0
GMC SIERRA 1500	CREW CAB M/BOX 4X4	5,359	153.1	235.4	74.0	29.6	79.9	39.4	42.5	68.3	1.15	61.2	45.0	25.0
RAM 1500*	CREW CAB 6.4-FT BOX 4X4	5,386	149.2	235.0	77.6	31.0	79.1	40.2	45.7	67.9	1.10	64.1	47.0	26.0

*Recommended MASH large passenger vehicle

Table 44. High, Low, and Midpoint Dimensional Property Values

High/Low	Curb Weight, lb	Wheelbase, in.	Overall Length, in.	Overall Height, in.	Calculated C.G. Height, in.	Overall Width, in.	Average Track Width, in.	Front Overhang, in.	Static Stability Factor (SSF)	C.G. Behind Front Axle, in.	Hood Height, in.	Front Bumper Height, in.
High	5,386	153.1	235.4	77.6	31.0	79.9	68.3	40.2	1.15	64.1	47.0	26.0
Midpoint	n/a	151.2	235.2	75.8	30.3	79.5	68.1	39.8	1.1	62.7	46.0	25.5
Low	5,359	149.2	235.0	74.0	29.6	79.1	67.9	39.4	1.10	61.2	45.0	25.0

Table 45. Recommended MASH Large Passenger Vehicle Properties

Property	Current MASH (2270P)	Proposed MASH	Change
Weight, lb			
Test Inertial	5,000 ± 110	5,400 ± 120	+400
Dummy	optional[a]	optional[a]	0
Max. Ballast	440	440	0
Gross Static	5,000 ± 110[a]	5,400 ± 120[a]	+400
Dimensions, in.			
Wheelbase	148 ± 12	148 ± 12	0
Front Overhang	39 ± 3	40 ± 3	+1
Overall Length	237 ± 13	235 ± 13	-2
Overall Width	78 ± 2	79 ± 2	+1
Hood Height	43 ± 4	46 ± 4	+3
Track Width[b]	67 ± 1.5	68 ± 1.5	+1
Front Bumper Height[c]	n/a	26 ± 3	n/a
Center of Mass Location[d], in.			
Aft of Front Axle	63 ± 4	63 ± 4	0
Above Ground (min.)[e]	28.0	28.0	0
Location of Engine	Front	Front	none
Location of Drive Axle	Rear	Four-Wheel Drive	yes
Transmission Type	Manual or Auto	Manual or Auto	none

a: If a dummy is used, gross static vehicle weight should be increased the weight of the dummy
b: Average of front and rear axles
c: Not currently specified in MASH
d: For “test inertial” weight
e: Pickup must meet minimum c.g. height requirement

CHAPTER 11 Passenger Vehicle Dimensional Properties: 2017

MASH passenger vehicle candidates were earlier identified based on target weight values, and recommended passenger vehicle dimensional properties were identified based on passenger vehicle candidates' dimensional properties. This chapter had no influence on vehicle selection criteria; however, it functions to provide insight about how recommended MASH passenger vehicle dimensional properties compare to all vehicles sold in 2017.

Similar to the weight distribution, vehicle dimensional properties were distributed using vehicle sales. During a crash event, barrier loading is reliant on vehicle kinetic energy, a function of weight and velocity. Weight is the primary measurement used for vehicle selection because it is critical that roadside safety hardware is designed to adequately contain and redirect vehicle kinetic energy. It is largely unknown how the dimensional properties affect crashworthiness and barrier performance, and documentation of these properties in future work could assist in identifying the effect of dimensional properties on crash performance.

Vehicle measurement distributions were created using the same high- and low-value method as described in Chapter CHAPTER 9 to identify possible ranges of vehicle dimensional properties, and then the median-value sales distribution method was applied to approximate actual measurement distribution. An estimated distribution of SSF was also created to provide insight on vehicle rollover potential. Note that SSF is an estimated value based on c.g. height estimations. Measurement distributions for specific vehicle types (CUVs, mid-size cars, pickup trucks, and small cars) can be found in APPENDIX E .

11.1 Wheelbase

Wheelbase distribution for all passenger vehicles is shown in Figure 48. Passenger vehicles exhibit a large range of wheelbase values, from 67 in. to 176 in. The proposed small passenger vehicle has a wheelbase of 103 in. ± 5 in. Approximately 35% of passenger vehicles sold in 2017 were within this range, and the proposed 103-in. wheelbase was of the 6th percentile for passenger vehicles sold in 2017. The proposed large passenger vehicle has a wheelbase of 148 in. ± 12 in. By the median distribution, nearly 15% of passenger vehicles sold in 2017 were within this range. The proposed 148-in. wheelbase was of the 96th percentile for passenger vehicles sold in 2017.

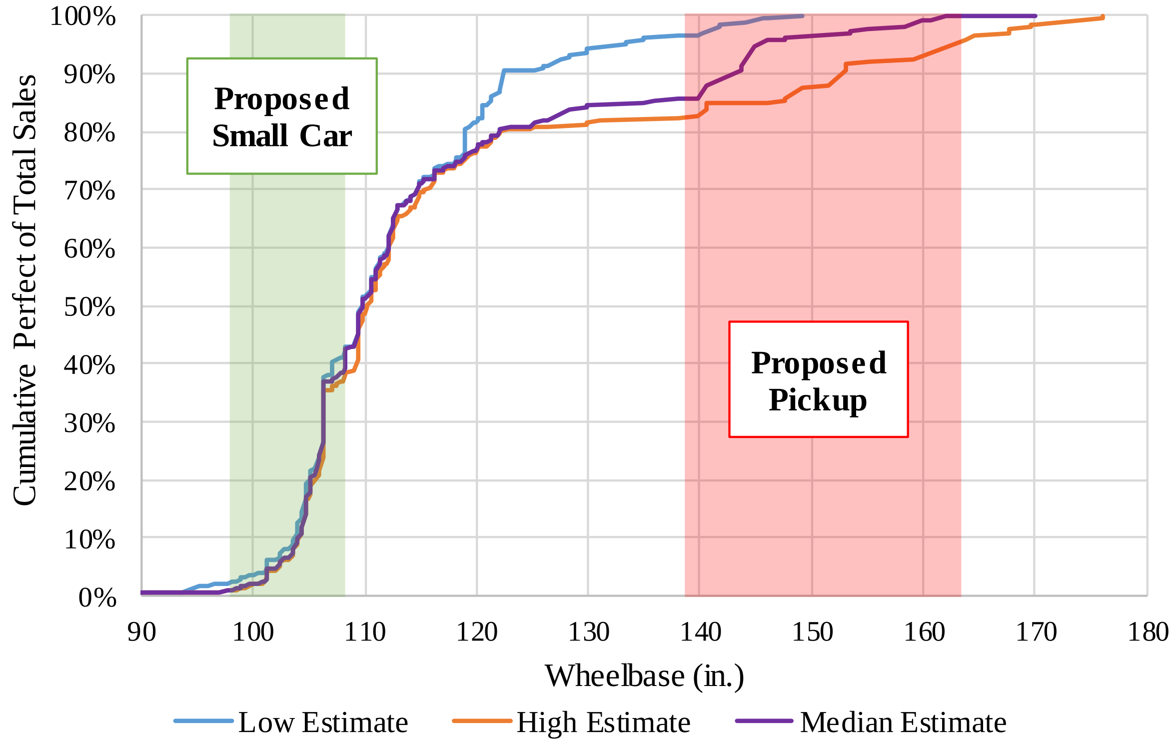


Figure 48. Passenger Vehicle Wheelbase Distribution

11.2 Overall Length

Overall vehicle length is another specified measurement in MASH, and the overall length distribution is shown in Figure 49. The proposed small passenger vehicle has an overall length of 169 in. ± 8 in. Approximately 30% - 35% of passenger vehicles sold in 2017 were within this range, and the proposed 169-in. overall length was of the 7th percentile for passenger vehicles sold in 2017. The proposed large passenger vehicle has an overall length of 235 in. ± 13 in. Nearly 15%

of passenger vehicles sold in 2017 were within this range, and the proposed 235-in. overall length was of the 96th percentile for passenger vehicles sold in 2017.

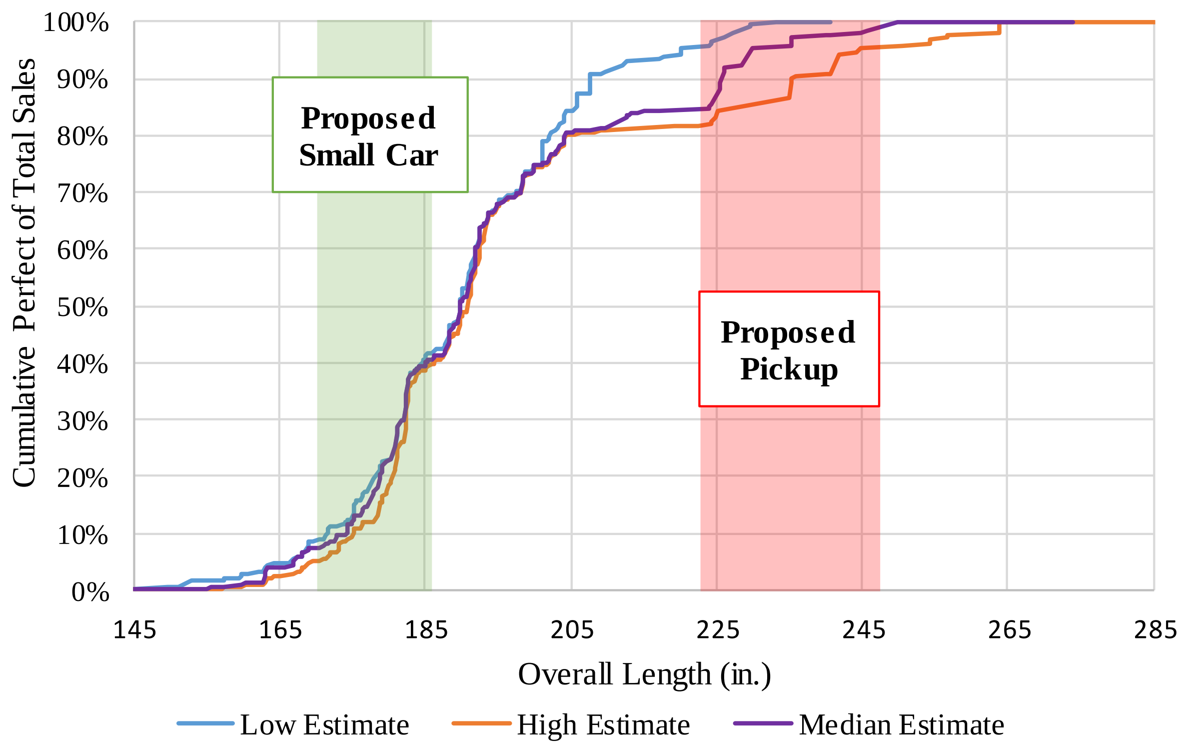


Figure 49. Passenger Vehicle Overall Length Distribution

11.3 Front Overhang

Front overhang is also a specified MASH vehicle measurement, and the front overhang distribution of passenger vehicles is shown in Figure 50. Little change has occurred to front overhang since passenger test vehicles were last selected. The proposed small passenger vehicle has a front overhang of 36 in. ± 4 in. Approximately 85% of passenger vehicles sold in 2017 were within this range, and the proposed 36-in. front overhang was of the 30th percentile for passenger vehicles sold in 2017. The proposed large passenger vehicle has a front overhang of 40 in. ± 3 in. Nearly 60% of passenger vehicles sold in 2017 were within this range, and the proposed 40-in. front overhang was of the 92nd percentile for passenger vehicles sold in 2017.

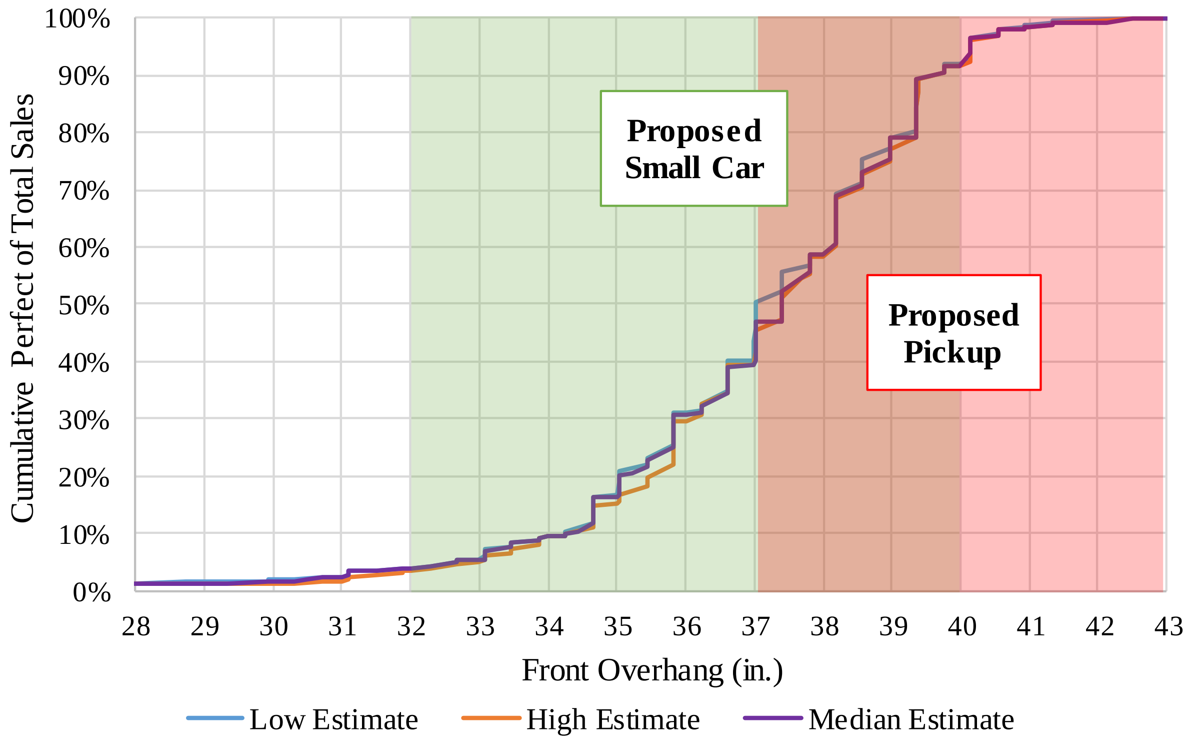


Figure 50. Passenger Vehicle Front Overhang Distribution

11.4 Overall Width

Overall width is another specified MASH vehicle measurement, and the overall width distribution for all passenger vehicles is shown in Figure 51. In general, overall widths of passenger vehicles have marginally increased since 2016. The proposed small passenger vehicle has an overall width of 71 in. ± 3 in. Approximately 50% of passenger vehicles sold in 2017 were within this range, and the proposed 71-in. overall width was of the 17th percentile for passenger vehicles sold in 2017. The proposed large passenger vehicle has an overall width of 79 in. ± 2 in. Nearly 25% of passenger vehicles sold in 2017 were within this range, and the proposed 79-in. overall width was of the 80th percentile for passenger vehicles sold in 2017. While the overall width of small cars has considerably shifted from the limits provided in MASH 2009, pickup truck overall widths remain similar to criteria specified in MASH 2009.

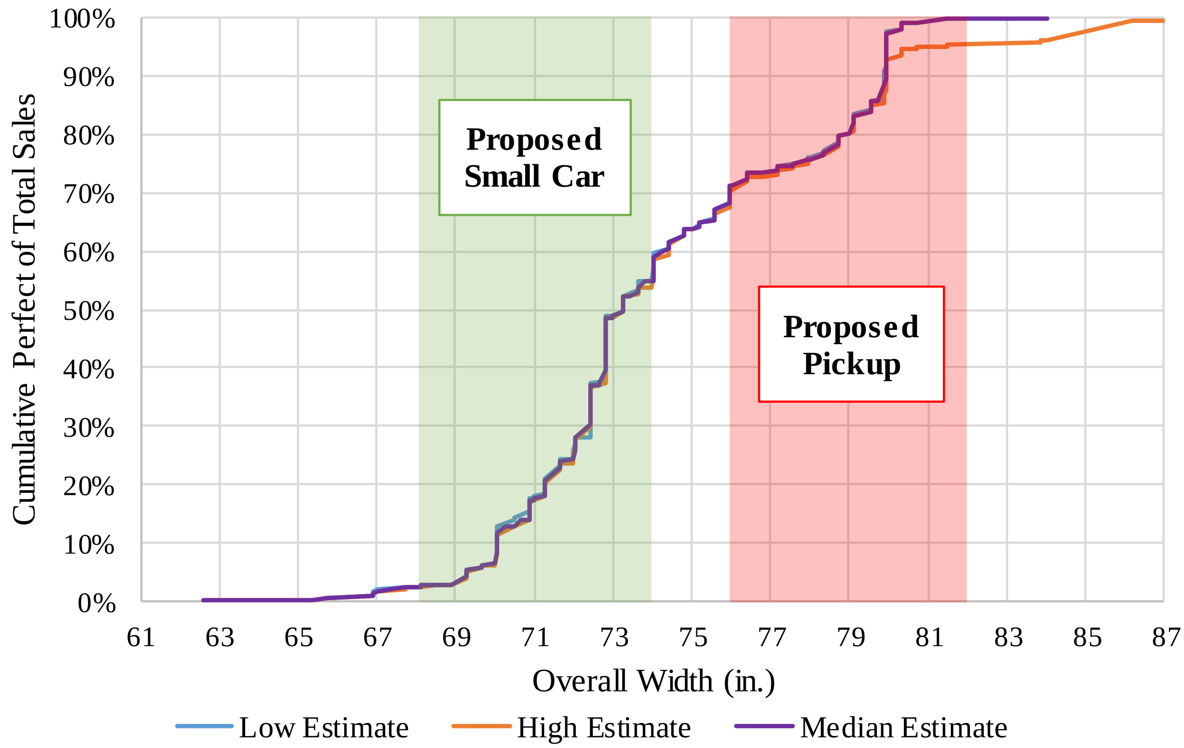


Figure 51. Passenger Vehicle Overall Width Distribution

11.5 Average Track Width

Average track width distribution for all passenger vehicles is shown in Figure 52. Calculating average track width is sometimes necessary if the vehicle's front and rear track widths are different. The proposed small passenger vehicle has an average track width of 60 in. ± 2 in. Approximately 30% of passenger vehicles sold in 2017 were within this range, and the proposed 60-in. average track width was of the 6th percentile for passenger vehicles sold in 2017. The proposed large passenger vehicle has an average track width of 68 in. ± 1½ in. Nearly 20% of passenger vehicles sold in 2017 were within this range, and the proposed 68-in. average track width was of the 90th percentile for passenger vehicles sold in 2017.

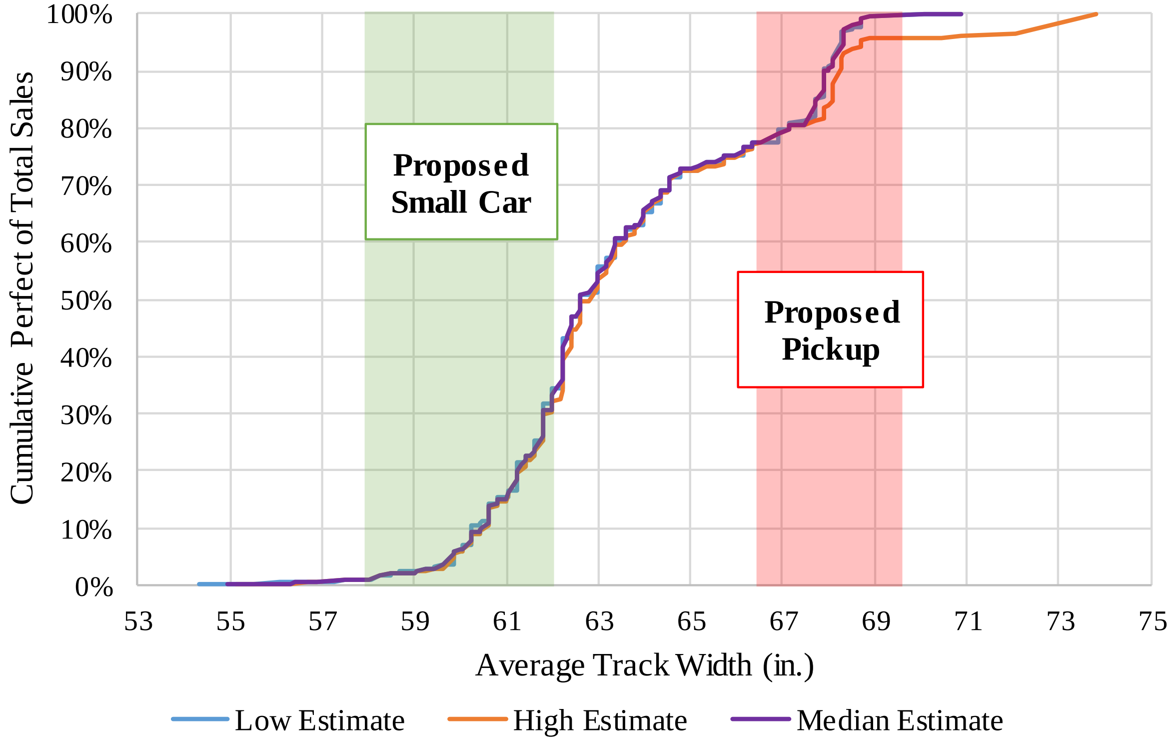


Figure 52. Passenger Vehicle Average Track Width Distribution

11.6 Static Stability Factor

SSF is not currently used in MASH specification criteria; however, it is useful in identifying vehicle potential risk of rollover. SSF is equal to one-half a vehicle's track width divided by its c.g. height. Experimental c.g. heights were not available for vehicles sold in 2017, so c.g. height was estimated to be 40% of a vehicle's overall height [56]. Approximate SSF values allowed observance of what can be expected for experimentally measured SSF values. The intent of MASH is to capture worst practical crash conditions; thus, vehicle stability should be evaluated with low SSF vehicles. The 2270P vehicle is the only passenger vehicle in MASH with a c.g. height requirement (minimum 28.0 in.). Test pickup trucks typically have c.g. heights right at 28 in., and for the minimum 2270P track width value of 65.5 in., the SSF is about 1.17. The approximate span of SSF values for pickup trucks sold in 2017 was 1.05 – 1.20. Distribution of the approximate SSF values for all passenger vehicles is shown in Figure 53.

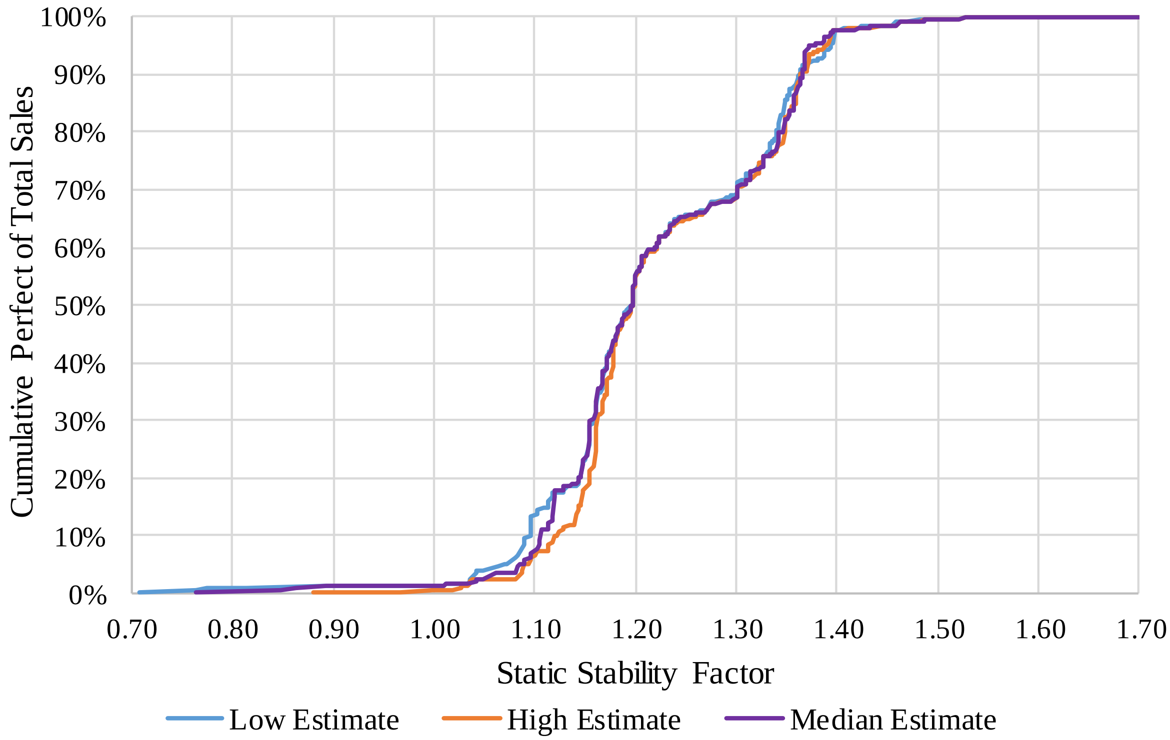


Figure 53. Passenger Vehicle Approximate SSF Distribution

11.7 Summary and Discussion

Identification of high-sales volume vehicle classes near the 5^{th} and 92.5 percentile weights were critical to selection of representative passenger vehicles and provided guidance for specification of other MASH dimensional properties, which were determined using a high-, low-, and midpoint-value method. Proposed MASH small and large passenger vehicle properties were then compared relative to all passenger vehicles sold in 2017. A summary of percentile distributions of proposed MASH small car and pickup truck dimensional properties is shown in Table 46.

Table 46. Distribution Percentile of Proposed Passenger Vehicle Properties

Passenger Vehicle	**Curb Weight**	**Wheelbase**	**Overall Length**	**Front Overhang**	**Overall Width**	**Average Track Width**
Small Car	5th	6th	7th	30th	17th	6th
Pickup	92.5	96th	96th	92nd	80th	90th

MASH additionally recommends that hood height and c.g. distance behind the front axle be specified [1]. Specification of front bumper height may assist in determining how a vehicle initially interacts with roadside hardware, thus front bumper height warrants consideration for inclusion in MASH as a specified dimensional property. Review of distributions of hood height, front bumper height, and c.g. distance behind the front axle was difficult because values were not available in database format. Moreover, the pickup truck hood height defined in MASH, consistent with the top support for the radiator, may not be the same dimension as shown in vehicle reference databases which typically uses the leading edge of the hood measured at the vehicle centerline. SSF is not currently tracked by MASH; however, it is an indicator of vehicle rollover potential, and it is recommended for inclusion in MASH vehicle documentation.

CHAPTER 12 Vehicle Selection Methodology

12.1 Domestic Vehicle Sales Technique

MASH recommends passenger vehicle selection parameters be updated periodically [1]. A similar approach to this study may be used for future passenger vehicle updates, and review of the passenger vehicle fleet should be conducted every five years. The recommended method for reviewing and revising criteria for MASH standard test vehicle selection is shown in a flow chart in Figure 54, and is summarized below.

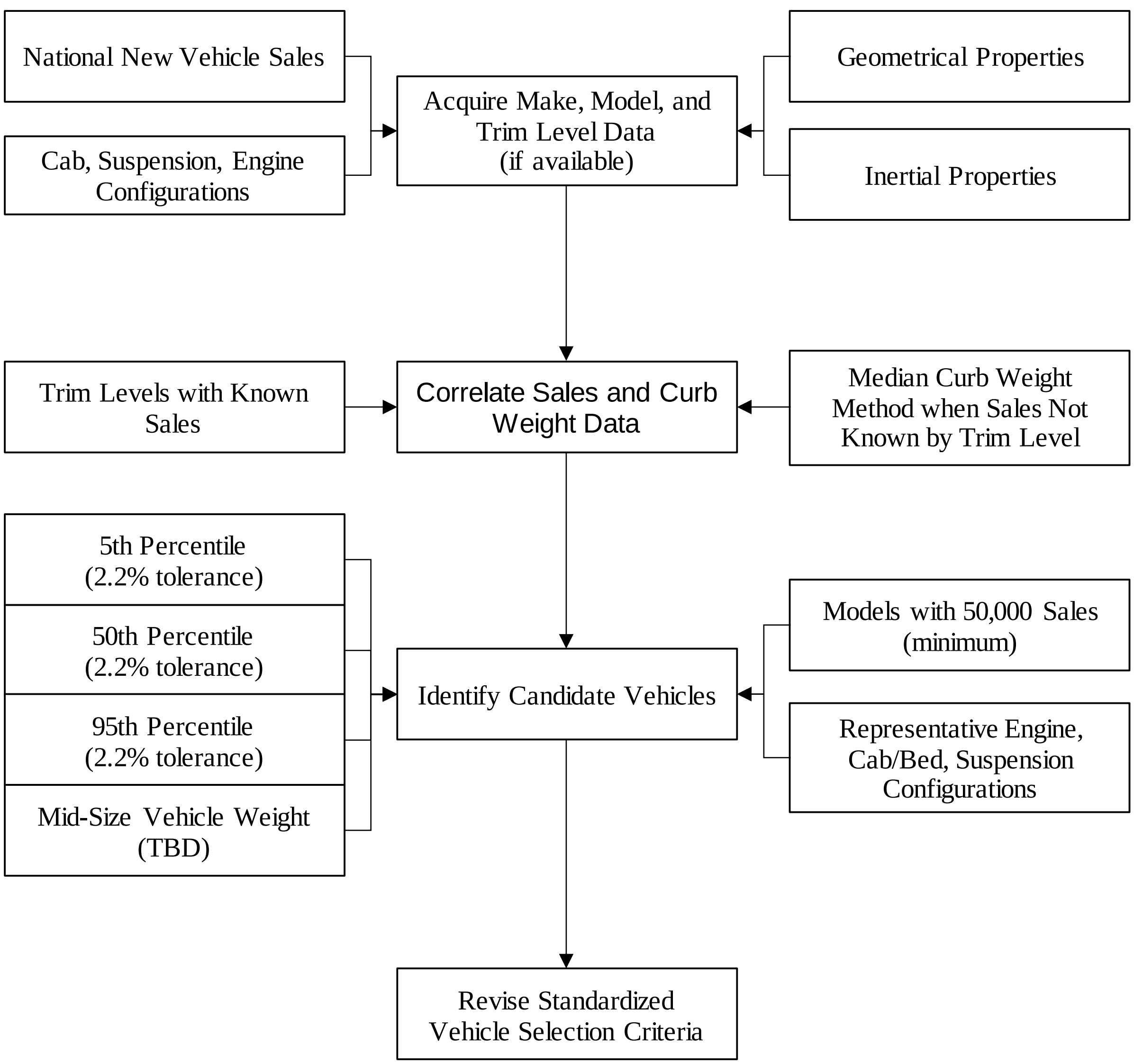


Figure 54. Recommended Procedure for Revising MASH Test Vehicle Specifications

Annual new vehicle sales data are critical, and should be identified in terms of sales by make and model. Further differentiation by trim levels is preferred if data are available. It is recommended that a minimum of five years of consecutive data be collected and sales trends and volumes be compared over the five-year span. One model year may be selected for further analysis; it is assumed that unless prevailing national circumstances or unusual events, including a short economic depression or the national shutdown associated with COVID-19 in 2020 occurs, that the most recent year of data would be selected.

New vehicle curb weights (masses) must also be obtained from manufacturers, online reference libraries or repositories (e.g., Edmunds.com), or from dedicated vehicle databases (e.g., 4N6XPRT Expert Autostats, Canadian Vehicle Specifications). Masses must be differentiated by trim level. Additional vehicle data, including suspension and payload capacity, engine type (gasoline or diesel, hybrid gas-electric, plug-in electric hybrid, battery-electric, fuel cell), cab, and box configuration must be identified and correlated with the weight (mass) data.

For this study, sales data was acquired from Wards Intelligence which provided total sales and model sales spanning for several decades. However, recent data in Wards Intelligence did not include a distribution of sales by vehicle model trim level. In addition, pickup truck sales for the three largest pickup models (Ford F-Series, Dodge Ram, and Chevrolet Silverado/GMC Sierra) were not known as a function of payload capacity (150 or 1500 = ½-ton, 250 or 2500 = ¾-ton, 350 or 3500 = 1-ton). If the annual sales are not identified by trim level, the first step for researchers will be to generate an estimated distribution of sales according to trim level.

An additional dataset such as Dominion Cross-Sell may be necessary to approximate pickup truck sales by payload capacity. Once model sales data is distributed for different suspension or payload capacities within a model, the preferred technique recommended in this study for distributing the remaining sales to different trim levels was to assign all model sales to the trim level with the median mass. It is assumed that the distribution of sales for most vehicles follows a normal distribution with regard to trim weight, and the highest sales will be associated near the median trim level mass. Alternative techniques, including distributed average, semi-normalized sales distribution, and external data (e.g., Cars.com) for allocating sales by trim level yielded very similar results but were more cumbersome, time-consuming, and potentially arbitrary. Standardization of the mass distribution technique will ensure that results are consistent and repeatable.

Vehicle masses should then be plotted against sales to determine the recommended curb weights for the lightweight and heavy passenger vehicles. These techniques are further detailed in Chapter 9. A discrete weight distribution can be created by arranging vehicle model trims from lightest to heaviest and plotting curb weight against cumulative market share. The 5^{th} and 95^{th} percentile weights should be identified and used as baseline weights for small and large passenger vehicle selection, respectively. The selection criteria for the mid-size test vehicle should be determined based on further research, and the methodology for selecting that vehicle class appended to this technique. and it is recommended that a standardize technique, selected on a mass basis, and guided by data including an ISPE or exploratory crash testing effort, be developed to identify attributes of the mid-size vehicle.

Sections 9.3 and 9.4 highlighted additional details of small and large passenger vehicle selection criteria. High-sales volume vehicles and common vehicle types (vehicles models/classes with more than 50,000 unit sales per year minimum, and 100,000 unit sales recommended) must be identified near the 5^{th} and 95^{th} percentile weights to determine which vehicle classes were representative of practical worst-case impact scenarios. Considerations in passenger vehicle selection should include, but not be limited to, vehicle power source, body style, cost, availability, and drivetrain. After identifying small and large passenger vehicle candidates, dimensional properties for each passenger vehicle class can be obtained, as detailed in Chapter 14. The "high- and low-value" midpoint method was used to specify recommended properties for MASH small and large passenger vehicles. For these evaluations, the quantity of sales per trim level may be considered as masses will vary with different trim levels.

It should be noted that candidate vehicles may not be available around the targeted 5^{th} and 95^{th} percentile weights, either due to trim sales variations or fluctuations in preferred vehicle classes (e.g., abundance of SUV or CUV vehicles, but lack of passenger car models, at an identified target weight). In these circumstances, researchers must weigh the importance of the attributes to be considered including vehicle class and vehicle-to-roadside feature interactions. Trends in vehicle sales should also be considered when deviating from the nominal 5^{th} or 95^{th} percentile weights.

Consideration for selection criteria of an intermediate passenger vehicle must be further investigated. Intermediate passenger vehicle properties (aside from weight) were not previously specified in MASH, and intermediate passenger vehicle recommendations for crash testing should be dependent on future research into crashworthiness of sedans and CUVs with existing roadside safety hardware designs.

12.2 Application to International Vehicle Selection

Vehicles sold in the U.S. are not representative of vehicles sold in other countries around the world. Similarly, speed limits and roadside design practices may significantly vary by country. If other countries or organizations outside the U.S. wish to identify/update passenger vehicle selection criteria, this vehicle selection methodology can be evaluated regionally. For example, if Australia desired to update passenger vehicles, a weight distribution based on passenger vehicle sales in Australia could be created using similar sales analysis techniques as used in this study. High-sales volume vehicles and vehicle classes in Australia could be identified so representative vehicle characteristics could be tabulated for passenger vehicle candidates at or near the 5th and 95th percentile weights (based on Australian sales).

CHAPTER 13 Summary and Conclusions

Few research studies have reviewed vehicle parameters since MASH was first published in 2009 and revised in 2016. Sales data was used as indicator of the modern vehicle fleet and was cheap and relatively quick to analyze as compared to crash data. Passenger vehicle selection was found to be most easily conducted using vehicle sales data, while registration and crash data provided other valuable information on vehicle availability and crashworthiness. Available sales data from 2017 did not include sales among trim levels or pickup truck payload capacities, and replication of this study in the future may need to obtain additional sales datasets. Vehicle sales data were analyzed, and the most notable sales shift was the increased market share of lights trucks, led by the emergence of CUVs which jumped from an approximate 12% passenger vehicle sales share in 2005 to 39% in 2017. Gas-powered passenger vehicles accounted for over 90% of passenger vehicle sales in 2017, and motorcycles were largely unchanged since last update to MASH passenger vehicles.

Vehicle model sales data were compared with registered and crashed vehicles to determine whether sales data is effective in approximating vehicle fleet composition to aid in MASH passenger vehicle selection. Sales, registrations, and crash data were used to evaluate the distribution of vehicle ages, body styles, and average age involved in fatal crashes. Registrations were typically reflective of sales data twelve years prior to registration year, and distribution of fatal crashes was approximately reflective of sales data four to seven years prior to a given crash year. Vehicle sales, registrations, and crashes were analyzed to find the most common body styles for crash test use. The most common body types were found to be sedans, CUVs, SUVs, and pickup trucks, and passenger vehicle weights were found to have increased compared to the current MASH passenger vehicles.

After determining that sales data served as an effective surrogate for approximating future vehicle registrations, a discrete weight distribution based on 2017 passenger vehicle sales and curb weights identified 5th and 95th percentile weights (2,800 lb and 5,850 lb, respectively). Passenger vehicle candidates near these weights were identified, and dimensional properties were tabulated to propose recommended passenger vehicle properties for MASH, as shown in Table 47. A 2,800-lb (5th percentile weight), gas-powered, four-door sedan was selected as MASH small passenger vehicle candidate. A 5,400-lb (92.5 percentile weight), half-ton, crew cab, 4WD pickup truck was selected as the MASH large passenger vehicle candidate. The recommended small passenger vehicle for MASH is the Hyundai Elantra (base-trim level, gas-powered, four-door sedan), and the recommended large passenger vehicle for MASH is the Ram 1500 pickup truck (base-trim, crew cab, four-wheel drive, 6.4-foot box). Additionally, the vehicle selection process has been documented in Chapter 12 so MASH passenger vehicle criteria can continually be updated and remain representative of the modern U.S. fleet. Supplemental testing of recommended small and large passenger vehicles is recommended to validate whether passenger vehicle candidates are suitable for MASH implementation.

Table 47. Proposed Small and Large Passenger Vehicle Properties

Vehicle Properties	Proposed Small Car	Proposed Pickup Truck
Weight, lb		
Test Inertial	2,800 ± 65	5,400 ± 120
Dummy	165	optional[a]
Max. Ballast	175	440
Gross Static	2,965 ± 65	5,400 ± 120[a]
Dimensions, in.		
Wheelbase	103 ± 5	148 ± 12
Front Overhang	36 ± 4	40 ± 3
Overall Length	178 ± 8	235 ± 13
Overall Width	71 ± 3	79 ± 2
Hood Height	28 ± 4	46 ± 4
Track Width[b]	60 ± 2	68 ± 1.5
Front Bumper Height[c]	19 ± 3	26 ± 3
Center of Mass Location[d], in.		
Behind Front Axle	43 ± 4	63 ± 4
Above Ground (min.)[e]	n/a	28.0
Location of Engine	Front	Front
Location of Drive Axle	Front	Four-Wheel Drive
Transmission Type	Manual or Auto	Manual or Auto

a: Anthropomorphic test dummies (ATDs) including instrumented dummies are strongly recommended. Dummy weights should not be included in test inertial weight, but should be included in gross static weight.
b: Average of front and rear axles
c: Not currently specified in MASH
d: For "test inertial" weight
e: Pickup must meet minimum c.g. height requirement

The MASH intermediate passenger vehicle evaluates cable barrier penetration, staged energy-absorbing terminals, crash cushions, and truck-mounted attenuators. Mid-size sedans have traditionally been the intermediate passenger vehicle, but sales indicate that CUVs would have greater availability and new vehicle sales representation. Viable intermediate passenger vehicle options include: (1) continue using the 3,300-lb mid-size sedan; (2) an increased weight, mid-size sedan; (3) adopt a class of high-selling, compact CUVs; and (4) adopt a 50th percentile weight, 3,850-lb mid-size vehicle (CUV most prevalent class at 50th percentile weight). Further research on intermediate passenger vehicle impact behaviors is needed to determine which options would be most appropriate for use as a MASH passenger vehicle.

At the end of this study, researchers observed changes in vehicle weights associated with overhauled models of major U.S.-production ½-ton pickups. Study conclusions were based on analysis of 2017 sales and vehicle properties data. If future models of ½-ton, quad- or crew-cab pickup trucks have significantly reduced curb weights compared to 2017 distribution, the selection criteria for the light pickup truck vehicle may need to be reviewed to confirm it remains an adequate representation of heavy vehicle class for roadside hardware evaluation. As well, pickup trucks, SUVs, and CUVs continue to improve in standardized performance testing such as NCAP and IIHS safety ratings. While it is believed that improved standardized test performance and safety ratings of vehicles will improve occupant survivability and injury risk during impacts with roadside hardware, it is not yet known whether newer vehicles will continue to interface well with existing roadside hardware. It will be necessary to review the criteria for evaluating roadside safety hardware performance as vehicle safety improves.

It is unknown when the next MASH passenger vehicle evaluation will occur. By that time, the vehicle fleet will have further evolved, and a similar vehicle selection study may be necessary. The recommended methodology to identify MASH small and large passenger vehicle properties is as follows:

1. Acquire Data by Make, Model, Trim Level (if available)
    1.1. National new vehicle sales
    1.2. Cab, suspension, engine configurations
    1.3. Geometrical properties
    1.4. Inertial properties
2. Correlate New Vehicle Sales with Curb Weight Data
    2.1. When possible, use known sales with trim level, curb weight data
    2.2. Use median curb weight method if sales distribution not known by trim level
3. Identify Candidate Vehicles
    3.1. Identify 5th, 50th, 95th percentile weights, mid-size vehicle weight (TBD)

3.2. Identify candidate vehicles near 5th, 50th, 95th percentile weights, mid-size vehicle weight (TBD) with a minimum of 50,000 model sales at desired trim level
3.3. Filter candidate vehicles based on engine type, cab, and bed configuration (if applicable), suspension configuration, and powertrain properties

4. Revise Standardized Vehicle Selection Criteria
   4.1. Identify acceptable range of variation in selection criteria (e.g., ±4 in. wheelbase)
   4.2. Select nominal "target" criteria and tolerance to encompass most candidate vehicles
   4.3. Reject candidate vehicles with significant deviation from nominal candidate vehicle range

CHAPTER 14 Recommendations

It is recommended that pilot testing be conducted using the new, proposed 2,800-lb small car and 5,400-lb pickup truck. The increased weight will increase nominal IS-values (impact severity) by 16% and 8%, respectively, and are likely to increase the vehicle-to-barrier lateral impact loading. Crash testing should be conducted with multiple barrier types, such as approach guardrail terminals, w-beam guardrail, concrete parapets, cable barriers, portable concrete barriers, and crash cushions/end terminals. Four-wheel drive pickup trucks have not been crash tested under MASH, so impact events between front tires and barriers may be noteworthy. This research study could be similar in execution to NCHRP Project No. 22-14 during the initial adoption of MASH [57]. Recommended MASH small and large passenger test vehicles are as follows, and it is recommended these vehicle models be obtained to verify that model weights and dimensions are within proposed vehicle property ranges:

- **Small passenger vehicle:** Hyundai Elantra – base-trim, gas-powered, four-door sedan
- **Large passenger vehicle:** Ram 1500 - base-trim, crew cab, four-wheel drive, 6.4-foot box pickup truck

Several potential intermediate passenger vehicle candidates were discussed, including two mid-size sedan classes and two CUV classes. CUV presence in crash, registration, and sales data suggest it is imperative to begin testing and evaluation of CUV impact events with roadside hardware. Immediate implementation of a CUV crash testing program or an in-service performance evaluation data (ISPE) is recommended to evaluate crash performance with multiple barrier types, including approach guardrail terminals, w-beam guardrail, concrete parapets, cable barriers, portable concrete barriers, and crash cushions/end terminals. CUV and mid-size car models used in the crash testing program will selected by the conducting facility from the lists of mid-size vehicle candidates in Section 9.5. Soon after CUV testing, specification of the preferred MASH intermediate passenger vehicle(s) should be completed in conjunction with the crash testing program or ISPE review. Exploration of the use of multiple intermediate passenger vehicles may be desirable if it is found that worst practical impact scenarios for different hardware types are critically dependent on different intermediate vehicle body styles (sedan or CUV). Additionally, statistical evaluation of vehicle dimensional properties should be explored to determine whether certain properties are linked to worse practical crash outcomes. Some properties not currently considered in MASH vehicle documentation may warrant consideration for specification.

New full-scale crash-test impact conditions, which are being investigated as a part of NCHRP Project No. 22-42 [58], should consider updated impact conditions during the conduction of pilot testing. New impact conditions and vehicles are anticipated to result in increased barrier impact loads which may result in undesirable performance of current barrier designs. Additionally, results should be documented similar to NCHRP Project No. 17-43, to adequately investigate each impact scenario with roadside hardware, in an attempt to research vehicle-to-barrier impact performance such as [59]:

- link between occupant compartment deformation and occupant risk in ran-off road crashes
- occupant risk associated with vehicle roll greater than 75-degrees (MASH roll allowance) by vehicle class
- link between impact conditions and probability of injury for common safety features and roadside hazards, and
- impact conditions, including speed, angle, and vehicle orientation, and their relation to safety performance evaluation.

APS vehicle sales should continue to be monitored to see whether their presence in the vehicle fleet surpasses that of sedans or gas-powered vehicles, specifically for small and intermediate passenger vehicle consideration. Recent NHTSA rollover crash testing results suggested that APS vehicles with underbody battery packs may be substantially more stable, but also heavier, than comparable ICE counterparts.

Actual c.g. heights were not available in vehicle dimensional data, so c.g. heights of recommended pickup trucks and high-sales volume SUVs should be experimentally determined to ensure MASH c.g. height requirements are representative of the modern vehicle fleet. If variation from 28.0 in. is observed, modification of required large passenger vehicle c.g. height may warrant consideration. Additionally, if SUV c.g. heights are found to contribute to vehicle instability not observed in pickup truck crash behavior, large vehicle selection criteria may require additional consideration, specifically when evaluating systems with vehicle instability concerns.

Observance of detailed vehicle registration records was desired; however, state DMVs were unable to contribute registration records. In the future, it would be desirable for collaboration with state DMVs to ensure quality and detail of registration data; however, sales data remains the most effective means of identifying passenger vehicles for crash testing.

MASH recommends that passenger vehicle selection be updated periodically; however, MASH does not specify how often revision should occur. As demonstrated by crash, sales, registrations, and abrupt changes in pickup truck weight, the modern vehicle fleet can change in just a few years' time. Thus, it is recommended that vehicle sales review and weight distribution creation occur every five years to ensure passenger vehicles used in MASH are representative of what is on roadways. Vehicle selection criteria used in this study may be used to aid in future passenger vehicle selection. Replication of this study includes obtainment of vehicle model sales, model-trim curb weights, and weight distribution creation. Specific methodology was established herein, and widely available vehicle model-trims at or near the 5th and 95th percentile weights should be considered potential passenger vehicles. Intermediate vehicle selection criteria required further study and may also warrant consideration for placement in the weight distribution.

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CHAPTER 15 APPENDICES

APPENDIX A Vehicle Model Classifications

Table A-1. CUVs – Make and Model (Crash and Sales Data)

Acura MDX	Chevrolet Blazer	Honda Pilot	Kia Sportage	Mercedes-Benz R-Class	Scion XB
Acura RDX	Chevrolet Bolt	Hyundai Nexo	Land Rover Discovery Sport	Mercury Mariner	Subaru Ascent
Acura ZDX	Chevrolet Captiva Sport	Hyundai Santa Fe	Land Rover Evoque	Mini Countryman	Subaru B9 Tribeca
Alfa Romeo Stelvio	Chevrolet Equinox	Hyundai Tucson	Land Rover Freelander	Mini Paceman	Subaru Crosstrek
Audi Allroad	Chevrolet HHR	Hyundai Veracruz	Land Rover Velar	Mitsubishi Eclipse Cross	Subaru Forester
Audi Q3	Chevrolet Tracker	Infiniti FX	Land Rover Defender	Mitsubishi Endeavor	Subaru Outback
Audi Q5	Chevrolet Traverse	Infiniti JX	Lexus RX	Mitsubishi Outlander Sport	Subaru Tribeca
Audi Q7	Chevrolet Trax	Infiniti QX30	Lexus UX	Mitsubishi Outlander	Subaru XV
Audi Q8	Chrysler PT Cruiser	Infiniti QX40	Lincoln-Mercury MKC	Nissan Juke	Suzuki XL7
Audi SQ5	Dodge Journey	Infiniti QX50	Lincoln-Mercury MKT	Nissan Kicks	Tesla Model X
BMW X1	Fiat 500X	Infiniti QX60	Lincoln-Mercury MKX	Nissan Murano	Toyota C-HR
BMW X2	Ford EcoSport	Infiniti QX70	Mazda CX-3	Nissan Pathfinder	Toyota Highlander
BMW X3	Ford Edge	Jaguar E-Pace	Mazda CX-5	Nissan Rogue	Toyota RAV4
BMW X4	Ford Escape	Jaguar F-Pace	Mazda CX-7	Nissan Rogue Sport	Toyota Venza
BMW X5	Ford Flex	Jaguar I-Pace	Mazda CX-9	Pontiac Aztek	Volkswagen Atlas
BMW X6	Geo Tracker	Jeep Cherokee	Mercedes-Benz GL	Pontiac Torrent	Volkswagen Tiguan
Buick Enclave	GMC Acadia	Jeep Compass	Mercedes-Benz GLA	Porsche Cayenne	Volkswagen Touareg
Buick Encore	GMC Terrain	Jeep Patriot	Mercedes-Benz GLC	Porsche Macan	Volvo XC40
Buick Envision	Honda Crosstour	Jeep Renegade	Mercedes-Benz GLE	Saab 9-4X	Volvo XC60
Cadillac SRX	Honda CR-V	Kia Niro	Mercedes-Benz GLK	Saturn Outlook	Volvo XC70
Cadillac XT4	Honda Element	Kia Rondo	Mercedes-Benz GLS	Saturn Vue	Volvo XC90
Cadillac XT5	Honda HR-V	Kia Sorento	Mercedes-Benz M-Class		

Table A-2. Pickup Trucks – Make and Model (Crash and Sales Data)

Chevrolet Avalance	Chevrolet Silverado	Ford Ranger	Hummer Hummer H3T	Mitsubishi Fuso Light-Duty	Ram Pickup Light-Duty
Chevrolet Colorado	Chevrolet SSR	GMC Canyon	International (Navistar) LT-Duty	Mitsubishi Raider	Subaru Baja
Chevrolet C-Series	Chevrolet W4 Tiltmaster	GMC Sierra	Isuzu i-Series	Nissan Diesel Light-Duty	Suzuki Equator
Chevrolet El Camino	Daimler Freightliner Light-Duty	GMC Sonoma	Isuzu Truck Light-Duty	Nissan Frontier	Toyota Tacoma
Chevrolet LCF	Daimler Sterling Light-Duty	GMC W4 Forward	Lincoln-Mercury Mark LT	Nissan Titan	Toyota Tundra
Chevrolet S-10	Ford F-Series	Honda Ridgeline	Mazda B-Series	Ram Dakota	Volvo UD Trucks Light-Duty

Table A-3. SUVs – Make and Model (Crash and Sales Data)

Buick Rainier	Dodge Nitro	Hummer Hummer H1	Jeep CJ	Land Rover Range Rover Sport	Nissan Armada
Buick Rendezvous	Ford Bronco	Hummer Hummer H2	Jeep Commander	Lexus GX	Nissan Xterra
Cadillac Escalade	Ford Excursion	Hummer Hummer H2 SUT	Jeep Grand Cherokee	Lexus LX	Oldsmobile Bravada
Cadillac Escalade ESV	Ford Expedition	Hummer Hummer H3	Jeep Liberty	Lincoln-Mercury Aviator	Ram Magnum
Cadillac Escalade EXT	Ford Explorer	Infiniti QX56	Jeep Wrangler	Lincoln-Mercury Nau+A219:C248 tilius	Saab 9-7X
Cadillac ST5	Ford Taurus X	Infiniti QX80	Kia Borrego	Lincoln-Mercury Navigator	Suzuki Grand Vitara
Chevrolet S-Blazer	GMC Envoy	Isuzu Amigo	Land Rover Discovery	Mazda Tribute	Suzuki Vitara
Chevrolet Suburban	GMC Yukon	Isuzu Ascender	Land Rover LR2	Mercedes-Benz G-Class	Toyota 4Runner
Chevrolet Tahoe	GMC Yukon XL	Isuzu Axiom	Land Rover LR3	Mercury Mountaineer	Toyota FJ Cruiser
Chevrolet TrailBlazer	GMC Jimmy	Isuzu Rodeo	Land Rover LR4	Mitsubishi Montero Sport	Toyota Land Cruiser
Chrysler Aspen	Honda Passport	Isuzu Trooper	Land Rover Range Rover	Mitsubishi Montero	Toyota Sequoia
Dodge Durango					

Table A-4. Vans – Make and Model (Crash and Sales Data)

Buick Terraza	Chrysler Pacifica	Ford Transit Connect	Honda Odyssey	Mercedes-Benz Sprinter	Ram Promaster
Chevrolet Astro Van	Chrysler Town & Country	Ford Transit Van	Hyundai Entourage	Mercury Villager	Ram Promaster City
Chevrolet Astro Wagon	Chrysler Voyager	Ford Transit Wagon	Kia Sedona	Nissan NV	Ram Sprinter Van
Chevrolet City Express	Dodge Caravan	Ford Windstar	Lincoln-Mercury Monterey	Nissan Quest	Ram Sprinter Wagon
Chevrolet Express Cargo	Ford Club Wagon	GMC Safari Van	Mazda Mazda5	Oldsmobile Silhouette	Saturn Relay
Chevrolet Express Passenger	Ford Econoline	GMC Safari Wagon	Mazda MPV	Pontiac Montana	Toyota Sienna
Chevrolet Uplander	Ford E-Series	GMC Savana Cargo	Mercedes-Benz Metris	Ram Cargo Van	Volkswagen Routan
Chevrolet Venture	Ford Freestar	GMC Savana Passenger			

Table A-5. Large Cars – Make and Model (Crash and Sales Data)

Buick Lucerne	Chevrolet Impala	Chrysler 300 Series	Dodge Charger	Ford Crown Victoria	Kia Amanti
Chevrolet Caprice					

Table A-6. Luxury Cars – Make and Model (Crash and Sales Data)

Acura CL	BMW 3-Series	Cadillac XTS	Jaguar F-Type	Lincoln-Mercury MKS	Pontiac Solstice
Acura Legend	BMW 4-Series	Chevrolet Corvette	Jaguar S-Type	Lincoln-Mercury MKZ	Porsche 911
Acura NSX	BMW 5-Series	Chevrolet SS	Jaguar Vanden Plas	Lincoln-Mercury Town Car	Porsche Boxster
Acura RL	BMW 6-Series	Chevrolet Volt	Jaguar XE	Lincoln-Mercury Zephyr	Porsche Cayman
Acura RLX	BMW 7-Series	Chrysler Crossfire	Jaguar XF	Mazda Millenia	Porsche GT
Acura RSX	BMW 8-Series	Dodge Viper	Jaguar XJ	Mercedes-Benz B-Class	Porsche Panamera
Acura TL	BMW ActiveE	Fiat Giulia	Jaguar XJR	Mercedes-Benz C-Class	Porsche Spyder
Acura TLX	BMW i3	Ford GT	Jaguar XK	Mercedes-Benz CL	Saab 9-3
Alfa Romeo 4C	BMW i8	Ford Thunderbird	Jaguar X-Type	Mercedes-Benz CLA	Saab 9-5
Audi A4 Cabrio	BMW M3	Honda Clarity	Kia Cadenza	Mercedes-Benz CLK	Saturn Sky
Audi A4	BMW Z4	Honda S2000	Kia K900	Mercedes-Benz CLS	Tesla Model 3
Audi A5	BMW Z8	Hyundai Azera	Kia Stinger	Mercedes-Benz E-Class	Tesla Model S
Audi A6	Buick Cascada	Hyundai Equus	Lexus CT	Mercedes-Benz GT	Tesla Roadster
Audi A7	Buick LaCrosse	Hyundai Genesis	Lexus ES	Mercedes-Benz S-Class	Toyota Avalon
Audi A8	Buick Park Ave.	Hyundai Tiburon	Lexus GS	Mercedes-Benz SL	Toyota Mirai
Audi R8	Buick Riviera	Hyundai XG350	Lexus HS	Mercedes-Benz SLC	Toyota MR2 Spyder
Audi S3	Cadillac ATS	Infiniti G20	Lexus IS	Mercedes-Benz SLK	Volkswagen CC
Audi S4	Cadillac CT6	Infiniti G35/37	Lexus LC	Mercedes-Benz SLS	Volkswagen Eos
Audi S5	Cadillac CTS	Infiniti I35	Lexus LFA	Mitsubishi Diamante	Volkswagen Phaeton
Audi S6	Cadillac Deville	Infiniti M35/45	Lexus LS	Nissan 350Z	Volvo 50-Series
Audi S7	Cadillac DTS	Infiniti Q40	Lexus RC	Nissan GT-R	Volvo 60-Series
Audi S8	Cadillac ELR	Infiniti Q45	Lexus SC	Nissan Maxima	Volvo 70-Series
Audi TT	Cadillac Seville	Infiniti Q50	Lincoln-Mercury Continental	Oldsmobile Aurora	Volvo 80-Series
BMW 1-Series	Cadillac STS	Infiniti Q60	Lincoln-Mercury LS	Pontiac GTO	Volvo 90-Series
BMW 2-Series	Cadillac XLR	Infiniti Q70			

Table A-7. Mid-Size Cars – Make and Model (Crash and Sales Data)

Acura ILX	Chrysler 200 Series	Ford Freestyle	Mazda Mazda6	Oldsmobile Achieva	Saab 9-2X
Acura TSX	Chrysler Cirrus	Ford Fusion	Mazda RX-8	Oldsmobile Alero	Saturn Aura
Audi A3	Chrysler Concorde	Ford Mustang	Mercury Grande Marquis	Oldsmobile Cutlass	Saturn Saturn L
Buick Century	Chrysler Sebring	Ford Probe	Mercury Milan	Oldsmobile Intrigue	Subaru Legacy
Buick LeSabre	Dodge Avenger	Ford Taurus	Mercury Montego	Plymouth Acclaim	Subaru WRX
Buick Regal	Dodge Caliber	Honda Accord	Mercury Sable	Plymouth Breeze	Suzuki Kizashi
Buick Skylark	Dodge Challenger	Honda FCX Clarity	Mitsubishi Eclipse	Pontiac Bonneville	Suzuki Verona
Buick Verano	Dodge Dynasty	Honda FCX	Mitsubishi Galant	Pontiac Firebird	Toyota Camry
Chevrolet Camaro	Dodge Intrepid	Honda Insight	Nissan 370Z	Pontiac G6	Toyota Prius
Chevrolet Chevelle	Dodge Magnum	Honda Prelude	Nissan Altima	Pontiac G8	Volkswagen Passat
Chevrolet Lumina	Ford C-Max	Hyundai Sonata	Nissan Leaf	Pontiac Grand Am	Volvo 30-Series
Chevrolet Malibu	Ford Contour	Kia Optima	Oldsmobile 88 Royale	Pontiac Grand Prix	Volvo 40-Series
Chevrolet Monte Carlo	Ford Five Hundred	Mazda Maxda 626			

Table A-8. Small Cars – Make and Model

Acura Integra	Fiat 124 Spider	Hyundai Veloster	Mitsubishi Mirage	Subaru Impreza	Toyota Scion tC
BMW Mini Cooper	Fiat 500e	Kia Forte	Nissan Cube	Suzuki Aerio	Toyota Scion xA
Chevrolet Aveo	Fiat 500L	Kia Rio	Nissan Sentra	Suzuki Forenza/Reno	Toyota Scion xB
Chevrolet Cavalier	Fiat 500	Kia Sephia	Nissan Versa	Suzuki SX4	Toyota Scion xD
Chevrolet Cobalt	Ford Fiesta	Kia Soul	Plymouth Neon	Toyota Celica	Toyota 86
Chevrolet Corsica	Ford Focus	Kia Spectra	Pontiac G3	Toyota Corolla	Toyota Yaris
Chevrolet Cruze	Geo Metro	Mazda Mazda2	Pontiac G5	Toyota Corolla iM	Toyota Yaris iA
Chevrolet Sonic	Geo Prizm	Mazda Mazda3	Pontiac Sunfire	Toyota Echo	Volkswagen Beetle
Chevrolet Spark	Honda Civic	Mazda MX-5 Miata	Pontiac Vibe	Toyota Matrix	Volkswagen Beetle Cabrio
Chrysler Cruiser Convertible	Honda CR-Z	Mercury Cougar	Saturn Astra	Toyota Prius C	Volkswagen Golf
Dodge Dart	Honda Fit	Mercury Topaz	Saturn Ion	Toyota Scion FR-S	Volkswagen GTI
Dodge Neon	Hyundai Accent	Mercury Tracer	Scion TC	Toyota Scion iA	Volkswagen Jetta
Dodge Stratus Coupe	Hyundai Elantra	Mitsubishi I	Smart Fortwo	Toyota Scion iM	Volkswagen R32
Dodge Stratus Sedan	Hyundai Ioniq	Mitsubishi Lancer	Subaru BRZ	Toyota Scion iQ	Volkswagen Rabbit

APPENDIX B Vehicle Sales

Table B-1. Passenger Car and Light Truck New Vehicle Sales: 1980-2018

Year	Car Sales	Car % of Sales	Light Truck Sales	Light Truck % of Sales	Total Sales
2018	5,303,580	30.8%	11,909,966	69.2%	17,213,546
2017	6,080,229	35.5%	11,055,250	64.5%	17,135,479
2016	6,872,729	39.4%	10,592,048	60.6%	17,464,777
2015	7,516,826	43.2%	9,879,465	56.8%	17,396,291
2014	7,708,000	46.9%	8,744,190	53.1%	16,452,190
2013	7,586,334	48.8%	7,943,767	51.2%	15,530,101
2012	7,245,169	50.2%	7,188,034	49.8%	14,433,203
2011	6,092,861	47.8%	6,648,955	52.2%	12,741,816
2010	5,635,739	48.8%	5,919,085	51.2%	11,554,824
2009	5,401,565	51.9%	5,000,792	48.1%	10,402,357
2008	6,769,134	51.3%	6,425,634	48.7%	13,194,768
2007	7,562,334	47.0%	8,526,888	53.0%	16,089,222
2006	7,761,592	47.0%	8,742,808	53.0%	16,504,400
2005	7,659,983	45.2%	9,287,771	54.8%	16,947,754
2004	7,482,555	44.4%	9,384,365	55.6%	16,866,920
2003	7,555,551	45.4%	9,083,502	54.6%	16,639,053
2002	8,042,255	47.8%	8,774,113	52.2%	16,816,368
2001	8,352,000	48.8%	8,770,369	51.2%	17,122,369
2000	8,777,723	50.6%	8,572,032	49.4%	17,349,755
1999	8,637,708	51.1%	8,255,830	48.9%	16,893,538
1998	8,084,989	52.0%	7,458,018	48.0%	15,543,007
1997	8,217,480	54.3%	6,904,241	45.7%	15,121,721
1996	8,478,545	56.2%	6,618,638	43.8%	15,097,183
1995	8,620,159	58.5%	6,107,889	41.5%	14,728,048
1994	8,990,517	59.7%	6,068,061	40.3%	15,058,578
1993	8,517,859	61.3%	5,378,121	38.7%	13,895,980
1992	8,213,113	63.8%	4,655,100	36.2%	12,868,213
1991	8,184,979	66.4%	4,143,641	33.6%	12,328,620
1990	9,301,206	67.1%	4,568,697	32.9%	13,869,903
1989	9,775,903	67.3%	4,754,828	32.7%	14,530,731
1988	10,543,617	68.2%	4,910,304	31.8%	15,453,921
1987	10,187,456	68.4%	4,713,580	31.6%	14,901,036
1986	11,404,112	71.0%	4,653,834	29.0%	16,057,946
1985	10,979,187	71.1%	4,461,266	28.9%	15,440,453
1984	10,323,695	72.7%	3,882,524	27.3%	14,206,219
1983	9,148,038	75.5%	2,974,228	24.5%	12,122,266
1982	7,956,460	76.8%	2,398,864	23.2%	10,355,324
1981	8,488,428	80.5%	2,053,550	19.5%	10,541,978
1980	8,948,755	80.0%	2,241,625	20.0%	11,190,380

APPENDIX C Additional Crash and Registration Data

Table C-1. Annual Crash Severity Distribution by Vehicle Type

Year	Crash Severity	Automobiles	Light Trucks	Large Trucks	Motorcycles	Other/ Unknown
2017	**Fatal**	21,031	19,986	4,657	5,326	1,645
	Injury	1,956,000	1,334,000	107,000	85,000	21,000
	PDO	4,354,000	4,542,000	475,000	26,000	83,000
2016	**Fatal**	21,077	20,231	4,251	5,467	1,688
	Injury	2,187,000	1,469,000	102,000	100,000	23,000
	PDO	4,535,000	3,181,000	351,000	28,000	65,000
2015	**Fatal**	19,810	18,869	4,075	5,131	1,593
	Injury	1,785,000	1,198,000	87,000	84,000	22,000
	PDO	4,438,000	3,197,000	342,000	13,000	60,000
2014	**Fatal**	17,895	17,160	3,749	4,705	1,441
	Injury	1,685,000	1,138,000	88,000	87,000	16,000
	PDO	4,279,000	3,028,000	346,000	19,000	67,000
2013	**Fatal**	17,957	16,928	3,921	4,800	1,495
	Injury	1,662,000	1,076,000	73,000	84,000	23,000
	PDO	3,989,000	2,776,000	265,000	18,000	53,000
2012	**Fatal**	18,269	17,350	3,825	5,113	1,403
	Injury	1,683,000	1,087,000	77,000	89,000	19,000
	PDO	3,875,000	2,706,000	253,000	18,000	50,000
2011	**Fatal**	17,508	16,806	3,633	4,769	1,403
	Injury	1,571,000	1,026,000	63,000	77,000	19,000
	PDO	3,754,000	2,582,000	221,000	18,000	51,000
2010	**Fatal**	17,804	17,491	3,494	4,651	1,422
	Injury	1,579,000	1,053,000	58,000	78,000	17,000
	PDO	3,754,000	2,704,000	214,000	14,000	51,000

Table C-2. Annual Crash Severity Distribution by Vehicle Type

Year	Crash Severity	Automobiles	Light Trucks	Large Trucks	Motorcycles	Other/ Unknown
2017	Fatal	0.3%	0.3%	0.8%	4.6%	1.6%
	Injury	30.9%	22.6%	18.2%	73.1%	19.9%
	PDO	68.8%	77.0%	81.0%	22.4%	78.6%
2016	Fatal	0.3%	0.4%	0.9%	4.1%	1.9%
	Injury	32.4%	31.5%	22.3%	74.9%	25.6%
	PDO	67.3%	68.1%	76.8%	21.0%	72.5%
2015	Fatal	0.3%	0.4%	0.9%	5.0%	1.9%
	Injury	28.6%	27.1%	20.1%	82.2%	26.3%
	PDO	71.1%	72.4%	79.0%	12.7%	71.8%
2014	Fatal	0.3%	0.4%	0.9%	4.3%	1.7%
	Injury	28.2%	27.2%	20.1%	78.6%	18.9%
	PDO	71.5%	72.4%	79.0%	17.2%	79.3%
2013	Fatal	0.3%	0.4%	1.1%	4.5%	1.9%
	Injury	29.3%	27.8%	21.3%	78.7%	29.7%
	PDO	70.4%	71.8%	77.5%	16.9%	68.4%
2012	Fatal	0.3%	0.5%	1.1%	4.6%	2.0%
	Injury	30.2%	28.5%	23.1%	79.4%	27.0%
	PDO	69.5%	71.0%	75.8%	16.1%	71.0%
2011	Fatal	0.3%	0.5%	1.3%	4.8%	2.0%
	Injury	29.4%	28.3%	21.9%	77.2%	26.6%
	PDO	70.3%	71.2%	76.8%	18.0%	71.4%
2010	Fatal	0.3%	0.5%	1.3%	4.8%	2.0%
	Injury	29.5%	27.9%	21.1%	80.7%	24.5%
	PDO	70.2%	71.6%	77.7%	14.5%	73.5%

Table C-3. Annual Vehicle Type Distribution by Injury Severity Level

Year	Crash Severity	Automobiles	Light Trucks	Large Trucks	Motorcycles	Other/ Unknown
2017	**Fatal**	39.9%	38.0%	8.8%	10.1%	3.1%
	Injury	55.8%	38.1%	3.1%	2.4%	0.6%
	PDO	45.9%	47.9%	5.0%	0.3%	0.9%
2016	**Fatal**	40.0%	38.4%	8.1%	10.4%	3.2%
	Injury	56.4%	37.9%	2.6%	2.6%	0.6%
	PDO	55.6%	39.0%	4.3%	0.3%	0.8%
2015	**Fatal**	40.0%	38.1%	8.2%	10.4%	3.2%
	Injury	56.2%	37.7%	2.7%	2.6%	0.7%
	PDO	55.1%	39.7%	4.2%	0.2%	0.7%
2014	**Fatal**	39.8%	38.2%	8.3%	10.5%	3.2%
	Injury	55.9%	37.8%	2.9%	2.9%	0.5%
	PDO	55.3%	39.1%	4.5%	0.2%	0.9%
2013	**Fatal**	39.8%	37.5%	8.7%	10.6%	3.3%
	Injury	57.0%	36.9%	2.5%	2.9%	0.8%
	PDO	56.2%	39.1%	3.7%	0.3%	0.7%
2012	**Fatal**	39.7%	37.8%	8.3%	11.1%	3.1%
	Injury	57.0%	36.8%	2.6%	3.0%	0.6%
	PDO	56.1%	39.2%	3.7%	0.3%	0.7%
2011	**Fatal**	39.7%	38.1%	8.2%	10.8%	3.2%
	Injury	57.0%	37.2%	2.3%	2.8%	0.7%
	PDO	56.7%	39.0%	3.3%	0.3%	0.8%
2010	**Fatal**	39.7%	39.0%	7.8%	10.4%	3.2%
	Injury	56.7%	37.8%	2.1%	2.8%	0.6%
	PDO	55.7%	40.1%	3.2%	0.2%	0.8%

Table C-4. 2017 Vehicle Registrations by State

State	%Share Cars	%Share Light Trucks	%Other	State	%Share Cars	%Share Light Trucks	%Other	State	%Share Cars	%Share Light Trucks	%Other
AK	21.6%	66.0%	12.4%	**LA**	35.6%	55.5%	8.9%	**OH**	42.6%	48.3%	9.1%
AL	40.9%	51.9%	7.2%	**MA**	35.4%	53.2%	11.4%	**OK**	35.7%	54.2%	10.1%
AR	32.7%	57.6%	9.7%	**ME**	43.6%	49.7%	6.7%	**OR**	37.6%	53.5%	8.9%
AZ	40.1%	52.0%	7.9%	**MD**	46.1%	46.8%	7.1%	**PA**	41.8%	48.8%	9.5%
CA	48.3%	43.5%	8.2%	**MI**	38.2%	54.5%	7.3%	**RI**	48.2%	44.6%	7.2%
CO	33.9%	57.6%	8.5%	**MN**	37.8%	52.1%	10.1%	**SC**	39.2%	49.9%	10.9%
CT	46.1%	47.3%	6.7%	**MS**	40.0%	52.4%	7.6%	**SD**	27.6%	53.2%	19.2%
DE	43.2%	50.4%	6.4%	**MT**	23.7%	53.2%	23.1%	**TN**	39.2%	53.0%	7.8%
FL	45.9%	46.6%	7.5%	**MZ**	38.5%	52.9%	8.7%	**TX**	36.5%	56.0%	7.5%
GA	41.9%	50.4%	7.7%	**NC**	41.1%	50.9%	8.0%	**UT**	38.8%	52.0%	9.2%
HI	40.7%	53.1%	6.3%	**ND**	26.2%	56.4%	17.5%	**VA**	42.7%	49.9%	7.5%
IA	33.8%	53.6%	12.6%	**NE**	34.5%	51.5%	14.0%	**VT**	35.1%	53.0%	12.0%
ID	30.0%	59.8%	10.3%	**NH**	38.3%	51.1%	10.6%	**WA**	39.3%	50.9%	9.7%
IL	42.8%	48.6%	8.7%	**NJ**	46.2%	46.4%	7.5%	**WI**	36.8%	50.9%	12.3%
IN	36.7%	50.2%	13.1%	**NM**	35.0%	55.0%	10.0%	**WV**	32.5%	57.6%	9.9%
KS	36.3%	52.9%	10.8%	**NV**	42.7%	50.8%	6.6%	**WY**	23.2%	64.0%	12.8%
KY	39.4%	52.7%	7.9%	**NY**	42.0%	49.9%	8.1%				

APPENDIX D Median Weight Distribution Details

Table D-1. Median-Weight Sales Distribution Estimate

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
SMART	FORTWO	2DR COUPE	2,050	3,071	0.00% - 0.02%
MITSUBISHI	MIRAGE	5DR HATCH	2,072	11,418	0.02% - 0.09%
MITSUBISHI	MIRAGE	G4 SEDAN	2,150	11,418	0.09% - 0.15%
CHEVROLET	SPARK	4DR HATCHBACK	2,247	18,071	0.15% - 0.26%
TOYOTA	YARIS	3DR HATCHBACK	2,271	--	0.26%
MAZDA	MX-5	2DR CONVERTIBLE	2,332	5,647	0.26% - 0.30%
MAZDA	MX-5	RF 2DR COUPE	2,332	5,647	0.30% - 0.33%
FIAT	500	2DR HATCHBACK POP/SPORT/LOUNGE	2,355	6,343	0.33% - 0.37%
TOYOTA	YARIS	5DR HATCHBACK LE/SE	2,392	8,653	0.37% - 0.42%
NISSAN	VERSA	4DR SEDAN	2,402	53,386	0.42% - 0.74%
TOYOTA	YARIS	4DR SEDAN	2,414	--	0.74%
FIAT	124 SPIDER	2DR CONVERTIBLE	2,456	4,478	0.74% - 0.76%
NISSAN	VERSA	NOTE 4DR HATCHBACK	2,456	53,386	0.76% - 1.08%
ALFA ROMEO	4C	2DR COUPE	2,465	204	1.08%
HYUNDAI	ACCENT	4DR SEDAN (MANUAL)	2,480	--	1.08%
ALFA ROMEO	4C	2DR SPIDER	2,487	204	1.09%
HYUNDAI	ACCENT	4DR HATCHBACK (MANUAL)	2,489	29,478	1.09% - 1.26%
FIAT	500	2DR HATCHBACK TURBO/ABARTH	2,491	6,343	1.26% - 1.30%
HONDA	FIT	4DR HATCH FWD DX/LX	2,493	24,727	1.30% - 1.45%
TOYOTA	PRIUS C	5DR HATCHBACK	2,496	12,415	1.45% - 1.52%
MITSUBISHI	iMiEV	4DR HATCHBACK ES	2,526	6	1.52%
FORD	FIESTA	4DR HATCH S/SE/TITANIUM	2,538	--	1.52%
HYUNDAI	ACCENT	4DR SEDAN (AUTO)	2,546	29,478	1.52% - 1.70%
HYUNDAI	ACCENT	4DR HATCHBACK (AUTO)	2,555	--	1.70%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
FORD	FIESTA	4DR SEDAN S/SE/TITANIUM	2,577	46,249	1.70% - 1.97%
HONDA	FIT	4DR HATCH FWD EX/EX-L NAVI	2,579	24,727	1.97% - 2.12%
HYUNDAI	VELOSTER	TURBO 3DR HATCHBACK	2,584	6,329	2.12% - 2.16%
BMW	COOPER	3DR HATCH FWD	2,606	--	2.16%
BMW	i SERIES i3	i SERIES i3	2,635	3,138	2.16% - 2.18%
KIA	RIO	4DR SEDAN	2,650	8,380	2.18% - 2.23%
KIA	RIO	5DR HATCHBACK	2,652	8,380	2.23% - 2.28%
HONDA	CR-Z	2DR HATCHBACK	2,657	705	2.28%
KIA	SOUL	LX	2,714	56,823	2.28% - 2.62%
HYUNDAI	VELOSTER	3DR HATCHBACK	2,740	6,329	2.62% - 2.66%
FORD	FIESTA	ST 4DR HATCHBACK	2,743	--	2.66%
HONDA	CIVIC	DX/LX/EX 4DR SEDAN	2,743	--	2.66%
BMW	COOPER	5DR HATCH FWD	2,749	--	2.66%
CHEVROLET	CRUZE	4DR SEDAN	2,756	92,376	2.66% - 3.21%
TOYOTA	86	2DR COUPE	2,758	6,846	3.21% - 3.25%
BMW	COOPER	3DR S HATCH FWD	2,760	--	3.25%
SUBARU	BRZ	2DR COUPE	2,765	4,131	3.25% - 3.28%
HONDA	CIVIC	LX 2DR COUPE	2,769	--	3.28%
CHEVROLET	SONIC	5DR HATCHBACK	2,784	15,145	3.28% - 3.37%
TOYOTA	COROLLA	4DR SEDAN	2,789	308,695	3.37% - 5.21%
KIA	FORTE	LX 4DR SEDAN	2,804	--	5.21%
VOLKSWAGEN	JETTA	4DR SEDAN 2.0L	2,804	--	5.21%
HYUNDAI	ELANTRA	4DR SEDAN	2,811	99,105	5.21% - 5.80%
MAZDA	CX-3	4DR SUV FWD	2,811	8,178	5.80% - 5.85%
KIA	SOUL	EX/SX	2,837	56,823	5.85% - 6.19%
BMW	COOPER	3DR JOHN WORKS HATCH FWD	2,844	--	6.19%
CHEVROLET	SONIC	4DR SEDAN	2,848	15,145	6.19% - 6.28%
BMW	COOPER	CONVERTIBLE 2DR FWD	2,855	--	6.28%
HYUNDAI	ELANTRA	GT 5DR HATCHBACK	2,855	99,105	6.28% - 6.87%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
CHEVROLET	SPARK	EV 4DR HATCHBACK	2,866	4,518	6.87% - 6.90%
NISSAN	SENTRA	4DR SEDAN	2,866	109,226	6.90% - 7.55%
KIA	FORTE	KOUPE EX 2DR COUPE	2,870	--	7.55%
MITSUBISHI	LANCER	4DR SEDAN FWD ES/SE LTD/GTS	2,888	--	7.55%
CHEVROLET	CRUZE	5DR HATCH	2,892	92,376	7.55% - 8.10%
BMW	COOPER	5DR S HATCH FWD	2,895	32,232	8.10% - 8.29%
HONDA	CIVIC	EX-T/TOURING 2DR COUPE	2,895	377,286	8.29% - 10.55%
BMW	i SERIES i3	RANGE EXTENDER	2,899	3,138	10.55% - 10.56%
KIA	FORTE	4DR SEDAN	2,906	58,798	10.56% - 10.92%
VOLKSWAGEN	GOLF	2DR HATCH 1.8 TSI	2,906	--	10.92%
VOLKSWAGEN	GOLF	4DR HATCH 1.8 TSI	2,906	--	10.92%
HONDA	HR-V	4DR CUV FWD	2,910	47,017	10.92% - 11.20%
KIA	FORTE	LX/ES 5DR HATCHBACK	2,912	58,798	11.20% - 11.55%
HONDA	CIVIC	5DR HATCH	2,917	--	11.55%
HONDA	CIVIC	EX-T/TOURING 4DR SEDAN	2,919	--	11.55%
FORD	FOCUS	4DR HATCHBACK SE/TITANIUM	2,926	--	11.55%
MAZDA	MAZDA3	GX/GS 4DR SEDAN	2,926	--	11.55%
MAZDA	MAZDA3	GX/GS 4DR HATCHBACK	2,932	37,509	11.55% - 11.77%
PORSCHE	718 BOXSTER	BASE/S 2DR CONVERTIBLE	2,943	2,287	11.77% - 11.78%
PORSCHE	718 CAYMAN	BASE/S 2DR COUPE RWD	2,943	2,800	11.78% - 11.80%
TOYOTA	COROLLA iM	5DR HATCHBACK	2,943	20,501	11.80% - 11.92%
VOLKSWAGEN	BEETLE	2DR COUPE 1.8 TSI	2,948	4,314	11.92% - 11.95%
MAZDA	CX-3	4DR SUV AWD	2,952	8,178	11.95% - 12.00%
FORD	FOCUS	4DR SEDAN S/SE/TITANIUM	2,954	156,568	12.00% - 12.93%
FIAT	500X	4DR SUV FWD MANUAL	2,967	--	12.93%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
KIA	FORTE	KOUPE SX/SXLUXURY 2DR COUPE	2,983	--	12.93%
BMW	COOPER	CONVERTIBLE S/JOHN COOPER WORKS 2DR FWD	2,985	--	12.93%
MITSUBISHI	LANCER	LANCER	2,987	12,725	12.93% - 13.01%
NISSAN	JUKE	4DR SUV SV FWD	2,998	--	13.01%
VOLKSWAGEN	JETTA	4DR SEDAN 1.8L TSI	3,007	115,737	13.01% - 13.70%
MINI	PACEMAN COOPER	PACEMAN S ALL4 2DR COUPE	3,009	9	13.70%
HYUNDAI	IONIQ	4DR HATCH	3,014	11,197	13.70% - 13.77%
NISSAN	SENTRA	TURBO 4DR SEDAN	3,020	109,226	13.77% - 14.42%
JEEP	RENEGADE	SPORT/LATITUDE/LIMITED FWD	3,025	--	14.42%
KIA	FORTE	SX/SX LUXURY 5DR HATCHBACK	3,025	--	14.42%
SUBARU	IMPREZA	4DR SEDAN	3,034	43,022	14.42% - 14.68%
VOLKSWAGEN	GOLF	2DR GTI HATCH	3,038	46,492	14.68% - 14.95%
VOLKSWAGEN	GOLF	4DR GTI/R HATCH	3,038	--	14.95%
SUBARU	IMPREZA	5DR HATCH	3,047	43,022	14.95% - 15.21%
MAZDA	MAZDA3	GT 4DR SEDAN	3,049	37,509	15.21% - 15.43%
MAZDA	MAZDA3	SPORT GT 4DR HATCHBACK	3,051	--	15.43%
FORD	GT	2DR COUPE	3,053	3	15.43%
HONDA	HR-V	4DR CUV AWD	3,062	47,017	15.43% - 15.71%
TOYOTA	PRIUS	5DR LIFTBACK	3,064	96,247	15.71% - 16.29%
CHEVROLET	MALIBU	L/LS/LT 4DR SEDAN	3,086	181,405	16.29% - 17.37%
FIAT	500X	4DR SUV FWD AUTOMATIC	3,095	7,665	17.37% - 17.42%
JEEP	COMPASS	4DR SUV FWD	3,097	41,627	17.42% - 17.67%
BMW	COOPER	CLUBMAN	3,104	--	17.67%
ACURA	ILX	4DR SEDAN	3,120	11,757	17.67% - 17.74%
VOLKSWAGEN	JETTA	GLI 4DR SEDAN 2.0L	3,124	--	17.74%
JEEP	PATRIOT	4DR SUV FWD	3,137	20,368	17.74% - 17.86%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
MITSUBISHI	LANCER	4DR SEDAN AWD ES/SE LTD/GTS AWC	3,142	--	17.86%
PORSCHE	911	CARRERA GTS 2DR COUPE RWD	3,142	--	17.86%
ALFA ROMEO	GUILIA	BASE/Ti RWD 4DR SEDAN	3,150	--	17.86%
PORSCHE	911	CARRERA BASE/S 2DR COUPE RWD	3,153	--	17.86%
PORSCHE	911	GT3 2DR COUPE RWD	3,153	--	17.86%
AUDI	TT	2DR COUPE	3,164	--	17.86%
KIA	NIRO	NIRO	3,166	27,237	17.86% - 18.02%
DODGE	DART	4DR SEDAN	3,172	10,082	18.02% - 18.08%
VOLKSWAGEN	PASSAT	1.8L TSI 4DR SEDAN	3,172	30,361	18.08% - 18.26%
NISSAN	JUKE	4DR SUV SV/SL AWD	3,181	10,157	18.26% - 18.32%
VOLKSWAGEN	GOLF	4DR ALLTRACK	3,186	--	18.32%
VOLKSWAGEN	GOLF	4DR SPORTWAGON	3,186	--	18.32%
JEEP	RENEGADE	SPORT/LATITUDE/LIMITED 4X4	3,190	103,434	18.32% - 18.94%
NISSAN	ALTIMA	2.5 4DR SEDAN	3,203	127,498	18.94% - 19.70%
SUBARU	XV CROSSTREK	TOURING/SPORT/LIMITED	3,208	110,093	19.70% - 20.36%
BMW	2 SERIES	228i 2DR COUPE RWD	3,219	--	20.36%
LEXUS	CT200h	4DR HATCHBACK/F-SPORT	3,219	4,690	20.36% - 20.39%
NISSAN	JUKE	4DR SUV NISMO AWD	3,219	--	20.39%
KIA	OPTIMA	LX/LX+/EX/LX ECO TURBO 4DR SEDAN	3,225	50,669	20.39% - 20.69%
VOLKSWAGEN	BEETLE	2DR CONVERTIBLE	3,225	4,314	20.69% - 20.71%
MERCEDES	B CLASS	B 250 4DR HATCHBACK FWD	3,230	372	20.72%
BMW	COOPER	CLUBMAN S	3,234	--	20.72%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
TOYOTA	CAMRY	4DR SEDAN	3,234	183,048	20.72% - 21.81%
BUICK	ENCORE	4DR SUV FWD	3,236	44,018	21.81% - 22.07%
MAZDA	MAZDA6	4DR SEDAN	3,250	33,402	22.07% - 22.27%
CHEVROLET	CITY EXPRESS VAN	CITY EXPRESS VAN	3,252	5,712	22.27% - 22.31%
FORD	FOCUS	ST/RS 4DR HATCHBACK	3,252	--	22.31%
HYUNDAI	SONATA	4DR SEDAN 2.4	3,252	60,461	22.31% - 22.67%
MITSUBISHI	OUTLANDER	4DR SUV ES FWD	3,252	17,655	22.67% - 22.77%
FIAT	500L	4DR HATCHBACK	3,254	1,664	22.78%
JEEP	COMPASS	4DR SUV AWD	3,261	41,627	22.78% - 23.03%
NISSAN	NV200	S/SV VAN	3,261	18,602	23.03% - 23.14%
BMW	Z4	sDRIVE28i 2DR CONV RWD	3,263	251	23.14%
HONDA	ACCORD	2DR COUPE EX/EX-L NAVI	3,263	--	23.14%
JEEP	PATRIOT	4DR SUV AWD	3,263	20,368	23.14% - 23.26%
MERCEDES	CLA CLASS	CLA250 4DR COUPE FWD	3,263	--	23.26%
PORSCHE	911	CARRERA 4/4S/4GTS 2DR COUPE AWD	3,263	--	23.26%
NISSAN	LEAF	4DR HATCHBACK S/SV	3,265	5,615	23.26% - 23.30%
AUDI	TT	2DR COUPE	3,274	2,294	23.30% - 23.31%
FIAT	500X	4DR SUV AWD	3,278	--	23.31%
MAZDA	CX-5	2.5L FWD 4DR SUV (2017)	3,283	--	23.31%
INFINITI	QX30	FWD 4DR SUV	3,287	7,047	23.31% - 23.35%
KIA	SOUL	EV	3,289	2,067	23.35% - 23.37%
BMW	2 SERIES	228i xDRIVE 2DR COUPE	3,296	--	23.37%
PORSCHE	911	CARRERA GTS CABRIOLET 2DR CONVERTIBLE	3,296	4,485	23.37% - 23.39%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
HONDA	ACCORD	4DR SEDAN LX/SPORT/EX-L/TOURING	3,298	150,324	23.39% - 24.29%
BUICK	VERANO	4DR SEDAN BASE/TURBO	3,300	4,277	24.29% - 24.32%
CHEVROLET	CORVETTE	COUPE STINGRAY/Z51	3,300	--	24.32%
DODGE	VIPER	2DR COUPE	3,300	585	24.32%
MINI	COOPER	COUNTRYMAN	3,300	--	24.32%
SUBARU	FORESTER	4DR SUV 2.5i	3,303	88,782	24.32% - 24.85%
PORSCHE	911	CARRERA BASE/S CABRIOLET 2DR CONVERTIBLE	3,307	4,485	24.85% - 24.88%
HONDA	CR-V	4DR SUV FWD	3,311	188,948	24.88% - 26.00%
VOLKSWAGEN	JETTA	4DR SEDAN TURBO HYBRID	3,311	70	26.00%
MAZDA	CX-5	GS 4DR SUV FWD (2016.5)	3,318	--	26.00%
MERCEDES	B CLASS	B 250 4MATIC 4DR HATCHBACK AWD	3,318	372	26.01%
MERCEDES	GLA CLASS	GLA 250 4MATIC 4DR SUV AWD	3,318	12,052	26.01% - 26.08%
MERCEDES	SLC CLASS	SLC 300 2DR CONVERTIBLE	3,318	1,400	26.09%
NISSAN	370Z	TOURING COUPE 2DR RWD	3,342	--	26.09%
BUICK	ENCORE	4DR SUV AWD	3,358	44,018	26.09% - 26.35%
AUDI	A3	SEDAN 2.0 TFSI	3,362	8,725	26.35% - 26.40%
CHEVROLET	CORVETTE	CONVERTIBLE STINGRAY/Z51	3,362	12,540	26.40% - 26.48%
VOLKSWAGEN	CC	4DR COUPE SPORTLINE/HIGHLINE 2.0 TSI	3,366	1,355	26.48%
SUBARU	WRX	STI 4DR SEDAN	3,369	15,679	26.48% - 26.58%
BMW	COOPER	CLUBMAN ALL4	3,371	--	26.58%
ALFA ROMEO	GUILIA	Ti AWD 4DR SEDAN	3,373	8,903	26.58% - 26.63%

Make	**Model**	**Trim**	**Curb Weight, lb**	**Median-Weight Sales Estimate, No. of Units**	**Percentile Weight Range**
AUDI	TT	ROADSTER 2DR CONVERTIBLE	3,373	--	26.63%
BMW	2 SERIES	M235i 2DR COUPE RWD	3,373	--	26.63%
CADILLAC	ATS	4DR SEDAN TURBO/3.6L V6 RWD	3,373	--	26.63%
CHEVROLET	CAMARO	2.0L 2DR COUPE	3,373	--	26.63%
MITSUBISHI	OUTLANDER	4DR SUV ES AWC	3,384	17,655	26.63% - 26.74%
CHEVROLET	MALIBU	PREMIER/HYBRID 4DR SEDAN	3,386	4,452	26.74% - 26.76%
VOLKSWAGEN	TIGUAN	2.0 FWD 4DR SUV	3,393	23,492	26.76% - 26.90%
MERCEDES	CLA CLASS	CLA250 4MATIC 4DR COUPE AWD	3,395	20,669	26.90% - 27.03%
NISSAN	LEAF	4DR HATCHBACK SL	3,397	5,615	27.03% - 27.06%
SUBARU	LEGACY	4DR SEDAN 2.5i AWD	3,402	24,919	27.06% - 27.21%
SUBARU	WRX	4DR SEDAN	3,402	15,679	27.21% - 27.30%
NISSAN	370Z	NISMO 2DR COUPE	3,411	4,614	27.30% - 27.33%
CADILLAC	ATS	2DR COUPE 2.0L RWD	3,417	--	27.33%
INFINITI	QX30	AWD 4DR SUV	3,417	7,047	27.33% - 27.37%
NISSAN	ROGUE	4DR SUV FWD	3,417	182,986	27.37% - 28.46%
PORSCHE	911	CARRERA 4/4S/4GTS CABRIOLET AWD	3,417	--	28.46%
TOYOTA	CAMRY	HYBRID 4DR SEDAN	3,417	20,985	28.46% - 28.59%
TOYOTA	CAMRY	V6 4DR SEDAN	3,422	183,048	28.59% - 29.68%
TOYOTA	RAV4	FWD 4DR SUV	3,428	178,518	29.68% - 30.75%
MAZDA	CX-5	2.5L AWD 4DR SUV (2017)	3,430	--	30.75%
FORD	FUSION	4DR SEDAN	3,435	142,517	30.75% - 31.60%
MAZDA	CX-5	GX 4DR SUV FWD (2016.5)	3,437	127,563	31.60% - 32.36%
HYUNDAI	TUCSON	4DR SUV FWD	3,439	57,368	32.36% - 32.70%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
BMW	COOPER	CLUBMAN S ALL4/JOHN COOPER WORKS ALL4	3,446	--	32.70%
VOLKSWAGEN	PASSAT	VR6 4DR SEDAN	3,446	30,361	32.70% - 32.88%
CHEVROLET	CAMARO	3.6L 2DR COUPE	3,448	--	32.88%
AUDI	S3	SEDAN TFSI QUATTRO	3,450	3,283	32.88% - 32.90%
BMW	3 SERIES	320i xDRIVE 4DR SEDAN AWD	3,450	--	32.90%
HYUNDAI	SANTA FE	SPORT FWD 4DR SUV	3,459	--	32.90%
PORSCHE	911	TARGA 4/4S/4GTS 2DR COUPE AWD	3,461	--	32.90%
NISSAN	ALTIMA	3.5 4DR SEDAN	3,470	127,498	32.90% - 33.66%
BMW	i SERIES i8	i8	3,472	488	33.67%
CHRYSLER	200 SERIES	4DR SEDAN I-4 FWD	3,472	--	33.67%
MAZDA	MAZDA5	4DR MINIVAN	3,479	10	33.67%
ACURA	TLX	4DR SEDAN FWD	3,481	17,423	33.67% - 33.77%
HONDA	CR-V	4DR SUV AWD	3,483	188,948	33.77% - 34.90%
JEEP	RENEGADE	TRAILHAWK 4X4	3,490	--	34.90%
KIA	OPTIMA	HYBRID 4DR SEDAN	3,490	4,778	34.90% - 34.93%
NISSAN	370Z	ROADSTER 2DR RWD	3,492	--	34.93%
AUDI	Q3	5DR SUV 2.0 TFSI FWD	3,494	10,317	34.93% - 34.99%
BMW	Z4	sDRIVE35i/35is 2DR CONV RWD	3,494	251	34.99%
MERCEDES	CLA CLASS	CLA45 AMG	3,494	--	34.99%
MERCEDES	GLA CLASS	GLA 45 AMG 4MATIC 4DR SUV AWD	3,494	12,052	34.99% - 35.06%
HYUNDAI	SONATA	4DR SEDAN HYBRID	3,497	9,815	35.06% - 35.12%
HYUNDAI	SONATA	4DR SEDAN SPORT 2.0T	3,505	60,461	35.12% - 35.48%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
MINI	COOPER	COUNTRYMAN ALL4 4DR SUV	3,510	14,864	35.48% - 35.57%
HONDA	ACCORD	HYBRID 4DR SEDAN	3,514	22,008	35.57% - 35.70%
JAGUAR	F-TYPE	V6 RWD 2DR COUPE/CONVERTIBLE	3,514	--	35.70%
MERCEDES	SLC CLASS	SLC 43 AMG 2DR CONVERTIBLE	3,516	1,400	35.71%
MITSUBISHI	OUTLANDER	4DR SUV SE/GT S AWC	3,516	99	35.71%
PORSCHE	911	TURBO/TURBO S COUPE 2DR AWD	3,516	--	35.71%
SUBARU	XV CROSSTREK	HYBRID	3,516	45	35.71%
CHEVROLET	CORVETTE	COUPE Z06	3,525	12,540	35.71% - 35.79%
BMW	2 SERIES	M235i xDRIVE 2DR COUPE AWD	3,527	11,737	35.79% - 35.86%
CADILLAC	ATS	2DR COUPE 3.6L RWD	3,530	--	35.86%
MAZDA	CX-5	GX 4DR SUV AWD (2016.5)	3,532	--	35.86%
ALFA ROMEO	GUILIA	QUADRIFOGLIO 4DR SEDAN	3,534	--	35.86%
HONDA	ACCORD	2DR COUPE EX-L V6	3,534	150,324	35.86% - 36.75%
CADILLAC	ATS	4DR SEDAN TURBO/3.6L V6 AWD	3,543	6,550	36.75% - 36.79%
CHEVROLET	VOLT	4DR HATCHBACK	3,543	20,349	36.79% - 36.91%
BMW	3 SERIES	340i 4DR SEDAN RWD	3,545	--	36.91%
LEXUS	ES350	4DR SEDAN	3,549	46,004	36.91% - 37.19%
NISSAN	ROGUE	4DR SUV AWD	3,549	182,986	37.19% - 38.28%
RAM	PROMASTER CITY	VAN	3,549	7,792	38.28% - 38.33%
TOYOTA	AVALON	4DR SEDAN	3,549	35,583	38.33% - 38.54%
TOYOTA	RAV4	AWD 4DR SUV	3,549	178,518	38.54% - 39.61%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
FORD	ESCAPE	4DR SUV FWD	3,552	154,148	39.61% - 40.53%
SUBARU	OUTBACK	4DR WAGON AWD 2.5i	3,558	94,443	40.53% - 41.09%
BMW	5 SERIES	520d 4DR SEDAN	3,560	--	41.09%
BMW	5 SERIES	530i 4DR SEDAN	3,560	--	41.09%
HONDA	ACCORD	4DR SEDAN EX-L V6/TOURING V6	3,560	--	41.09%
JAGUAR	XE	2.0L DIESEL 4DR SEDAN	3,560	4,639	41.09% - 41.12%
CADILLAC	ATS	2DR COUPE 2.0L AWD	3,571	6,550	41.12% - 41.16%
BMW	4 SERIES	435i 2DR COUPE RWD	3,580	--	41.16%
CHEVROLET	CORVETTE	CONVERTIBLE Z06	3,580	--	41.16%
FORD	TRANSIT CONNECT	VAN XL/XLT	3,580	17,237	41.16% - 41.26%
AUDI	A3	CABRIOLET	3,583	8,725	41.26% - 41.31%
AUDI	A5	2DR COUPE 2.0 TFSI QUATTRO	3,583	14,689	41.31% - 41.40%
CHEVROLET	BOLT	4DR HATCHBACK	3,583	23,297	41.40% - 41.54%
LEXUS	IS	200t RWD SEDAN	3,583	13,241	41.54% - 41.62%
MERCEDES	C CLASS	C 300 4MATIC 4DR SEDAN	3,583	--	41.62%
NISSAN	MAXIMA	4DR SEDAN	3,587	67,627	41.62% - 42.02%
MAZDA	CX-5	2.0L FWD 4DR SUV (2017)	3,591	--	42.02%
VOLKSWAGEN	TIGUAN	2.0 4MOTION 4DR SUV	3,591	23,492	42.02% - 42.16%
BMW	3 SERIES	328i xDRIVE 4DR SEDAN AWD	3,594	--	42.16%
KIA	OPTIMA	SX/SXL 4DR SEDAN	3,594	50,669	42.16% - 42.46%
KIA	SPORTAGE	FWD 4DR SUV	3,596	--	42.46%
BUICK	LACROSSE	4DR SEDAN FWD	3,598	10,081	42.46% - 42.52%
HYUNDAI	TUCSON	4DR SUV AWD	3,602	57,368	42.52% - 42.87%
VOLVO	V60	4DR WAGON T5 AWD	3,602	--	42.87%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
VOLVO	V60	CROSS COUNTRY 4DR WAGON T5 AWD	3,602	--	42.87%
FORD	C-MAX	HYBRID 4DR HATCHBACK	3,607	10,221	42.87% - 42.93%
BUICK	REGAL	4DR SEDAN FWD	3,611	5,780	42.93% - 42.96%
INFINITI	Q50	4DR SEDAN RWD	3,611	20,166	42.96% - 43.08%
AUDI	A3	SPORTBACK e-tron	3,616	2,877	43.08% - 43.10%
HYUNDAI	SANTA FE SPORT	AWD 4DR SUV	3,616	66,586	43.10% - 43.50%
LAND ROVER	RANGE ROVER EVOQUE	CONVERTIBLE	3,616	5,990	43.50% - 43.53%
BMW	3 SERIES	328d xDRIVE 4DR SEDAN AWD	3,620	--	43.53%
CADILLAC	CTS	4DR SEDAN 2.0L RWD	3,620	--	43.53%
CHRYSLER	200	4DR SEDAN V6 FWD	3,622	18,457	43.53% - 43.64%
AUDI	A4	4DR SEDAN	3,627	31,453	43.64% - 43.83%
CHEVROLET	CAMARO	2.0L 2DR CONVERTIBLE	3,627	33,970	43.83% - 44.03%
MERCEDES	GT S	2DR COUPE	3,627	1,608	44.04%
MINI	COOPER	COUNTRYMAN S / JOHN COOPER WORKS ALL4 4DR SUV	3,629	--	44.04%
KIA	CADENZA	4DR SEDAN BASE/PREMIUM	3,633	3,625	44.04% - 44.06%
BMW	4 SERIES	428i xDRIVE 2DR COUPE AWD	3,635	--	44.06%
SUBARU	FORESTER	4DR SUV 2.0XT	3,635	88,782	44.06% - 44.59%
CADILLAC	CT6	2.0L 4DR SEDAN	3,646	--	44.59%
CHEVROLET	CAMARO	3.6L 2DR CONVERTIBLE	3,646	33,970	44.59% - 44.80%
AUDI	R8	2DR COUPE	3,649	386	44.80%
HYUNDAI	SONATA	4DR SEDAN PHEV	3,649	1,066	44.81%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
VOLVO	S60	4DR SEDAN T5/T6 FWD	3,655	--	44.81%
MAZDA	CX-5	GS/GT 4DR SUV AWD (2016.5)	3,657	--	44.81%
BMW	X1	xDRIVE28i 4DR SUV	3,660	30,826	44.81% - 44.99%
FORD	FUSION	4DR SEDAN HYBRID	3,660	57,474	44.99% - 45.33%
LEXUS	ES	300h HYBRID 4DR SEDAN	3,660	5,394	45.33% - 45.37%
CHEVROLET	IMPALA	4DR SEDAN 2.5L LS/LT/LTZ/2.4ECO	3,662	37,939	45.37% - 45.59%
PORSCHE	911	TURBO CABRIOLET /TURBO S CABRIOLET	3,671	--	45.59%
FORD	FOCUS	ELECTRIC 4D HATCHBACK	3,673	1,817	45.59% - 45.60%
FORD	ESCAPE	4DR SUV AWD	3,677	154,148	45.60% - 46.52%
JEEP	CHEROKEE	4DR SUV FWD	3,680	84,941	46.52% - 47.03%
AUDI	Q3	5DR SUV 2.0 TFSI QUATTRO	3,682	10,317	47.03% - 47.09%
BMW	5 SERIES	530i xDRIVE 4DR SEDAN	3,682	--	47.09%
BMW	5 SERIES	540i 4DR SEDAN	3,682	--	47.09%
BMW	2 SERIES	M235i 2DR CABRIOLET RWD	3,693	--	47.09%
BUICK	REGAL	4DR SEDAN AWD	3,693	5,780	47.09% - 47.13%
CADILLAC	ATS	2DR COUPE 3.6L AWD	3,693	--	47.13%
BMW	3 SERIES	340i xDRIVE 4DR SEDAN AWD	3,695	55,477	47.13% - 47.46%
SUBARU	LEGACY	4DR SEDAN 3.6R AWD	3,697	24,919	47.46% - 47.61%
RAM	PROMASTER CITY	WAGON	3,699	7,792	47.61% - 47.65%
KIA	SORENTO	L/LX FWD	3,704	--	47.65%
JAGUAR	F-TYPE	V6 AWD 2DR COUPE/CONVERTIBLE	3,713	4,108	47.65% - 47.68%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
CHEVROLET	CAMARO	6.2L 2DR COUPE	3,715	--	47.68%
VOLVO	V60	4DR WAGON T5 DRIVE-E FWD	3,724	16,823	47.68% - 47.78%
MERCEDES	C CLASS	C 43 AMG 4MATIC 4DR SEDAN	3,726	--	47.78%
BMW	4 SERIES	435i xDRIVE 2DR COUPE AWD	3,735	--	47.78%
BMW	5 SERIES	520d xDRIVE 4DR SEDAN	3,737	37,355	47.78% - 48.00%
LEXUS	IS	300/350 AWD SEDAN	3,737	13,241	48.00% - 48.08%
BMW	4 SERIES	GRAN COUPE 428i xDRIVE 4DR SEDAN AWD	3,739	39,634	48.08% - 48.32%
KIA	SPORTAGE	AWD 4DR SUV	3,739	72,824	48.32% - 48.75%
AUDI	R8	2DR SPYDER	3,743	386	48.75%
ACURA	TLX	4 DR SEDAN SH-AWD	3,748	17,423	48.75% - 48.86%
CADILLAC	CTS	4DR SEDAN 3.6L RWD	3,754	--	48.86%
MERCEDES	C CLASS	C300 4MATIC 2DR COUPE	3,759	--	48.86%
TOYOTA	VENZA	4DR SUV FWD	3,759	--	48.86%
CHEVROLET	EQUINOX	4DR SUV 2.4L FWD LS/LT/LTZ	3,761	--	48.86%
KIA	CADENZA	4DR SEDAN LIMITED	3,770	3,625	48.86% - 48.88%
BMW	2 SERIES	228i xDRIVE 2DR CABRIOLET	3,774	--	48.88%
NISSAN	FRONTIER	KING CAB S/BOX 4X2 S	3,774	--	48.88%
CADILLAC	CTS	4DR SEDAN 2.0L AWD	3,777	5,172	48.88% - 48.91%
BMW	5 SERIES	530d 4DR SEDAN	3,781	--	48.91%
MERCEDES	C CLASS	C 63 AMG 4DR SEDAN	3,781	--	48.91%
CHEVROLET	IMPALA	4DR SEDAN 3.6L LT/LTZ	3,785	37,939	48.91% - 49.14%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
JEEP	WRANGLER	2DR SUV 4WD SPORT/WILLYS WHEELER	3,785	--	49.14%
INFINITI	Q50	4DR SEDAN AWD	3,788	20,166	49.14% - 49.26%
BMW	3 SERIES	TOURING 328d xDRIVE 4DR WAGON	3,790	--	49.26%
KIA	OPTIMA	PHEV 4DR SEDAN	3,792	1,378	49.26%
CHRYSLER	200	4DR SEDAN V6 AWD	3,794	--	49.26%
JAGUAR	XE	3.0L V6 4DR SEDAN	3,794	4,639	49.26% - 49.29%
NISSAN	MURANO	4DR SUV FWD	3,794	38,366	49.29% - 49.52%
ACURA	NSX	NSX	3,803	581	49.52%
CADILLAC	ATS-V	2DR COUPE RWD	3,803	--	49.52%
CADILLAC	ATS-V	4DR SEDAN RWD	3,812	--	49.52%
AUDI	A4	ALLROAD	3,825	3,240	49.52% - 49.54%
BMW	5 SERIES	540i xDRIVE 4DR SEDAN	3,825	--	49.54%
DODGE	JOURNEY	4DR SUV FWD I4	3,825	--	49.54%
MERCEDES	SL CLASS	SL450 2DR CONVERTIBLE	3,825	--	49.54%
JAGUAR	F-TYPE	V8 AWD 2DR COUPE/CONVERTIBLE	3,836	--	49.54%
BUICK	LACROSSE	4DR SEDAN AWD	3,838	10,081	49.54% - 49.60%
KIA	SORENTO	LX AWD	3,840	--	49.60%
LAND ROVER	DISCOVERY SPORT	DISCOVERY SPORT	3,845	14,187	49.60% - 49.69%
SUBARU	OUTBACK	4DR WAGON AWD 3.6R	3,845	94,443	49.69% - 50.25%
GMC	TERRAIN	4DR SUV FWD	3,854	42,721	50.25% - 50.51%
ACURA	RDX	4DR SUV AWD	3,856	51,295	50.51% - 50.81%
VOLVO	S60	4DR SEDAN T5/T6 AWD	3,856	--	50.81%
AUDI	S5	2DR COUPE 3.0 TFSI QUATTRO	3,858	3,306	50.81% - 50.83%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
FORD	C-MAX	ENERGI 4DR HATCHBACK	3,858	8,169	50.83% - 50.88%
INFINITI	Q60	2DR COUPE	3,858	10,751	50.88% - 50.95%
INFINITI	Q70	AWD 4DR SEDAN	3,862	--	50.95%
LEXUS	NX200t	4DR SUV AWD	3,869	29,671	50.95% - 51.12%
VOLVO	S60	CROSS COUNTRY 4DR SEDAN	3,874	--	51.12%
BMW	3 SERIES	TOURING 330i xDRIVE 4DR WAGON	3,876	--	51.12%
KIA	SORENTO	EX/LIMITED FWD	3,878	49,842	51.12% - 51.42%
LINCOLN-MERCURY	MKZ	HYBRID 4DR SEDAN	3,878	5,931	51.42% - 51.46%
VOLVO	S90	4DR SEDAN T5 FWD	3,878	--	51.46%
BMW	4 SERIES	GRAN COUPE 435i xDRIVE 4DR SEDAN AWD	3,885	--	51.46%
CADILLAC	CTS	4DR SEDAN 3.6L AWD	3,887	5,172	51.46% - 51.49%
JAGUAR	XF	4DR SEDAN	3,887	4,541	51.49% - 51.51%
LEXUS	GS 350	AWD 4DR SEDAN	3,891	7,723	51.51% - 51.56%
LEXUS	RC	300/350 AWD 2DR COUPE	3,891	3,682	51.56% - 51.58%
MERCEDES	E CLASS	E300 4MATIC 4DR SEDAN	3,891	--	51.58%
TOYOTA	RAV4	HYBRID	3,891	50,559	51.58% - 51.88%
BMW	5 SERIES	530d xDRIVE 4DR SEDAN	3,902	--	51.88%
BMW	5 SERIES	530e 4DR SEDAN	3,902	3,303	51.88% - 51.90%
LAND ROVER	RANGE ROVER	EVOQUE 4DR SUV	3,902	5,990	51.90% - 51.94%
BMW	3 SERIES	330e iPERFORMANCE SEDAN	3,909	3,972	51.94% - 51.96%
LINCOLN-MERCURY	MKZ	2.0L AWD 4DR SEDAN	3,909	10,728	51.96% - 52.03%
FORD	EDGE	4DR SUV FWD	3,911	71,302	52.03% - 52.45%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
JAGUAR	F-PACE	2.0L DIESEL 4DR SUV	3,913	9,473	52.45% - 52.51%
TOYOTA	TACOMA	ACCESS CAB L/BOX RWD	3,913	--	52.51%
CHEVROLET	EQUINOX	4DR SUV 3.6L FWD LS/LT/LTZ	3,920	145,229	52.51% - 53.38%
NISSAN	GT-R	2DR COUPE	3,922	578	53.38%
CADILLAC	CT6	3.6L AWD 4DR SEDAN	3,924	--	53.38%
CHEVROLET	EQUINOX	4DR SUV 2.4L AWD LS/LT/LTZ	3,929	145,229	53.38% - 54.25%
DODGE	CHALLENGER	2DR COUPE RWD V6	3,935	--	54.25%
DODGE	CHARGER	4DR SEDAN RWD V6	3,935	--	54.25%
NISSAN	MURANO	4DR SUV AWD	3,940	38,366	54.25% - 54.48%
JEEP	CHEROKEE	4DR SUV AWD	3,942	84,941	54.48% - 54.98%
HYUNDAI	SANTA FE	XL FWD 4DR SUV	3,946	66,586	54.98% - 55.38%
TOYOTA	VENZA	4DR SUV AWD	3,946	14	55.38%
CHEVROLET	COLORADO	EXTENDED CAB L/BOX 2WD	3,948	--	55.38%
GMC	CANYON	EXTENDED CAB L/BOX 2WD	3,948	--	55.38%
LINCOLN-MERCURY	MKC	4DR SUV AWD	3,951	27,048	55.38% - 55.54%
BMW	2 SERIES	M235i xDRIVE 2DR CABRIOLET	3,955	--	55.54%
CHEVROLET	CAMARO	6.2L 2DR CONVERTIBLE	3,955	--	55.54%
GMC	ACADIA	4DR SUV FWD	3,955	55,638	55.54% - 55.87%
MERCEDES	E CLASS	E 400 4MATIC 2DR COUPE AWD	3,955	--	55.87%
AUDI	A6	4DR SEDAN 2.0 TFSI QUATTRO	3,957	7,449	55.87% - 55.92%
LEXUS	RC	F 2DR COUPE RWD	3,957	3,682	55.92% - 55.94%
MERCEDES	SL CLASS	SL550 2DR CONVERTIBLE	3,957	1,470	55.95%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
CHRYSLER	300	4DR SEDAN V6 RWD	3,962	--	55.95%
FORD	FUSION	4DR SEDAN ENERGI PHEV	3,962	9,632	55.95% - 56.01%
KIA	SORENTO	V6 FWD	3,968	49,842	56.01% - 56.30%
MERCEDES	C CLASS	C43 4MATIC 2DR COUPE	3,968	77,447	56.30% - 56.77%
JEEP	WRANGLER	2DR SUV 4WD SAHARA	3,975	--	56.77%
FORD	TRANSIT CONNECT	WAGON XL/XLT/TITANIUM	3,977	17,237	56.77% - 56.87%
BUICK	CASCADA	CASCADA	3,979	5,595	56.87% - 56.90%
MERCEDES	C CLASS	C300 4MATIC 2DR CONVERTIBLE	3,979	--	56.90%
CADILLAC	CTS	VSPORT 4DR SEDAN RWD	3,984	--	56.90%
KIA	SPORTAGE	AWD TURBO 4DR SUV	3,997	--	56.90%
CADILLAC	XT5	4DR SUV FWD	3,999	34,156	56.90% - 57.11%
MERCEDES	GLC CLASS	300 4MATIC 4DR SUV	4,001	--	57.11%
MERCEDES	GLC CLASS	300 4MATIC COUPE	4,001	48,632	57.11% - 57.40%
PORSCHE	PANAMERA	PANAMERA	4,001	--	57.40%
KIA	SORENTO	EX/LIMITED AWD	4,004	--	57.40%
CADILLAC	XTS	4DR SEDAN FWD	4,006	8,138	57.40% - 57.45%
MERCEDES	E CLASS	E400 4MATIC 4DR SEDAN	4,012	--	57.45%
VOLVO	XC60	4DR SUV T5 DRIVE-E/T6 DRIVE-E FWD	4,012	531	57.45%
JAGUAR	F-PACE	3.0L V6 4DR SUV	4,015	9,473	57.45% - 57.51%
FORD	TAURUS	4DR SEDAN FWD	4,017	20,618	57.51% - 57.63%
VOLVO	V60	4DR WAGON T6 AWD	4,017	--	57.63%
GMC	TERRAIN	4DR SUV AWD	4,019	42,721	57.63% - 57.88%
BMW	3 SERIES	330i xDRIVE Gran Turismo	4,023	--	57.88%
INFINITI	QX50	AWD 4DR SUV	4,028	16,857	57.88% - 57.98%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
MERCEDES	E CLASS	E 550 2DR COUPE	4,032	24,737	57.98% - 58.13%
CHEVROLET	COLORADO	CREW CAB S/BOX 2WD	4,041	--	58.13%
GMC	CANYON	CREW CAB S/BOX 2WD	4,041	--	58.13%
DODGE	JOURNEY	4DR SUV FWD V6	4,043	89,470	58.13% - 58.67%
MERCEDES	E CLASS	E 400 CABRIOLET 2DR CONV	4,043	24,737	58.67% - 58.81%
LEXUS	NX	300h 4DR SUV AWD	4,045	29,671	58.81% - 58.99%
TOYOTA	VENZA	4DR SUV AWD V6	4,045	--	58.99%
FORD	F-150	P/U REG CAB 6.5-FT BOX 2WD	4,050	--	58.99%
MAZDA	CX-9	4DR SUV FWD	4,050	12,914	58.99% - 59.07%
BUICK	ENVISION	4DR SUV AWD	4,054	41,040	59.07% - 59.31%
VOLVO	S90	4DR SEDAN T5 AWD	4,057	10,972	59.31% - 59.38%
FORD	EDGE	4DR SUV AWD	4,059	71,302	59.38% - 59.80%
INFINITI	Q70	AWD SPORT 4DR SEDAN	4,059	5,772	59.80% - 59.84%
MERCEDES	SL CLASS	SL63 AMG 2DR CONVERTIBLE	4,068	1,470	59.85%
MERCEDES	C CLASS	AMG C63/C63S 2DR COUPE	4,074	--	59.85%
AUDI	Q5	5DR SUV 2.0 TFSI QUATTRO	4,079	26,065	59.85% - 60.00%
DODGE	CHALLENGER	2DR COUPE RWD V8	4,083	32,269	60.00% - 60.20%
INFINITI	Q50	HYBRID AWD 4DR SEDAN	4,085	407	60.20%
FORD	MUSTANG	V6/ECOBOOST 2DR COUPE RWD	4,090	--	60.20%
AUDI	A6	4DR SEDAN 3.0 TFSI QUATTRO	4,101	7,449	60.20% - 60.24%
JEEP	WRANGLER	UNLIMITED 4DR SUV 4WD SPORT/WILLYS WHEELER	4,101	95,261	60.24% - 60.81%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
KIA	SORENTO	V6 AWD	4,101	--	60.81%
HONDA	PILOT	4DR SUV FWD	4,103	63,640	60.81% - 61.19%
BMW	3 SERIES	340i xDRIVE Gran Turismo	4,112	--	61.19%
LEXUS	GS	450h 4DR SEDAN HYBRID	4,112	50	61.19%
PORSCHE	MACAN	4DR SUV AWD	4,112	10,715	61.19% - 61.26%
DODGE	CHALLENGER	GT 2DR COUPE AWD V6	4,116	32,269	61.26% - 61.45%
MERCEDES	CLS CLASS	CLS 63 AMG 4DR SEDAN	4,123	920	61.45%
PORSCHE	PANAMERA	4 / 4S	4,123	--	61.45%
JAGUAR	XJ	SWB 4DR SEDAN XJ/XJR	4,125	1,361	61.46%
BMW	X4	xDRIVE28i 4DR SUV	4,129	--	61.46%
JEEP	WRANGLER	2DR SUV 4WD RUBICON	4,129	95,261	61.46% - 62.03%
TOYOTA	TACOMA	ACCESS CAB L/BOX 4WD	4,129	--	62.03%
CADILLAC	CTS-V	4DR SEDAN RWD	4,145	--	62.03%
MERCEDES	E CLASS	AMG E43 4MATIC 4DR SEDAN	4,145	--	62.03%
MERCEDES	GLC CLASS	43 4MATIC 4DR SUV	4,145	--	62.03%
NISSAN	FRONTIER	KING CAB S/BOX 4X2 SV	4,145	--	62.03%
VOLVO	S90	4DR SEDAN T6 AWD	4,145	--	62.03%
CHEVROLET	EQUINOX	4DR SUV 3.6L AWD LS/LT/LTZ	4,147	--	62.03%
BMW	X3	xDRIVE28i 4DR SUV	4,149	20,346	62.03% - 62.15%
FORD	F-150	P/U REG CAB 8-FT BOX 2WD	4,154	--	62.15%
JAGUAR	XJ	LWB 4DR SEDAN XJL/XJR	4,154	1,361	62.16%
BMW	5 SERIES	M550i xDRIVE 4DR SEDAN	4,156	--	62.16%
DODGE	CHARGER	4DR SEDAN AWD	4,158	--	62.16%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
BMW	4 SERIES	428i xDRIVE 2DR CABRIOLET AWD	4,160	--	62.16%
CADILLAC	CT6	3.0L TWIN TURBO AWD 4DR SEDAN	4,165	10,542	62.16% - 62.22%
CHEVROLET	COLORADO	EXTENDED CAB L/BOX 4X4	4,169	56,498	62.22% - 62.56%
DODGE	CHALLENGER	2DR COUPE RWD SRT 392 / HELLCAT	4,169	--	62.56%
GMC	CANYON	EXTENDED CAB L/BOX 4X4	4,169	16,053	62.56% - 62.66%
FORD	MUSTANG	V6/ECOBOOST 2DR CONVERTIBLE RWD	4,193	--	62.66%
LINCOLN-MERCURY	MKZ	3.0L AWD 4DR SEDAN	4,200	10,728	62.66% - 62.72%
MERCEDES	C CLASS	AMG C63/C63S 2DR CONVERTIBLE	4,206	--	62.72%
AUDI	A7	4DR SPORTBACK 3.0 TFSI QUATTRO	4,211	3,367	62.72% - 62.74%
CADILLAC	XTS	4DR SEDAN AWD	4,215	8,138	62.74% - 62.79%
MERCEDES	C CLASS	C43 4MATIC 2DR CONVERTIBLE	4,220	--	62.79%
MERCEDES	METRIS CARGO	VAN	4,222	3,790	62.79% - 62.81%
LINCOLN-MERCURY	CONTINENTAL	CONTINENTAL	4,224	12,012	62.81% - 62.88%
FORD	TAURUS	4DR SEDAN AWD	4,228	20,618	62.88% - 63.01%
BMW	X3	xDRIVE35i 4DR SUV	4,231	20,346	63.01% - 63.13%
BMW	X4	M40i 4DR SUV	4,235	5,198	63.13% - 63.16%
PORSCHE	MACAN	TURBO 4DR SUV AWD	4,244	10,715	63.16% - 63.22%
DODGE	JOURNEY	4DR SUV AWD V6	4,246	--	63.22%
TOYOTA	TACOMA	ACCESS CAB L/BOX 4WD V-6	4,248	198,124	63.22% - 64.41%
HONDA	PILOT	4DR SUV AWD	4,255	63,640	64.41% - 64.79%
BMW	X4	xDRIVE35i 4DR SUV	4,259	--	64.79%
CHEVROLET	COLORADO	CREW CAB L/BOX 2WD	4,259	56,498	64.79% - 65.12%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
GMC	CANYON	CREW CAB L/BOX 2WD	4,259	16,053	65.12% - 65.22%
CADILLAC	CT6	3.6L AWD PLATINUM 4DR SEDAN	4,262	--	65.22%
DODGE	CHARGER	4DR SEDAN RWD V8	4,264	88,351	65.22% - 65.75%
MERCEDES	E CLASS	E 550 CABRIOLET 2DR CONV	4,264	--	65.75%
MERCEDES	E CLASS	E400 4MATIC 4DR WAGON	4,266	--	65.75%
VOLVO	XC60	4DR SUV T5 AWD/T6 AWD/T6 R-DESIGN AWD	4,266	21,985	65.75% - 65.88%
BMW	4 SERIES	435i xDRIVE 2DR CABRIOLET AWD	4,270	--	65.88%
CHRYSLER	300	4DR SEDAN HEMI RWD	4,270	51,237	65.88% - 66.18%
NISSAN	PATHFINDER	FWD 4DR SUV	4,275	--	66.18%
CADILLAC	XT5	4DR SUV AWD	4,277	34,156	66.18% - 66.39%
KIA	K900	V6 4DR SEDAN	4,277	228	66.39%
MERCEDES	CLS CLASS	CLS 550 4MATIC 4DR SEDAN	4,277	920	66.39%
GENESIS	G80	4DR SEDAN AWD 3.8	4,295	8,098	66.39% - 66.44%
JEEP	WRANGLER	UNLIMITED 4DR SUV 4WD SAHARA	4,295	--	66.44%
MERCEDES	SL CLASS	SL65 AMG 2DR CONVERTIBLE	4,299	--	66.44%
AUDI	S5	2DR CABRIOLET 3.0 TFSI QUATTRO	4,310	3,306	66.44% - 66.46%
FORD	F-150	P/U REG CAB 6.5-FT BOX 4X4	4,310	--	66.46%
NISSAN	FRONTIER	KING CAB 4X4 SV/PRO-4X	4,312	37,180	66.46% - 66.68%
BMW	6 SERIES	GRAN COUPE 640i xDRIVE 4DR SEDAN	4,330	--	66.68%
CHRYSLER	PACIFICA	4DR MINIVAN	4,330	113,873	66.68% - 67.36%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
TOYOTA	HIGHLANDER	FWD 4DR SUV	4,332	99,456	67.36% - 67.96%
VOLVO	XC90	4DR SUV FWD T5	4,336	--	67.96%
HYUNDAI	SANTA FE	XL AWD 4DR SUV	4,339	--	67.96%
JEEP	WRANGLER	UNLIMITED 4DR SUV 4WD RUBICON	4,341	--	67.96%
MAZDA	CX-9	4DR SUV AWD	4,341	12,914	67.96% - 68.03%
ACURA	MDX	4DR SUV AWD	4,343	54,886	68.03% - 68.36%
AUDI	Q5	5DR SUV 3.0 TFSI QUATTRO	4,354	26,065	68.36% - 68.52%
TOYOTA	TACOMA	DOUBLE CAB L/BOX 4WD (AUTO)	4,354	--	68.52%
INFINITI	Q70L	AWD 4DR SEDAN	4,361	--	68.52%
ACURA	RLX	4DR SEDAN AWD HYBRID	4,365	1,237	68.52%
PORSCHE	PANAMERA	4 / 4S EXECUTIVE	4,365	6,677	68.52% - 68.56%
FORD	F-150	P/U SUPERCAB 6.5-FT BOX 2WD	4,372	--	68.56%
TOYOTA	TACOMA	DOUBLE CAB S/BOX 4WD (MANUAL)	4,374	--	68.56%
AUDI	A8	4DR SEDAN 3.0 TFSI QUATTRO	4,376	--	68.56%
CADILLAC	CT6	3.0L TWIN TURBO AWD PLATINUM 4DR SEDAN	4,385	--	68.56%
FORD	F-150	P/U REG CAB 8-FT BOX 4X4	4,385	--	68.56%
INFINITI	QX70	4DR SUV AWD	4,385	3,439	68.56% - 68.58%
LINCOLN-MERCURY	MKX	4DR SUV	4,387	31,031	68.58% - 68.77%
AUDI	S6	4DR SEDAN 4.0 TFSI QUATTRO	4,398	1,407	68.78%
FORD	MUSTANG	GT 2DR COUPE RWD	4,398	81,866	68.78% - 69.27%
PORSCHE	PANAMERA	TURBO	4,398	--	69.27%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
DODGE	CHARGER	4DR SEDAN RWD R/T SCAT PACK/SRT392	4,400	--	69.27%
HONDA	ODYSSEY	4DR MINIVAN LX/SE/EX/EX RES	4,400	50,154	69.27% - 69.57%
GMC	ACADIA	4DR SUV AWD	4,405	55,638	69.57% - 69.90%
AUDI	SQ5	5DR SUV 3.0 TFSI QUATTRO	4,409	5,511	69.90% - 69.93%
BMW	6 SERIES	650i xDRIVE 2DR COUPE AWD	4,409	--	69.93%
CHEVROLET	COLORADO	CREW CAB S/BOX 4X4	4,411	--	69.93%
GMC	CANYON	CREW CAB S/BOX 4X4	4,411	--	69.93%
KIA	SEDONA	L/LX/SX 5DR VAN FWD	4,414	11,908	69.93% - 70.00%
NISSAN	PATHFINDER	S/SV/SL AWD 4DR SUV	4,420	81,068	70.00% - 70.49%
TOYOTA	SIENNA	BASE/LE FWD	4,431	--	70.49%
INFINITI	QX60	4DR SUV FWD	4,438	20,182	70.49% - 70.61%
HONDA	RIDGELINE	4DR PICKUP	4,442	34,749	70.61% - 70.81%
LEXUS	RX	350 4DR SUV	4,453	54,154	70.81% - 71.14%
FORD	F-150	P/U SUPERCREW 5.5-FT BOX 2WD	4,471	--	71.14%
BMW	6 SERIES	GRAN COUPE ALPINA B6	4,475	3,355	71.14% - 71.16%
TOYOTA	HIGHLANDER	AWD 4DR SUV	4,475	99,456	71.16% - 71.75%
VOLVO	XC90	4DR SUV AWD T5	4,475	28,768	71.75% - 71.92%
CHEVROLET	COLORADO	CREW CAB L/BOX 4X4	4,480	--	71.92%
GMC	CANYON	CREW CAB L/BOX 4X4	4,480	--	71.92%
BMW	7 SERIES	750i xDRIVE 4DR SEDAN SWB	4,500	4,307	71.92% - 71.95%
AUDI	S7	4DR SPORTBACK 4.0 TFSI QUATTRO	4,508	1,443	71.96%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
RAM	RAM 1500	REG CAB 6.4-FT BOX 2WD	4,511	--	71.96%
CHRYSLER	300	4DR SEDAN V6 AWD	4,513	--	71.96%
DODGE	GRAND CARAVAN	4DR VAN FWD	4,519	125,196	71.96% - 72.70%
CHEVROLET	SILVERADO 1500	REG CAB M/BOX 2WD	4,522	--	72.70%
GMC	SIERRA 1500	REG CAB M/BOX 2WD	4,522	--	72.70%
AUDI	A8	4DR SEDAN 4.0 TFSI QUATTRO	4,530	1,378	72.71%
FORD	F-150	P/U SUPERCAB 8-FT BOX 2WD	4,539	286,632	72.71% - 74.42%
FORD	MUSTANG	GT 2DR CONVERTIBLE RWD	4,555	--	74.42%
FORD	MUSTANG	GT350 2DR COUPE RWD	4,555	--	74.42%
KIA	K900	V8 ELITE 4DR SEDAN	4,555	228	74.43%
FORD	EXPLORER	4DR SUV FWD	4,557	135,566	74.43% - 75.23%
HONDA	ODYSSEY	4DR MINIVAN EX-L RES/EX-L NAVI/TOURING	4,557	50,154	75.23% - 75.53%
MERCEDES	S CLASS	S63 AMG 4MATIC 2DR COUPE	4,564	--	75.53%
RAM	PROMASTER	1500 LOW ROOF 118 IN. WB CARGO VAN	4,568	--	75.53%
BMW	6 SERIES	GRAN COUPE 650i xDRIVE 4DR SEDAN	4,570	--	75.53%
NISSAN	FRONTIER	CREW CAB 4X4 SV	4,570	37,180	75.53% - 75.76%
DODGE	CHARGER	4DR SEDAN RWD HELLCAT	4,575	--	75.76%
INFINITI	QX60	4DR SUV AWD	4,579	20,182	75.76% - 75.88%
AUDI	A8L	4DR SEDAN LWB 4.2 TFSI QUATTRO	4,586	1,378	75.88%
FORD	F-150	P/U SUPERCAB 6.5-FT BOX 4X4	4,588	286,632	75.88% - 77.60%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
VOLVO	S90	4DR SEDAN T8 eAWD PHEV	4,588	117	77.60%
NISSAN	FRONTIER	CREW CAB 4X4 PRO-4X	4,597	--	77.60%
PORSCHE	CAYENNE	S/GTS 4DR SUV	4,597	--	77.60%
FORD	F-150	P/U SUPERCREW 6.5-FT BOX 2WD	4,601	--	77.60%
INFINITI	QX70	SPORT 4DR SUV AWD	4,601	3,439	77.60% - 77.62%
MERCEDES	S CLASS	S550 4MATIC 2DR COUPE	4,608	--	77.62%
TOYOTA	SIENNA	SE/LIMITED FWD	4,608	111,489	77.62% - 78.28%
BMW	7 SERIES	750Li xDRIVE 4DR SEDAN LWB	4,610	4,307	78.28% - 78.31%
MERCEDES	S CLASS	S 400 4MATIC 4DR SEDAN	4,619	--	78.31%
PORSCHE	PANAMERA	TURBO EXECUTIVE	4,630	--	78.31%
VOLVO	XC90	4DR SUV AWD T6	4,632	--	78.31%
RAM	PROMASTER	1500 LOW ROOF 136 IN. WB CARGO VAN	4,639	--	78.31%
CHEVROLET	TRAVERSE	LS/LT/LTZ FWD 4DR SUV	4,645	61,753	78.31% - 78.68%
BMW	6 SERIES	CABRIOLET 650i xDRIVE 2DR CONV AWD	4,650	--	78.68%
LEXUS	LS	460 AWD 4DR SEDAN	4,652	2,047	78.68% - 78.69%
PORSCHE	CAYENNE	4DR SUV	4,652	11,511	78.69% - 78.76%
TOYOTA	4RUNNER	4DR SUV 4WD SR5 V6	4,654	--	78.76%
TESLA	MODEL S	4DR SEDAN RWD	4,656	13,731	78.76% - 78.84%
TOYOTA	SIENNA	AWD V6	4,663	--	78.84%
NISSAN	PATHFINDER	PLATINUM AWD 4DR SUV	4,672	--	78.84%
JEEP	GRAND CHEROKEE	4DR SUV LAREDO 4X4	4,676	--	78.84%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
INFINITI	QX60	HYBRID AWD 4DR SUV	4,683	81	78.84%
AUDI	S8	PLUS 4DR SEDAN 4.0 TFSI QUATTRO	4,685	372	78.84%
GENESIS	G80	4DR SEDAN AWD 5.0	4,687	8,098	78.84% - 78.89%
CHEVROLET	SILVERADO 1500	REG CAB L/BOX 2WD	4,689	--	78.89%
GMC	SIERRA 1500	REG CAB L/BOX 2WD	4,689	--	78.89%
KIA	SEDONA	SXL 5DR VAN FWD	4,689	11,908	78.89% - 78.96%
FORD	F-150	P/U SUPERCREW 5.5-FT BOX 4X4	4,696	--	78.96%
VOLKSWAGEN	TOUAREG	3.6L VR6 4DR SUV AWD	4,696	3,545	78.96% - 78.98%
RAM	RAM 1500	REG CAB 8-FT BOX 2WD	4,705	--	78.98%
BUICK	ENCLAVE	4DR SUV FWD	4,725	24,282	78.98% - 79.13%
RAM	RAM 1500	REG CAB 6.4-FT BOX 4X4	4,725	--	79.13%
MERCEDES	S CLASS	S 550 4MATIC 4DR SEDAN SWB	4,729	--	79.13%
RAM	PROMASTER	1500 HIGH ROOF 136 IN. WB CARGO VAN	4,729	--	79.13%
FORD	EXPLORER	4DR SUV AWD	4,731	135,566	79.13% - 79.94%
BMW	7 SERIES	740Le 4DR SEDAN LWB	4,740	662	79.94%
LEXUS	RX	450H 4DR SUV	4,740	54,154	79.94% - 80.26%
CHEVROLET	SILVERADO 1500	REG CAB M/BOX 4X4	4,749	--	80.26%
GMC	SIERRA 1500	REG CAB M/BOX 4X4	4,749	--	80.26%
NISSAN	FRONTIER	CREW CAB 4X4 SL	4,749	--	80.26%
BMW	X6	xDRIVE 35i 4DR SUV	4,751	--	80.26%
TOYOTA	4RUNNER	4DR SUV 4WD TRAIL EDITION V6	4,751	128,296	80.26% - 81.03%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
MERCEDES	S CLASS	S 550 4MATIC 4DR SEDAN LWB	4,773	--	81.03%
RAM	PROMASTER	2500 HIGH ROOF 136 IN. WB CARGO VAN	4,782	40,483	81.03% - 81.27%
PORSCHE	PANAMERA	4 E-HYBRID	4,784	14	81.27%
BMW	X5	xDRIVE35i 4DR SUV	4,791	--	81.27%
GENESIS	G90	3.3T 4DR SEDAN AWD	4,793	2,199	81.27% - 81.29%
AUDI	A8L	4DR SEDAN LWB W12 6.3 FSI QUATTRO	4,806	--	81.29%
MERCEDES	S CLASS	S 63 AMG 4MATIC 4DR SEDAN	4,806	--	81.29%
TOYOTA	4RUNNER	4DR SUV 4WD LIMITED V6	4,806	--	81.29%
MERCEDES	S CLASS	S550 / S63 AMG 4MATIC CABRIOLET	4,817	15,144	81.29% - 81.38%
MERCEDES	S CLASS	S63 AMG 4MATIC CABRIOLET	4,817	--	81.38%
MERCEDES	S CLASS	S65 AMG 2DR COUPE	4,817	--	81.38%
MERCEDES	S CLASS	S550 CABRIOLET	4,819	--	81.38%
CHEVROLET	TRAVERSE	LS/LT/LTZ AWD 4DR SUV	4,844	61,753	81.38% - 81.74%
LAND ROVER	DISCOVERY	DISCOVERY	4,846	6,398	81.74% - 81.78%
MERCEDES	METRIS	PASSENGER VAN	4,850	3,790	81.78% - 81.80%
LEXUS	LS460L	AWD 4DR SEDAN	4,872	2,047	81.80% - 81.82%
JEEP	GRAND CHEROKEE	4DR SUV LIMITED 4X4	4,874	120,348	81.82% - 82.54%
MERCEDES	S CLASS	S 550e 4DR SEDAN	4,883	744	82.54%
FORD	F-150	P/U SUPERCAB 8-FT BOX 4X4	4,888	--	82.54%
RAM	RAM 1500	REG CAB 8-FT BOX 4X4	4,890	--	82.54%
MERCEDES	GLE	COUPE 43 AMG 4MATIC	4,894	--	82.54%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
TOYOTA	HIGHLANDER	HYBRID 4DR SUV	4,894	16,864	82.54% - 82.64%
RAM	RAM 1500	QUAD CAB 6.4-FT BOX 2WD	4,905	174,067	82.64% - 83.68%
GENESIS	G90	5.0 4DR SEDAN AWD	4,914	2,199	83.68% - 83.69%
TOYOTA	TUNDRA	REG CAB L/BOX 2WD	4,916	--	83.69%
BUICK	ENCLAVE	4DR SUV AWD	4,923	24,282	83.69% - 83.84%
RAM	PROMASTER	2500 HIGH ROOF 159 IN. WB CARGO VAN	4,923	--	83.84%
MERCEDES	GLE CLASS	400 4MATIC	4,927	--	83.84%
BMW	X5	xDRIVE35d 4DR SUV	4,930	--	83.84%
FORD	F-150	P/U SUPERCREW 6.5-FT BOX 4X4	4,930	--	83.84%
AUDI	Q7	4DR SUV 3.0 TFSI QUATTRO	4,938	38,346	83.84% - 84.07%
CHRYSLER	PACIFICA	HYBRID 4DR MINIVAN	4,943	4,401	84.07% - 84.09%
LINCOLN-MERCURY	MKT	4DR SUV	4,943	3,005	84.09% - 84.11%
BMW	X5	xDRIVE35i THIRD ROW SEATING 4DR SUV	4,949	--	84.11%
RAM	RAM 1500	CREW CAB 5.7-FT BOX 2WD	4,949	174,067	84.11% - 85.15%
CHEVROLET	SILVERADO 1500	REG CAB L/BOX 4X4	4,952	--	85.15%
GMC	SIERRA 1500	REG CAB L/BOX 4X4	4,952	--	85.15%
PORSCHE	PANAMERA	4 E_HYBRID EXECUTIVE	4,960	13	85.15%
RAM	PROMASTER	3500 HIGH ROOF 159 IN. WB CARGO VAN	4,963	--	85.15%
MERCEDES	S CLASS	S 65 AMG 4DR SEDAN	4,969	--	85.15%
TESLA	MODEL S	4DR SEDAN AWD	4,969	13,731	85.15% - 85.23%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
MERCEDES	S CLASS	S65 AMG CABRIOLET	4,971	--	85.23%
MERCEDES	GLE CLASS	43 4MATIC	4,982	27,060	85.23% - 85.39%
PORSCHE	CAYENNE	TURBO/TURBO S 4DR SUV	4,982	--	85.39%
JEEP	GRAND CHEROKEE	4DR SUV OVERLAND/SUMMIT 4X4	4,985	120,348	85.39% - 86.11%
DODGE	DURANGO	4DR SUV AWD V6	4,987	34,381	86.11% - 86.32%
FORD	TRANSIT VAN	150 LONG WB LOW ROOF	5,000	--	86.32%
FORD	TRANSIT VAN	150 LONG WB MEDIUM ROOF	5,000	--	86.32%
FORD	TRANSIT VAN	150 REGULAR WB LOW ROOF	5,000	--	86.32%
FORD	TRANSIT VAN	150 REGULAR WB MEDIUM ROOF	5,000	--	86.32%
FORD	TRANSIT VAN	250 LONG WB EL HIGH ROOF	5,000	--	86.32%
FORD	TRANSIT VAN	250 LONG WB HIGH ROOF	5,000	--	86.32%
FORD	TRANSIT VAN	250 LONG WB LOW ROOF	5,000	--	86.32%
FORD	TRANSIT VAN	250 LONG WB MEDIUM ROOF	5,000	--	86.32%
FORD	TRANSIT VAN	250 REGULAR WB LOW ROOF	5,000	--	86.32%
FORD	TRANSIT VAN	250 REGULAR WB MEDIUM ROOF	5,000	--	86.32%
CHEVROLET	SILVERADO 1500	DOUBLE CAB M/BOX 2WD	5,002	222,043	86.32% - 87.64%
GMC	SIERRA 1500	DOUBLE CAB M/BOX 2WD	5,002	--	87.64%
RAM	PROMASTER	3500 HIGH ROOF 150 IN. WB EXT CARGO VAN	5,033	--	87.64%
MERCEDES	S CLASS	S 600 4DR SEDAN	5,038	--	87.64%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
CHEVROLET	SILVERADO 1500	CREW CAB S/BOX 2WD	5,073	222,043	87.64% - 88.97%
GMC	SIERRA 1500	CREW CAB S/BOX 2WD	5,073	82,601	88.97% - 89.46%
RAM	RAM 1500	QUAD CAB 6.4-FT BOX 4X4	5,082	--	89.46%
PORSCHE	PANAMERA	TURBO S E-HYBRID	5,093	14	89.46%
TOYOTA	TUNDRA	DOUBLE CAB M/BOX 2WD SR5 4.6L	5,093	--	89.46%
BMW	X5	XDRIVE35d THIRD ROW SEATING 4DR SUV	5,099	45,682	89.46% - 89.73%
FORD	TRANSIT VAN	350 LONG WB EL HIGH ROOD	5,110	23,164	89.73% - 89.87%
FORD	TRANSIT VAN	350 LONG WB HIGH ROOF	5,110	23,164	89.87% - 90.01%
FORD	TRANSIT VAN	350 LONG WB LOW ROOF	5,110	23,164	90.01% - 90.15%
FORD	TRANSIT VAN 350	350 LONG WB MEDIUM ROOF	5,110	23,164	90.15% - 90.29%
VOLVO	XC90	4DR SUV AWD T8 PHEV	5,115	2,228	90.29% - 90.30%
MERCEDES	SPRINTER 2500	CARGO VAN 144-IN WB STARDARD RO	5,124	--	90.30%
LAND ROVER	RANGE ROVER	SWB 4DR SUV	5,137	8,435	90.30% - 90.35%
BMW	X5	xDRIVE50i 4DR SUV	5,150	--	90.35%
JEEP	GRAND CHEROKEE	SRT 4DR SUV	5,150	--	90.35%
RAM	RAM 1500	CREW CAB 5.7-FT BOX 4X4	5,150	--	90.35%
CHEVROLET	SILVERADO 1500	CREW CAB M/BOX 2WD	5,161	--	90.35%
GMC	SIERRA 1500	CREW CAB M/BOX 2WD	5,161	82,601	90.35% - 90.84%
BMW	X6	xDRIVE 50i 4DR SUV	5,170	6,780	90.84% - 90.88%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
LEXUS	GX	460 4DR SUV /PREMIUM	5,179	27,190	90.88% - 91.05%
BMW	X5M	4DR SUV	5,181	--	91.05%
MERCEDES	GLE	COUPE AMG 63 S 4MATIC	5,181	27,060	91.05% - 91.21%
PORSCHE	CAYENNE	S E-HYBRID 4DR SUV	5,181	1,692	91.21% - 91.22%
MERCEDES	SPRINTER	2500 CARGO VAN 144-IN WB HIGH ROOF	5,187	--	91.22%
RAM	RAM 1500	CREW CAB 6.4-FT BOX 2WD	5,192	--	91.22%
TOYOTA	TUNDRA	REG CAB L/BOX 4WD	5,203	58,143	91.22% - 91.57%
CHEVROLET	EXPRESS CARGO	3500 VAN SWB	5,205	--	91.57%
GMC	SAVANA CARGO	3500 VAN SWB	5,205	--	91.57%
CHEVROLET	SILVERADO 1500	DOUBLE CAB M/BOX 4X4	5,216	--	91.57%
GMC	SIERRA 1500	DOUBLE CAB M/BOX 4X4	5,216	--	91.57%
BMW	X5	xDRIVE40e 4DR SUV	5,221	5,133	91.57% - 91.60%
MERCEDES	GLE CLASS	AMG 63 S 4MATIC	5,225	--	91.60%
GMC	SIERRA 1500	CREW CAB S/BOX DENALI	5,227	--	91.60%
TESLA	MODEL X	4DR SUV AWD	5,269	16,715	91.60% - 91.70%
CHEVROLET	SILVERADO 1500	CREW CAB S/BOX 4X4	5,278	--	91.70%
GMC	SIERRA 1500	CREW CAB S/BOX 4X4	5,278	--	91.70%
CHEVROLET	EXPRESS CARGO	2500 VAN SWB	5,291	27,436	91.70% - 91.86%
GMC	SAVANA CARGO	2500 VAN SWB	5,291	14,386	91.86% - 91.95%
CHEVROLET	TAHOE	4DR SUV RWD	5,309	49,481	91.95% - 92.24%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
GMC	YUKON	4DR SUV RWD SLE/SLT	5,309	--	92.24%
PORSCHE	PANAMERA	TURBO S E-HYBRID EXECUTIVE	5,313	13	92.24%
BMW	X5	xDRIVE50i THIRD ROW SEATING 4DR SUV	5,320	--	92.24%
LAND ROVER	RANGE ROVER	LWB 4DR SUV	5,320	8,435	92.24% - 92.29%
MERCEDES	SPRINTER	2500 CARGO VAN 4X4 144-IN WB STANDARD ROOF	5,320	--	92.29%
BMW	X6M	4DR SUV AWD	5,324	--	92.29%
GMC	SIERRA 1500	CREW CAB M/BOX DENALI	5,324	--	92.29%
DODGE	DURANGO	4DR SUV AWD V8	5,331	34,381	92.29% - 92.50%
MERCEDES	GLS CLASS	GLS 450 4MATIC 4DR SUV	5,335	--	92.50%
CHEVROLET	SILVERADO 1500	CREW CAB M/BOX 4X4	5,359	--	92.50%
GMC	SIERRA 1500	CREW CAB M/BOX 4X4	5,359	--	92.50%
MERCEDES	SPRINTER	2500 CARGO VAN 4X4 144-IN WB HIGH ROOF	5,386	--	92.50%
RAM	RAM 1500	CREW CAB 6.4-FT BOX 4X4	5,386	--	92.50%
TOYOTA	TUNDRA	DOUBLE CAB M/BOX 4WD SR5 4.6L/SR5 5.7/	5,401	58,143	92.50% - 92.84%
MERCEDES	GLE CLASS	550e 4MATIC	5,456	410	92.85%
LAND ROVER	RANGE ROVER SPORT	SE/HSE	5,487	9,577	92.85% - 92.90%
CHEVROLET	EXPRESS CARGO	2500 VAN LWB	5,505	27,436	92.90% - 93.07%
GMC	SAVANA CARGO	2500 VAN LWB	5,505	14,386	93.07% - 93.15%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
FORD	F-150	RAPTOR SUPERCAB 5.5-FT BOX 4X4	5,525	--	93.15%
CHEVROLET	SUBURBAN	4DR SUV RWD	5,536	28,258	93.15% - 93.32%
GMC	YUKON-XL	4DR SUV RWD SLE/SLT	5,536	--	93.32%
CHEVROLET	TAHOE	4DR SUV AWD	5,545	49,481	93.32% - 93.62%
GMC	YUKON	4DR SUV 4WD SLE/SLT	5,545	49,183	93.62% - 93.91%
MERCEDES	SPRINTER	2500 CARGO VAN 170-IN WB HIGH ROOF2	5,545	--	93.91%
MERCEDES	SPRINTER	2500 CARGO VAN 170-IN WB SUPER HIGH	5,558	--	93.91%
CHEVROLET	EXPRESS CARGO	3500 VAN LWB	5,567	--	93.91%
GMC	SAVANA CARGO	3500 VAN LWB	5,567	--	93.91%
FORD	TRANSIT WAGON	150 LOW ROOF	5,569	--	93.91%
FORD	TRANSIT WAGON	150 MID ROOF	5,569	--	93.91%
MERCEDES	GLS CLASS	GLS 550 4MATIC 4DR SUV	5,578	32,062	93.91% - 94.10%
TOYOTA	TUNDRA	DOUBLE CAB L/BOX 4WD	5,600	--	94.10%
MERCEDES	G CLASS	4DR SUV 4WD	5,622	4,188	94.10% - 94.13%
MERCEDES	SPRINTER 3500	CARGO VAN 144-IN WB HIGH ROOF	5,626	--	94.13%
CHEVROLET	SILVERADO 2500	HD REG CAB L/BOX 2WD	5,631	--	94.13%
GMC	SIERRA 2500	HD REG CAB L/BOX 2WD	5,631	--	94.13%
TOYOTA	TUNDRA	CREW MAX S/BOX 4WD SR5/PLATINUM	5,633	--	94.13%
NISSAN	TITAN	SINGLE CAB S/SV	5,668	--	94.13%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
MERCEDES	SPRINTER 2500	CARGO VAN 170-IN WB EXTRALONG H	5,677	--	94.13%
FORD	F-250	SD P/U REG CAB L/BOX	5,684	--	94.13%
NISSAN	TITAN	CREW CAB S/SV	5,688	--	94.13%
MERCEDES	SPRINTER 2500	CARGO VAN 170-IN WB EXTRALONG S	5,690	--	94.13%
NISSAN	TITAN	XD SINGLE CAB 4X2	5,695	--	94.13%
FORD	F-150	RAPTOR SUPERCREW 5.5-FT BOX 4X4	5,697	--	94.13%
FORD	TRANSIT VAN	350HD DRW EL HIGH ROOF	5,710	--	94.13%
LAND ROVER	RANGE ROVER SPORT	SUPERCHARGED/AUTOBIOGRAPHY	5,710	9,577	94.13% - 94.18%
MERCEDES	SPRINTER 2500	CARGO VAN 170-IN WB HIGH ROOF	5,717	--	94.18%
MERCEDES	SPRINTER 2500	PASSENGER VAN 144-IN WB STANDARD	5,739	--	94.18%
GMC	YUKON	4DR SUV 4WD DENALI	5,745	--	94.18%
MERCEDES	GLS CLASS	AMG GLS 63 4DR SUV AWD	5,754	--	94.18%
CHEVROLET	SILVERADO 3500	HD DOUBLE CAB L/BOX SRW 2WD	5,774	--	94.18%
CHEVROLET	SILVERADO 3500	HD REG CAB L/BOX SRW 2WD	5,774	--	94.18%
GMC	SIERRA 3500	HD DOUBLE CAB L/BOX SRW 2WD	5,774	--	94.18%
GMC	SIERRA 3500	HD REG CAB L/BOX SRW 2WD	5,774	--	94.18%
CHEVROLET	SUBURBAN	4DR SUV AWD	5,776	28,258	94.18% - 94.35%
GMC	YUKON-XL	4DR SUV 4WD SLE/SLT	5,776	35,059	94.35% - 94.56%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
MERCEDES	SPRINTER 2500	PASSENGER VAN 144-IN WB HIGH ROOF	5,800	13,708	94.56% - 94.64%
MERCEDES	SPRINTER 3500	CARGO VAN 4X4 144-IN WB HIGH ROOF	5,805	13,708	94.64% - 94.73%
NISSAN	NV1500	STARDARD ROOF S	5,807	--	94.73%
NISSAN	TITAN	CREW CAB PRO-4X	5,816	--	94.73%
MERCEDES	SPRINTER 2500	CARGO VAN 4X4 170-IN WB EXTRALONG H	5,838	--	94.73%
CADILLAC	ESCALADE	ESCALADE	5,840	22,994	94.73% - 94.86%
FORD	EXPEDITION	4WD SUV	5,847	25,942	94.86% - 95.02%
CHEVROLET	2500 EXPRESS	PASSENGER VAN SWB	5,873	--	95.02%
GMC	2500 SAVANA	PASSENGER VAN SWB	5,873	--	95.02%
INFINITI	QX80	AWD 4DR SUV	5,889	17,881	95.02% - 95.12%
NISSAN	NV2500	STANDARD ROOF V6 S/V6 SV/V8 S	5,889	--	95.12%
NISSAN	NV3500	STANDARD ROOF V8 S	5,893	--	95.12%
FORD	F-350	SD P/U REG CAB L/BOX	5,908	--	95.12%
LEXUS	LX570	4DR SUV	5,908	6,004	95.12% - 95.16%
NISSAN	ARMADA	4DR SUV	5,917	35,667	95.16% - 95.37%
MERCEDES	SPRINTER 2500	PASSENGER VAN 4X4 144-IN WB STANDARD	5,926	--	95.37%
FORD	F-250	SD P/U SUPERCAB S/BOX	5,933	--	95.37%
NISSAN	TITAN	CREW CAB SL/PLATINUM RESERVE	5,935	--	95.37%
NISSAN	TITAN	SD SINGLE CAB 4X4	5,957	52,924	95.37% - 95.69%
CHEVROLET	SILVERADO 2500	HD REG CAB L/BOX 4X4	5,961	--	95.69%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
GMC	SIERRA 2500	HD REG CAB L/BOX 4X4	5,961	--	95.69%
RAM	RAM 2500	REG CAB L/BOX 2WD	5,966	--	95.69%
TOYOTA	SEQUOIA	4DR SUV 4WD	5,968	12,156	95.69% - 95.76%
GMC	YUKON-XL	4DR SUV 4WD DENALI	5,981	--	95.76%
NISSAN	NV2500	HIGHROOF V6 S	5,988	--	95.76%
MERCEDES	SPRINTER 2500	PASSENGER VAN 4X4 144-IN WB HIGH ROOF	5,992	--	95.76%
MERCEDES	SPRINTER 3500	CARGO VAN 170-IN WB HIGH ROOF	6,021	--	95.76%
RAM	RAM 3500	REG CAB L/BOX 2WD SRW	6,023	--	95.76%
FORD	F-250	SD P/U SUPERCAB L/BOX	6,027	--	95.76%
MERCEDES	SPRINTER	3500 CARGO VAN 170-IN WB SUPER HIGH	6,034	--	95.76%
CADILLAC	ESCALADE	ESV	6,041	14,700	95.76% - 95.85%
FORD	F-250	SD P/U CREW CAB S/BOX	6,052	--	95.85%
NISSAN	NV	2500 STANDARD ROOF V8 SV	6,058	--	95.85%
NISSAN	NV	3500 STANDARD ROOF V8 SV	6,063	--	95.85%
NISSAN	NV	3500 HIGHROOF V8 S	6,065	17,858	95.85% - 95.96%
LINCOLN-MERCURY	NAVIGATOR	4DR SUV 4WD	6,069	5,262	95.96% - 95.99%
NISSAN	NV	2500 HIGHROOF V6 SV/V8 S	6,083	--	95.99%
CHEVROLET	EXPRESS PASSENGER	3500 VAN SWB	6,087	14,292	95.99% - 96.07%
GMC	SAVANA PASSENGER	3500 VAN SWB	6,087	907	96.08%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
CHEVROLET	SILVERADO 3500	HD DOUBLE CAB L/BOX SRW 4X4	6,091	--	96.08%
CHEVROLET	SILVERADO 3500	HD REG CAB L/BOX SRW 4X4	6,091	--	96.08%
GMC	SIERRA 3500	HD DOUBLE CAB L/BOX SRW 4X4	6,091	--	96.08%
GMC	SIERRA 3500	HD REG CAB L/BOX SRW 4X4	6,091	--	96.08%
FORD	EXPEDITION	MAX 4WD SUV	6,102	25,942	96.08% - 96.23%
FORD	F-250	SD P/U REG CAB L/BOX 4X4	6,107	88,869	96.23% - 96.76%
FORD	F-350	SD P/U SUPERCAB S/BOX	6,120	--	96.76%
CHEVROLET	SILVERADO 2500	HD CREW CAB M/BOX 2WD	6,153	--	96.76%
CHEVROLET	SILVERADO 2500	HD DOUBLE CAB M/BOX 2WD	6,153	--	96.76%
GMC	SIERRA 2500	HD CREW CAB M/BOX 2WD	6,153	--	96.76%
GMC	SIERRA 2500	HD DOUBLE CAB M/BOX 2WD	6,153	--	96.76%
MERCEDES	SPRINTER	3500 CARGO VAN 170-IN WB EXTRALONG H	6,164	--	96.76%
CHEVROLET	SILVERADO 3500	HD DOUBLE CAB L/BOX DRW 2WD	6,177	--	96.76%
CHEVROLET	SILVERADO 3500	HD REG CAB L/BOX DRW 2WD	6,177	--	96.76%
GMC	SIERRA 3500	HD DOUBLE CAB L/BOX DRW 2WD	6,177	--	96.76%
GMC	SIERRA 3500	HD REG CAB L/BOX DRW 2WD	6,177	--	96.76%
MERCEDES	SPRINTER	3500 CARGO VAN 170-IN WB EXTRALONG S	6,177	--	96.76%
MERCEDES	SPRINTER	3500 CARGO VAN 170-IN WB HIGH ROOF1	6,180	--	96.76%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
MERCEDES	SPRINTER	2500 PASSENGER VAN 170-IN WB HIGH RO	6,182	--	96.76%
NISSAN	NV	2500 HIGHROOF V8 SV	6,230	--	96.76%
NISSAN	NV	3500 HIGHROOF V8 SV	6,235	--	96.76%
FORD	F-350	SD P/U SUPERCAB L/BOX	6,241	--	96.76%
CHEVROLET	SILVERADO 2500	HD CREW CAB L/BOX 2WD	6,252	--	96.76%
CHEVROLET	SILVERADO 2500	HD DOUBLE CAB L/BOX 2WD	6,252	103,112	96.76% - 97.38%
GMC	SIERRA 2500	HD CREW CAB L/BOX 2WD	6,252	38,358	97.38% - 97.61%
GMC	SIERRA 2500	HD DOUBLE CAB L/BOX 2WD	6,252	--	97.61%
FORD	F-350	SD P/U CREW CAB S/BOX	6,279	--	97.61%
FORD	F-250	SD P/U CREW CAB L/BOX	6,292	88,869	97.61% - 98.14%
LINCOLN-MERCURY	NAVIGATOR	L 4DR SUV 4WD	6,296	5,262	98.14% - 98.17%
FORD	F-350	SD P/U REG CAB L/BOX DRW	6,305	--	98.17%
CHEVROLET	SILVERADO 3500	HD CREW CAB M/BOX 2WD	6,314	19,334	98.17% - 98.29%
GMC	SIERRA 3500	HD CREW CAB M/BOX 2WD	6,314	--	98.29%
RAM	RAM 2500	CREW CAB S/BOX 2WD	6,316	--	98.29%
RAM	RAM 2500	REG CAB L/BOX 4WD	6,332	--	98.29%
FORD	F-350	SD P/U REG CAB L/BOX 4X4	6,336	--	98.29%
MERCEDES	SPRINTER	3500 CARGO VAN 4X4 170-IN WB EXTRALONG H	6,345	--	98.29%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
FORD	TRANSIT WAGON	350 HIGH ROOF	6,352	34,705	98.29% - 98.49%
FORD	TRANSIT WAGON	350 LOW ROOF	6,352	--	98.49%
FORD	TRANSIT WAGON	350 MID ROOF	6,352	--	98.49%
MERCEDES	SPRINTER	2500 PASSENGER VAN 4X4 170-IN WB HIGH ROOF	6,367	--	98.49%
RAM	RAM 3500	REG CAB L/BOX 4WD SRW	6,369	--	98.49%
FORD	F-250	SD P/U SUPERCAB S/BOX 4X4	6,371	--	98.49%
CHEVROLET	SILVERADO 3500	HD CREW CAB L/BOX SRW 2WD	6,391	19,334	98.49% - 98.61%
GMC	SIERRA 3500	HD CREW CAB L/BOX SRW 2WD	6,391	7,192	98.61% - 98.65%
CHEVROLET	EXPRESS PASSENGER	3500 VAN LWB	6,407	--	98.65%
GMC	SAVANA PASSENGER	3500 VAN LWB	6,407	--	98.65%
RAM	RAM 3500	CREW CAB S/BOX 2WD	6,411	--	98.65%
RAM	RAM 3500	REG CAB L/BOX 2WD DRW	6,413	--	98.65%
CHEVROLET	SILVERADO 2500	HD CREW CAB M/BOX 4X4	6,433	--	98.65%
CHEVROLET	SILVERADO 2500	HD DOUBLE CAB M/BOX 4X4	6,433	--	98.65%
GMC	SIERRA 2500	HD CREW CAB M/BOX 4X4	6,433	--	98.65%
GMC	SIERRA 2500	HD DOUBLE CAB M/BOX 4X4	6,433	--	98.65%
FORD	F-250	SD P/U SUPERCAB L/BOX 4x4	6,442	--	98.65%
RAM	RAM 2500	CREW CAB L/BOX 2WD	6,468	44,968	98.65% - 98.92%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
FORD	F-250	SD P/U CREW CAB S/BOX 4X4	6,477	--	98.92%
FORD	F-350	SD P/U CREW CAB L/BOX	6,517	--	98.92%
RAM	RAM 3500	CREW CAB L/BOX 2WD SRW	6,523	--	98.92%
CHEVROLET	SILVERADO 3500	HD DOUBLE CAB L/BOX DRW 4X4	6,526	--	98.92%
CHEVROLET	SILVERADO 3500	HD REG CAB L/BOX DRW 4X4	6,526	--	98.92%
GMC	SIERRA 3500	HD DOUBLE CAB L/BOX DRW 4X4	6,526	7,192	98.92% - 98.96%
GMC	SIERRA 3500	HD REG CAB L/BOX DRW 4X4	6,526	--	98.96%
FORD	F-350	SD P/U SUPERCAB S/BOX 4X4	6,543	41,723	98.96% - 99.21%
GMC	SIERRA 2500	HD CREW CAB M/BOX 4X4 DENALI	6,550	--	99.21%
CHEVROLET	SILVERADO 2500	HD CREW CAB L/BOX 4X4	6,594	--	99.21%
CHEVROLET	SILVERADO 2500	HD DOUBLE CAB L/BOX 4X4	6,594	--	99.21%
GMC	SIERRA 2500	HD CREW CAB L/BOX 4X4	6,594	--	99.21%
GMC	SIERRA 2500	HD DOUBLE CAB L/BOX 4X4	6,594	--	99.21%
CHEVROLET	SILVERADO 3500	HD CREW CAB M/BOX 4X4	6,609	--	99.21%
GMC	SIERRA 3500	HD CREW CAB M/BOX 4X4	6,609	--	99.21%
RAM	RAM 2500	CREW CAB S/BOX 4WD	6,625	44,968	99.21% - 99.48%
FORD	TRANSIT WAGON	350HD DRW HIGH ROOF	6,649	--	99.48%
FORD	F-350	SD P/U SUPERCAB L/BOX 4X4	6,651	41,723	99.48% - 99.73%
RAM	RAM 3500	MEGA CAB S/BOX 2WD SRW	6,660	--	99.73%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
FORD	F-350	SD P/U CREW CAB S/BOX 4X4	6,693	--	99.73%
FORD	F-250	SD P/U CREW CAB L/BOX 4X4	6,695	--	99.73%
GMC	SIERRA 3500	HD CREW CAB M/BOX 4X4 DENALI	6,720	--	99.73%
NISSAN	TITAN	XD CREW CAB S / SV 4X2	6,724	--	99.73%
FORD	F-350	SD P/U SUPERCAB L/BOX DRW	6,729	--	99.73%
CHEVROLET	SILVERADO 3500	HD CREW CAB L/BOX SRW 4X4	6,733	--	99.73%
GMC	SIERRA 3500	HD CREW CAB L/BOX SRW 4X4	6,733	--	99.73%
RAM	RAM 3500	CREW CAB S/BOX 4WD	6,733	22,726	99.73% - 99.86%
NISSAN	NV	3500 PASSENGER VAN STANDARD ROOF S V6/S V8/	6,764	--	99.86%
FORD	F-350	SD P/U REG CAB L/BOX DRW 4X4	6,766	--	99.86%
CHEVROLET	SILVERADO 3500	HD CREW CAB L/BOX DRW 2WD	6,781	--	99.86%
GMC	SIERRA 3500	HD CREW CAB L/BOX DRW 2WD	6,781	--	99.86%
RAM	RAM 2500	MEGA CAB S/BOX 2WD	6,786	--	99.86%
RAM	RAM 3500	REG CAB L/BOX 4WD DRW	6,790	22,726	99.86% - 100.00%
RAM	RAM 2500	CREW CAB L/BOX 4WD	6,812	--	100.00%
RAM	RAM 3500	CREW CAB L/BOX 4WD SRW	6,909	--	100.00%
FORD	F-350	SD P/U CREW CAB L/BOX 4X4	6,927	--	100.00%
NISSAN	NV	3500 PASSENGER VAN STANDARD ROOF SV V8/SL V	6,929	--	100.00%

Make	Model	Trim	Curb Weight, lb	Median-Weight Sales Estimate, No. of Units	Percentile Weight Range
RAM	RAM 3500	MEGA CAB S/BOX 4WD SRW	6,945	--	100.00%
FORD	F-350	SD P/U CREW CAB L/BOX DRW	6,973	--	100.00%
RAM	RAM 3500	CREW CAB L/BOX 2WD DRW	6,978	--	100.00%
NISSAN	TITAN	XD CREW CAB S / SV 4X4	7,000	--	100.00%
RAM	RAM 2500	MEGA CAB S/BOX 4WD	7,055	--	100.00%
CHEVROLET	SILVERADO 3500	HD CREW CAB L/BOX DRW 4X4	7,110	--	100.00%
GMC	SIERRA 3500	HD CREW CAB L/BOX DRW 4X4	7,110	--	100.00%
NISSAN	TITAN	XD CREW CAB SL / PLATINUM RESERVE 4X2	7,125	--	100.00%
FORD	F-350	SD P/U SUPERCAB L/BOX DRW 4X4	7,147	--	100.00%
RAM	RAM 3500	MEGA CAB S/BOX 2WD DRW	7,216	--	100.00%
NISSAN	TITAN	XD CREW CAB PRO-4X	7,271	--	100.00%
RAM	RAM 3500	CREW CAB L/BOX 4WD DRW	7,328	--	100.00%
FORD	F-350	SD P/U CREW CAB L/BOX DRW 4X4	7,379	--	100.00%
NISSAN	TITAN	XD CREW CAB SL / PLATINUM RESERVE 4X4	7,403	--	100.00%
RAM	RAM 3500	MEGA CAB S/BOX 4WD DRW	7,414	--	100.00%
GMC	SIERRA 3500	HD CREW CAB L/BOX DRW 4X4 DENALI	8,014	--	100.00%

APPENDIX E CUV, Mid-Size Car, Pickup Truck, and Small Car Measurement Distributions

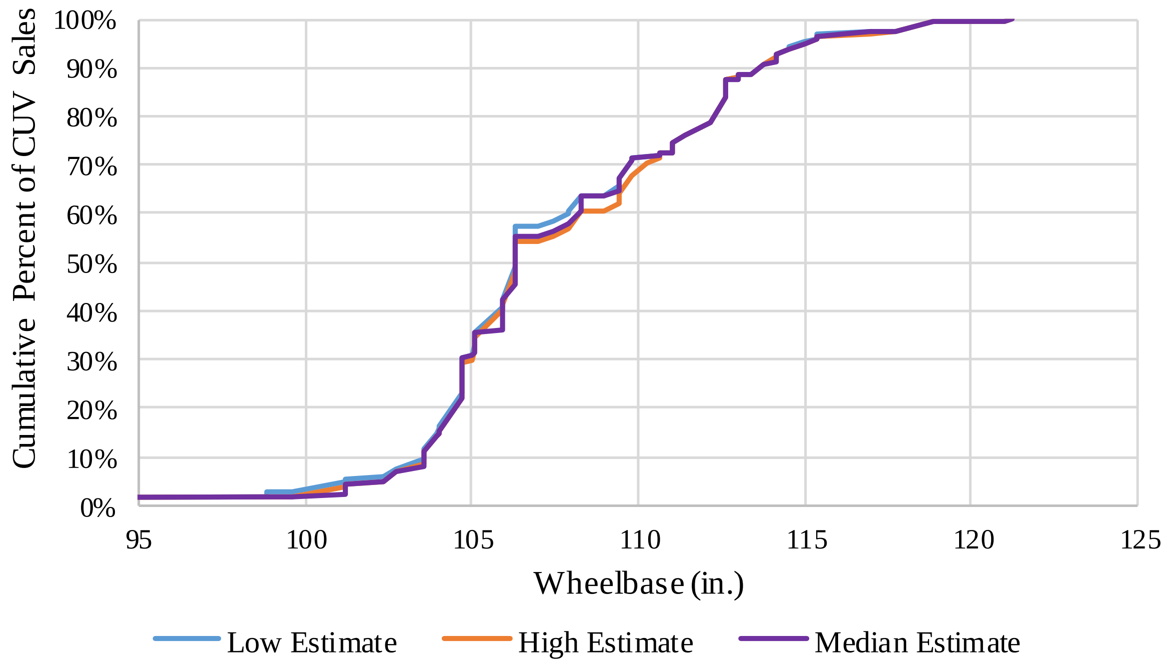

Figure E-1. CUV Wheelbase Distribution

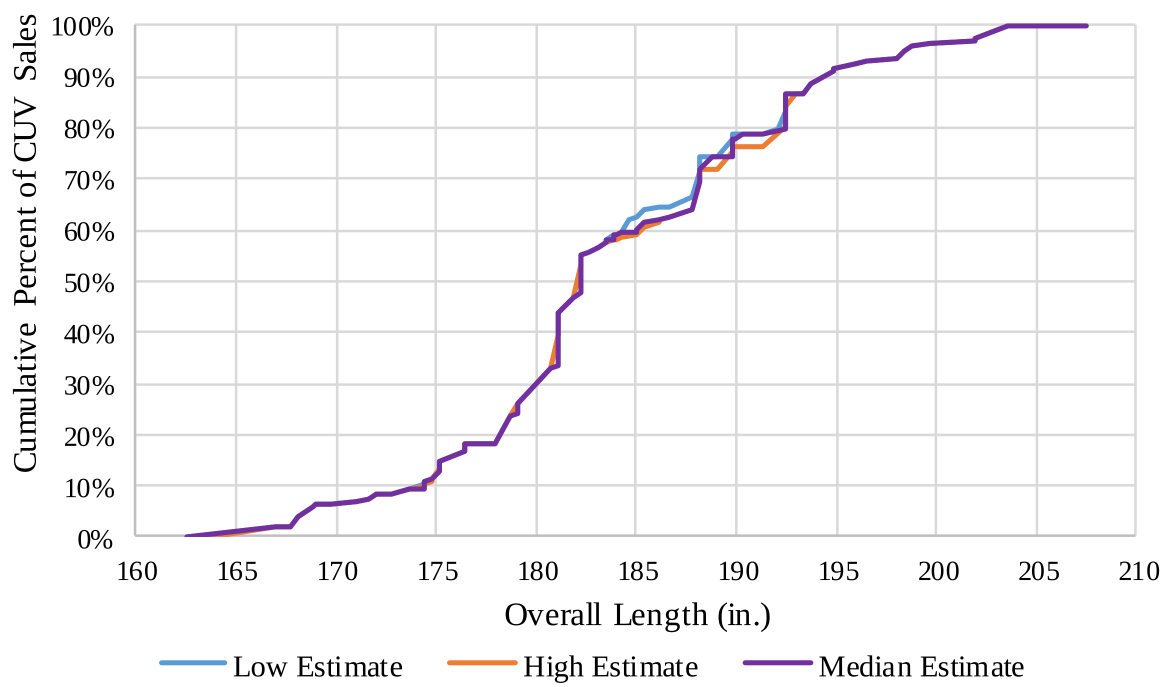

Figure E-2. CUV Overall Length Distribution

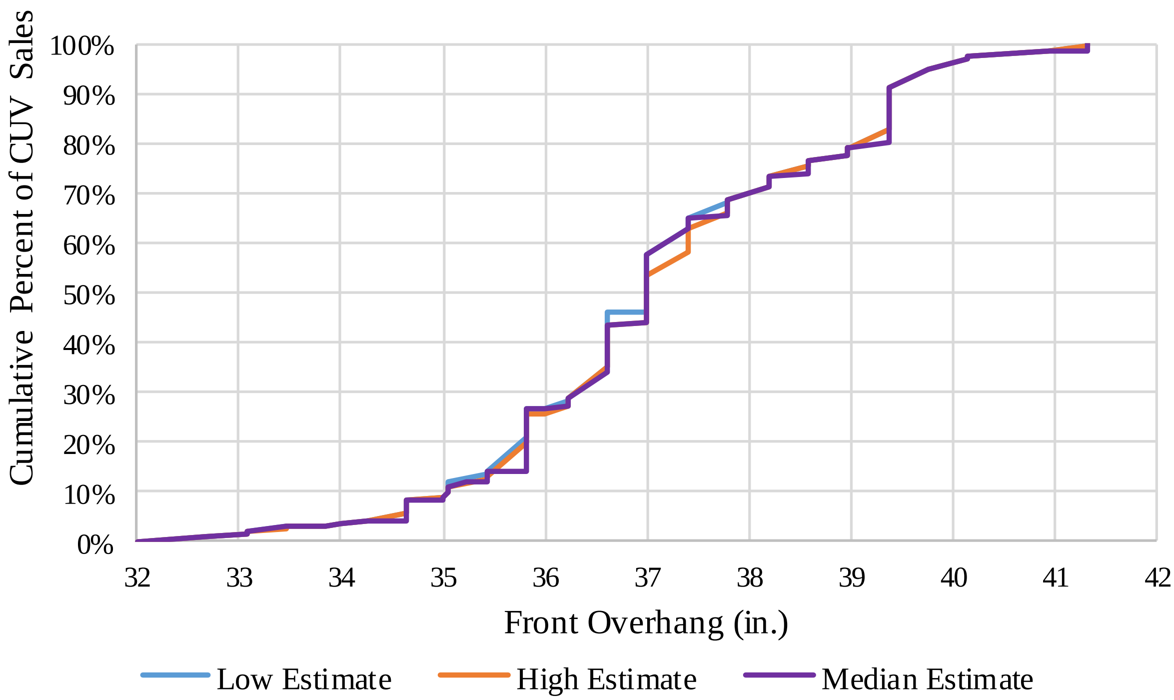

Figure E-3. CUV Front Overhang Distribution

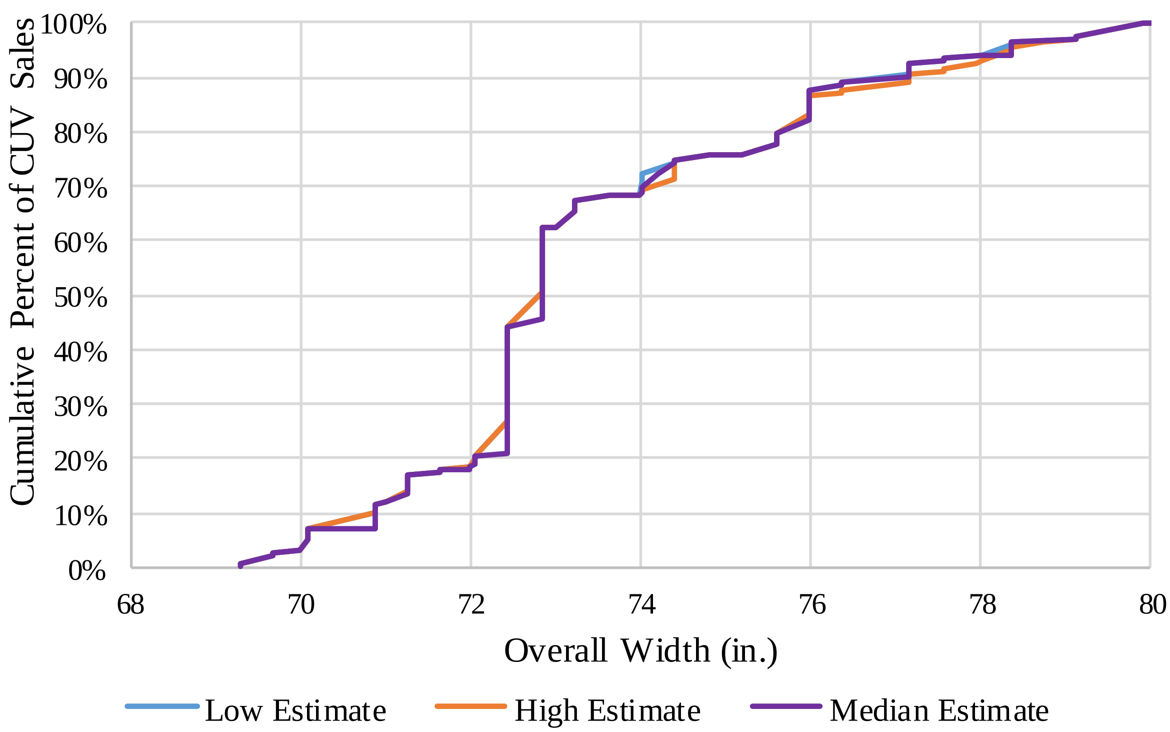

Figure E-4. CUV Overall Width Distribution

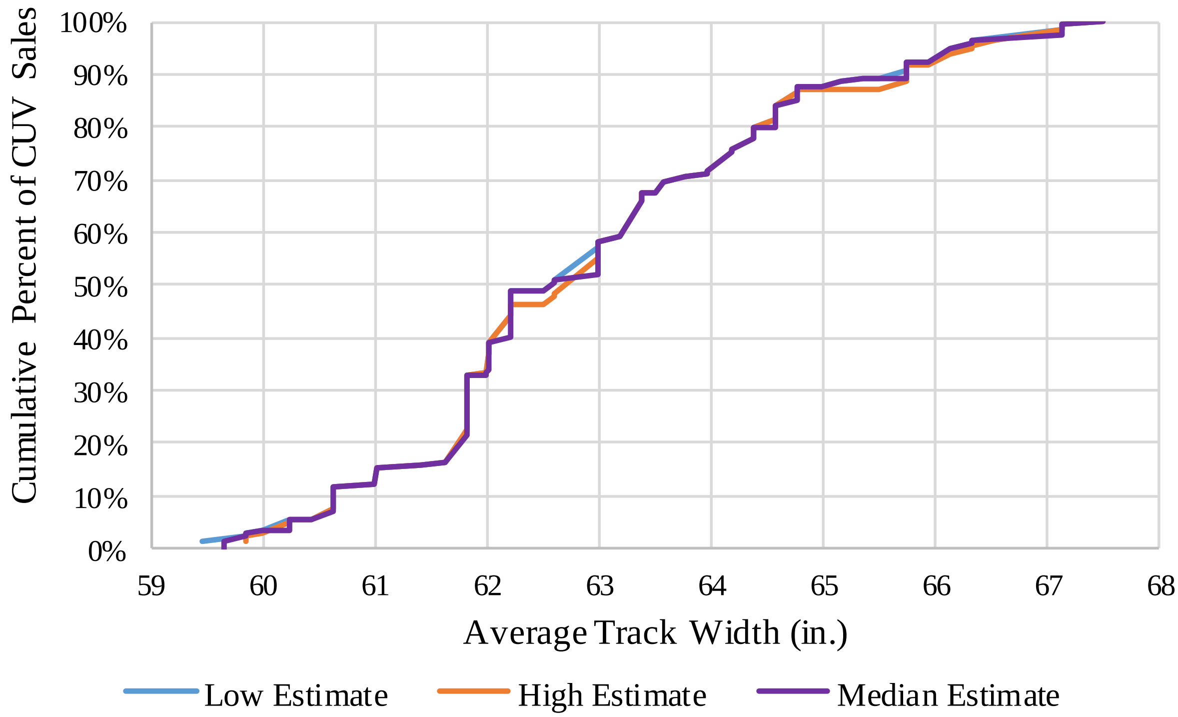

Figure E-5. CUV Average Track Width Distribution

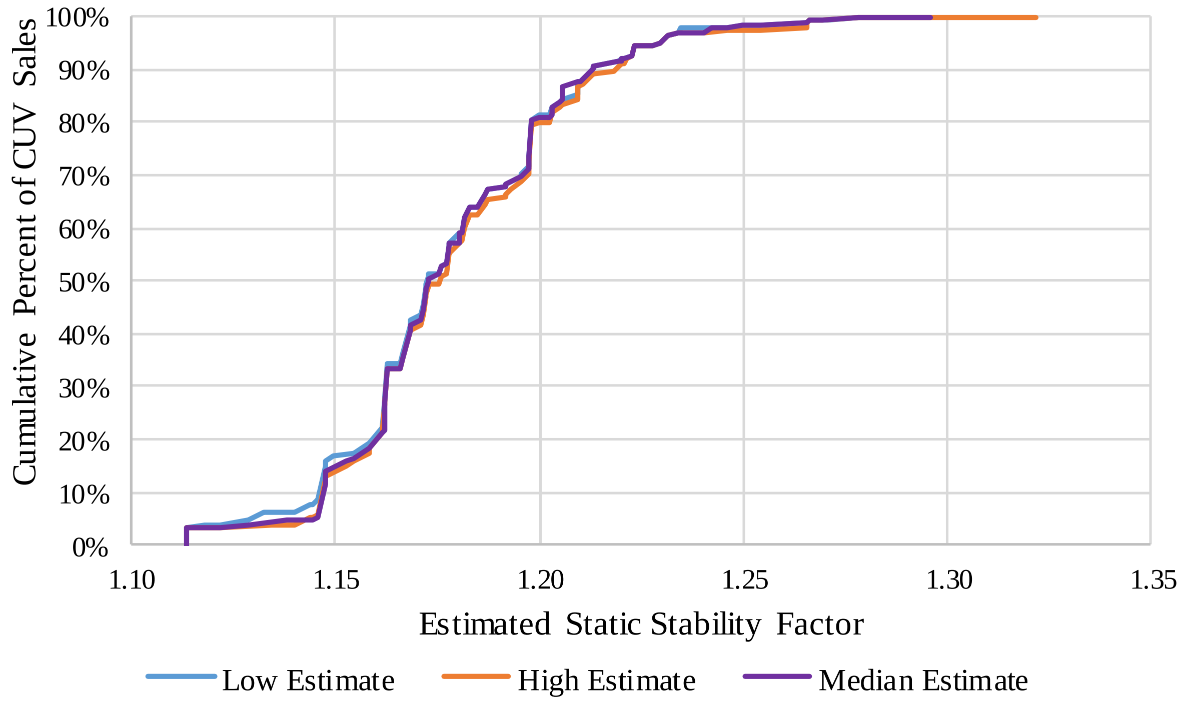

Figure E-6. Estimated CUV SSF Distribution

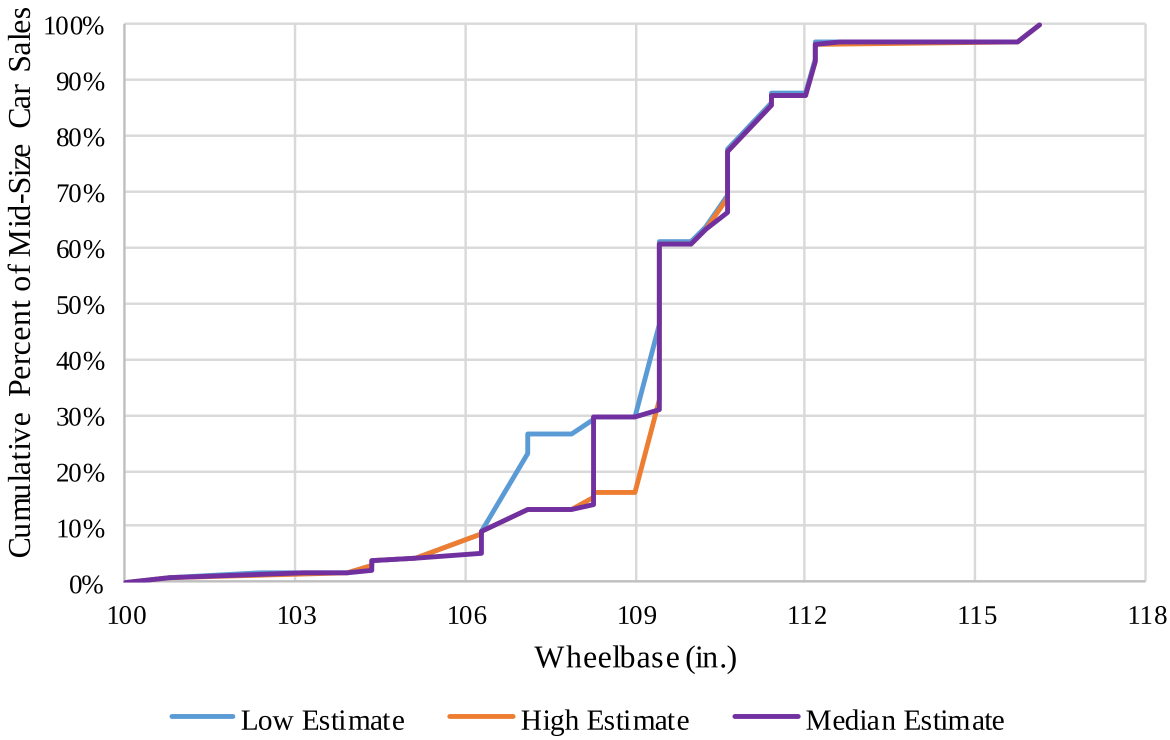

Figure E-7. Mid-Size Car Wheelbase Distribution

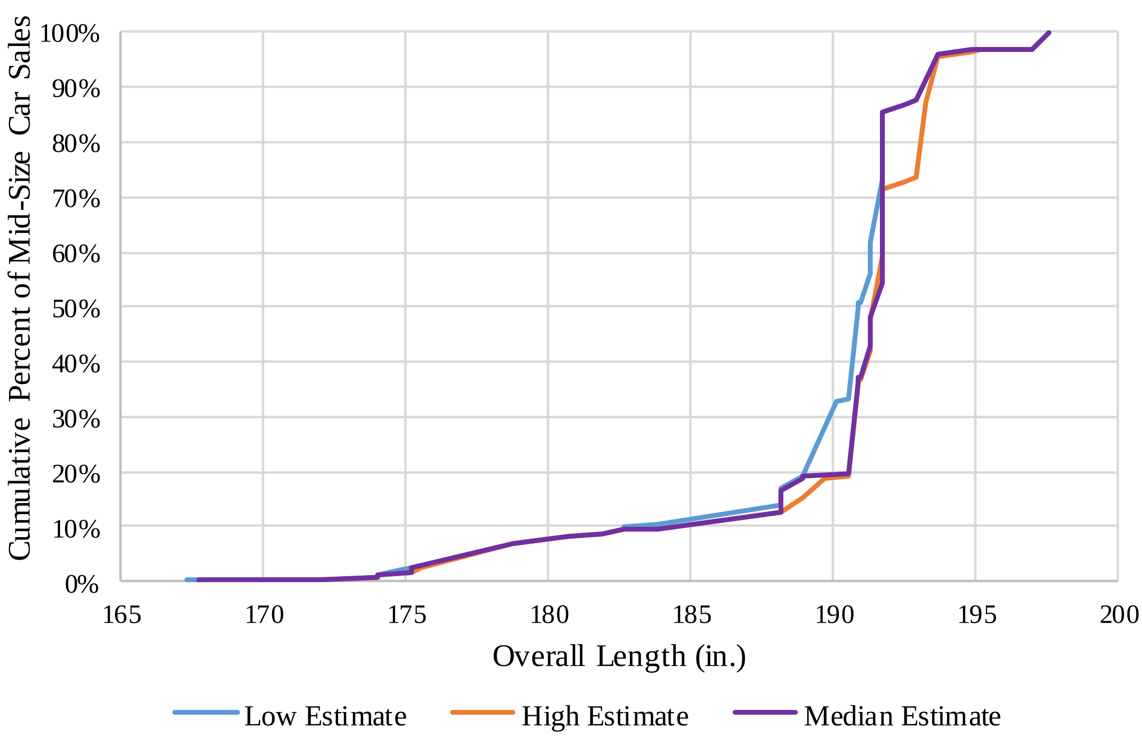

Figure E-8. Mid-Size Car Overall Length Distribution

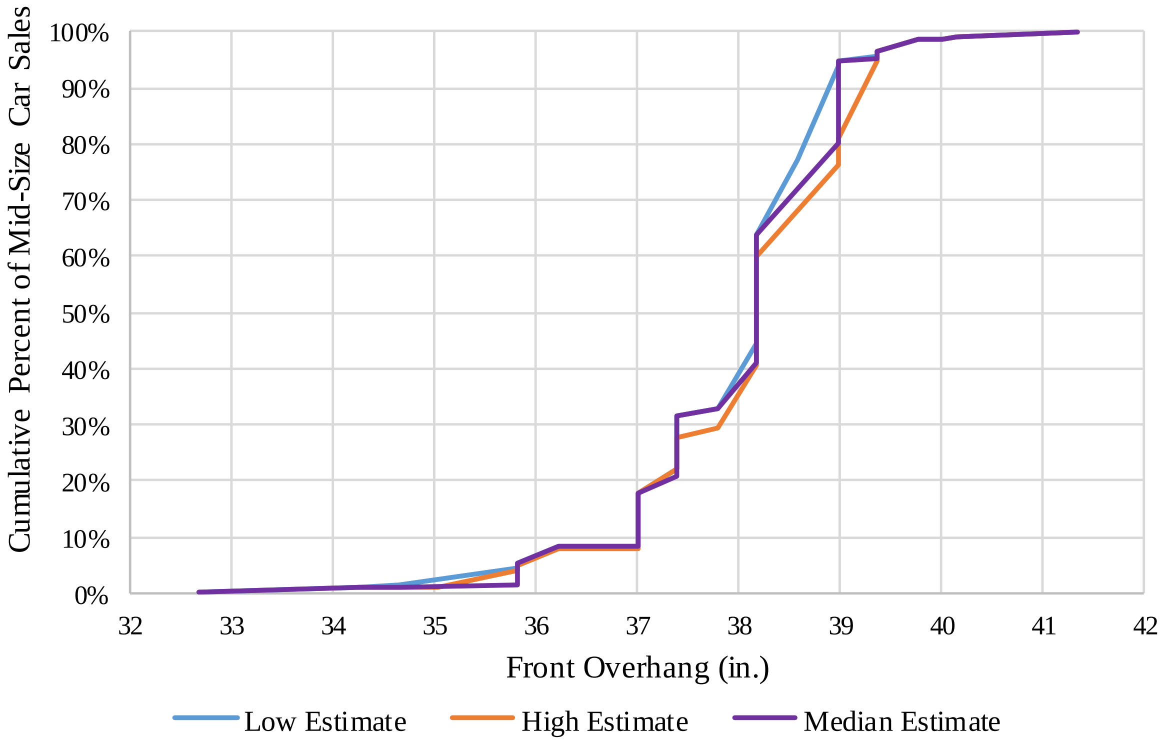

Figure E-9. Mid-Size Car Front Overhang Distribution

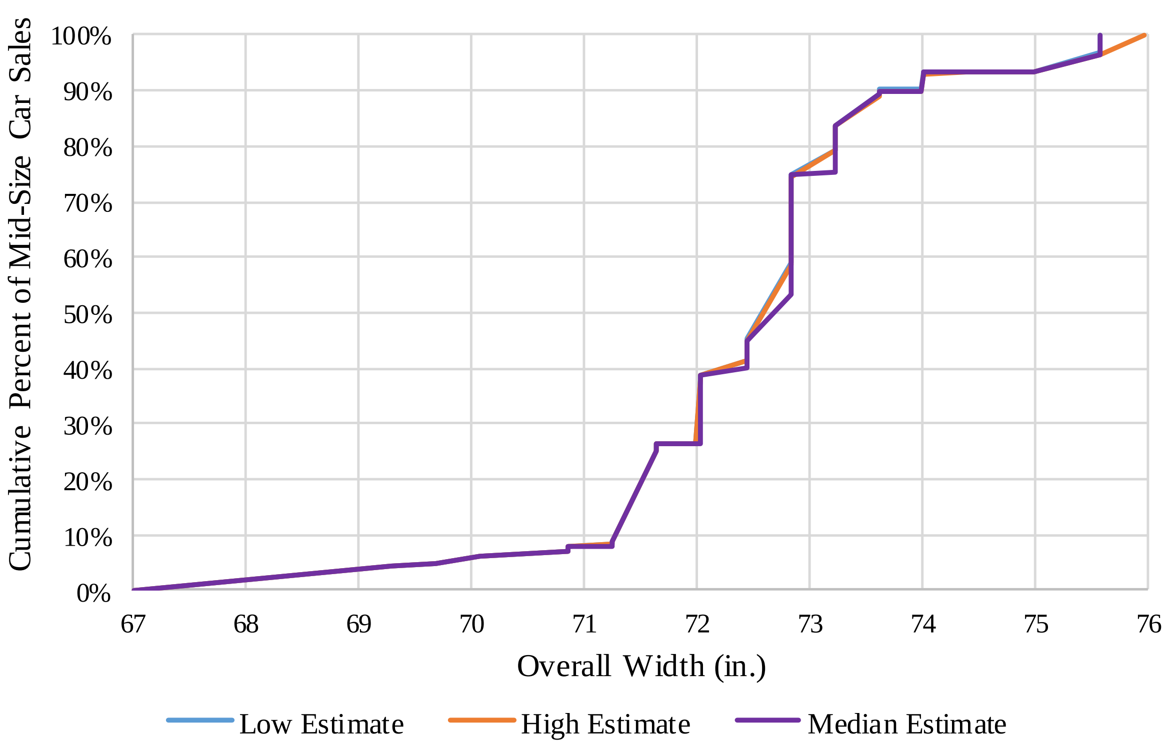

Figure E-10. Mid-Size Car Overall Width Distribution

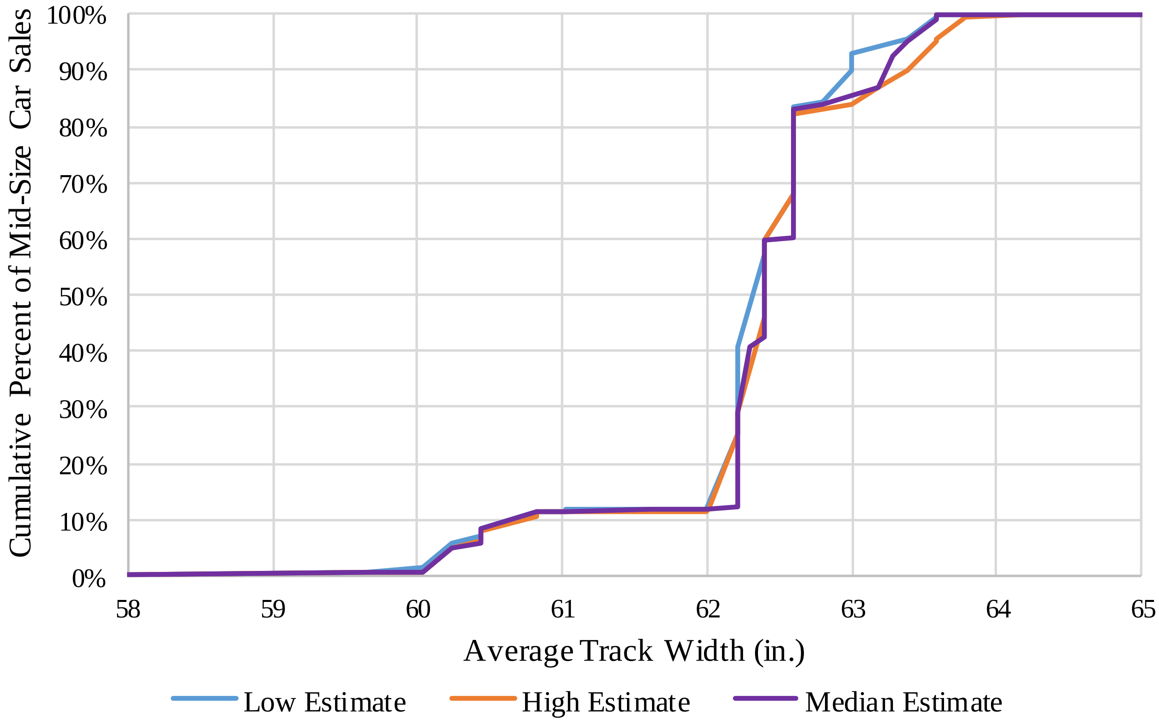

Figure E-11. Mid-Size Car Average Track Width Distribution

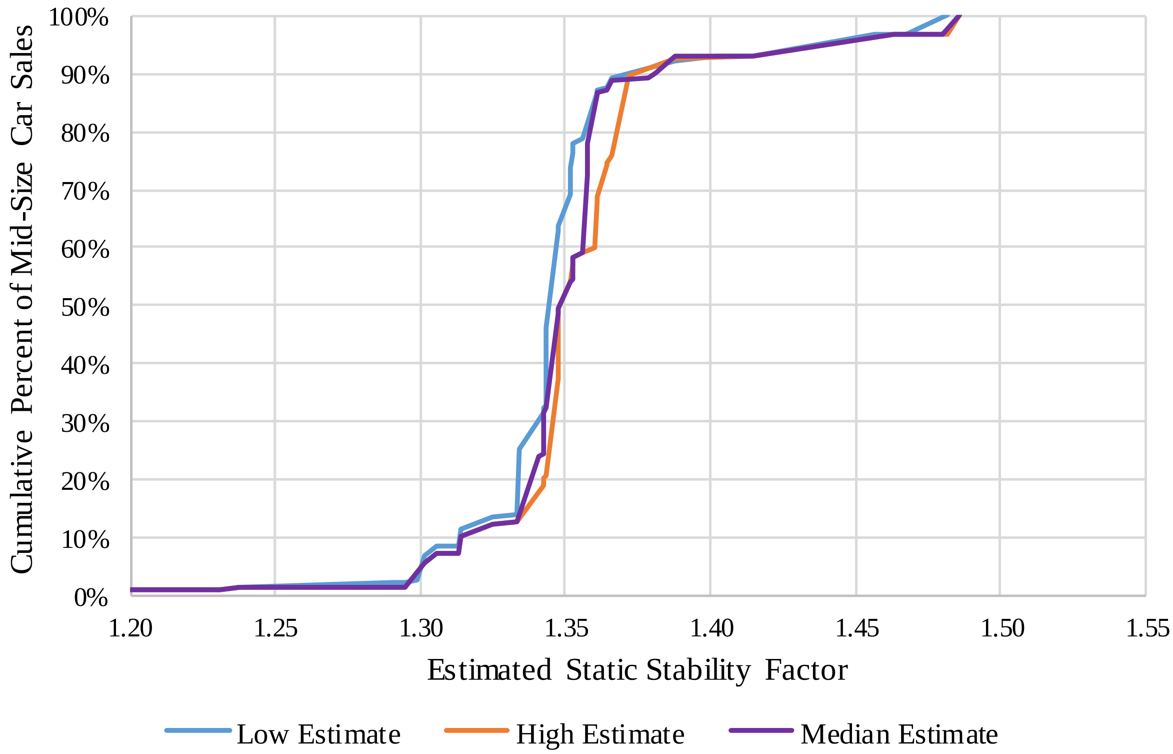

Figure E-12. Estimated Mid-Size Car SSF Distribution

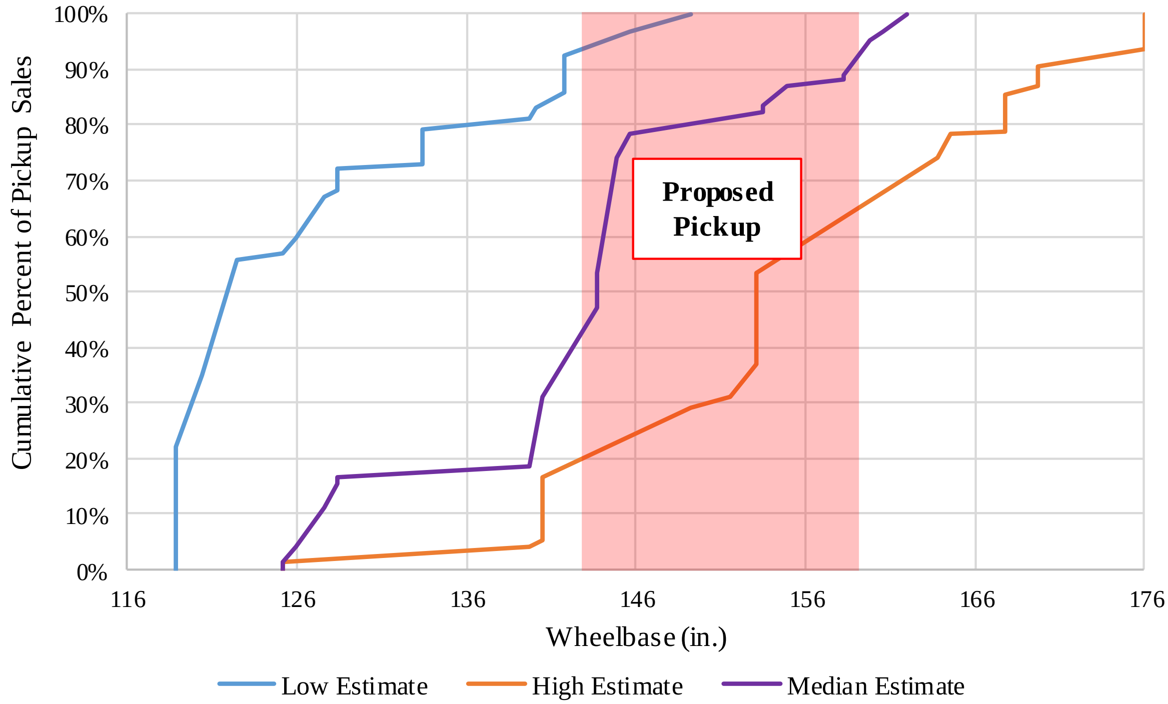

Figure E-13. Pickup Truck Wheelbase Distribution

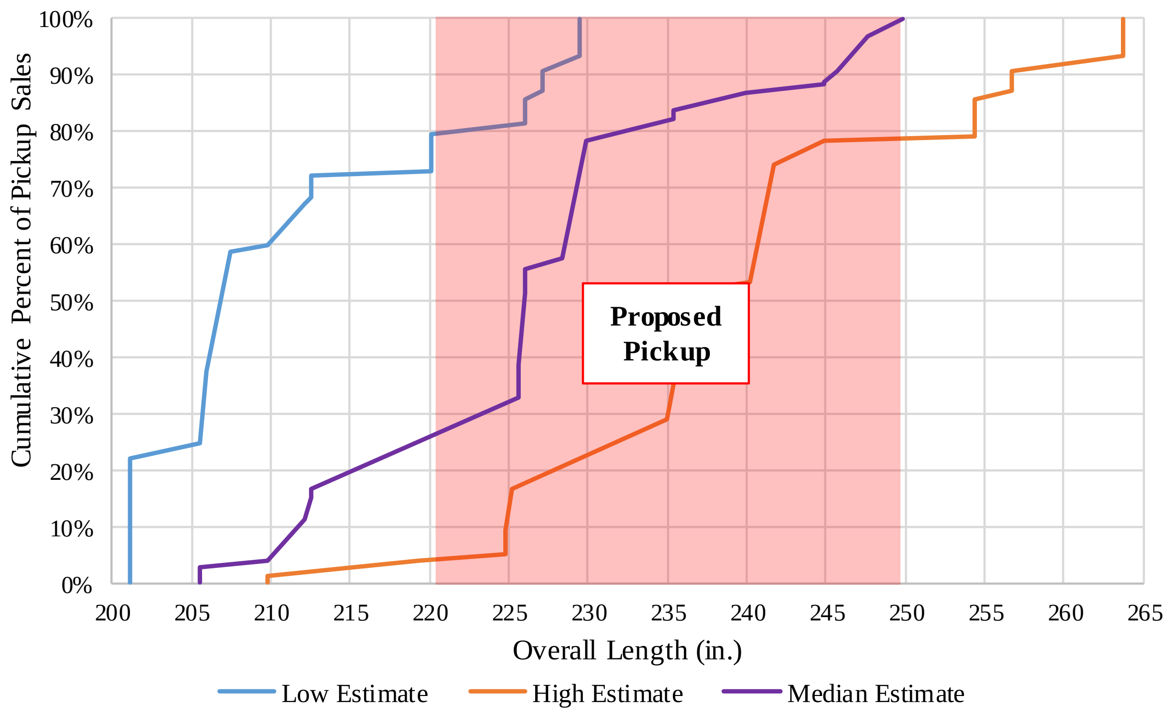

Figure E-14. Pickup Truck Overall Length Distribution

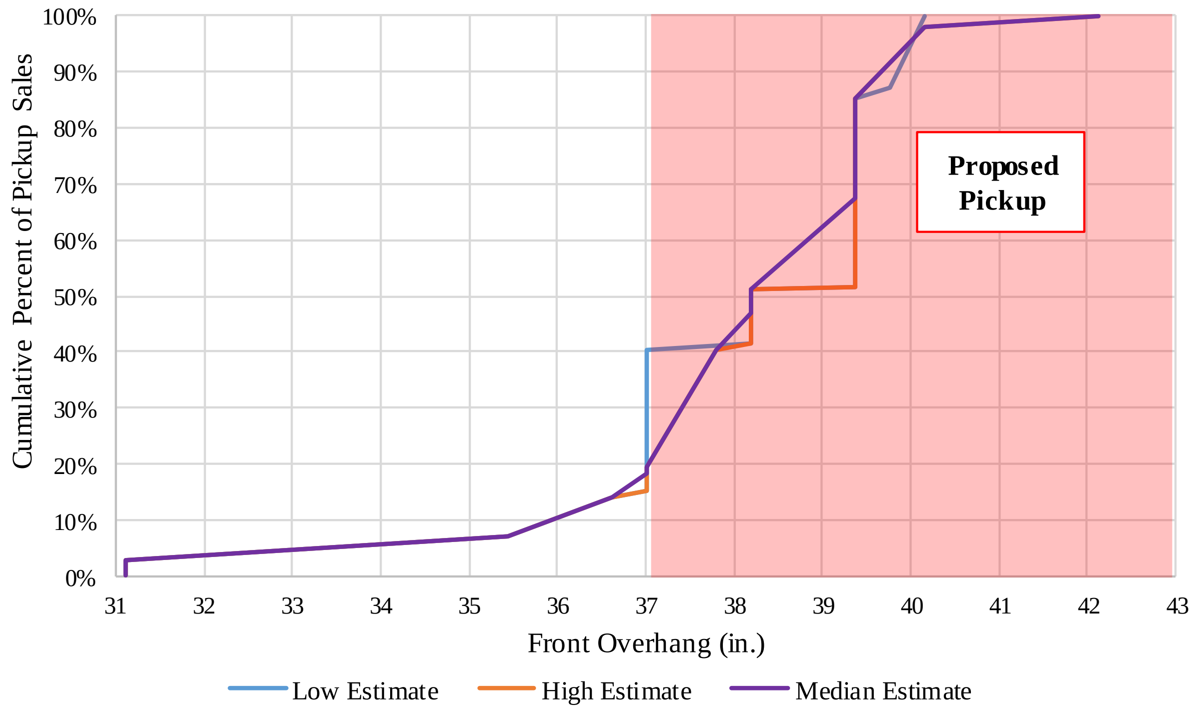

Figure E-15. Pickup Truck Front Overhang Distribution

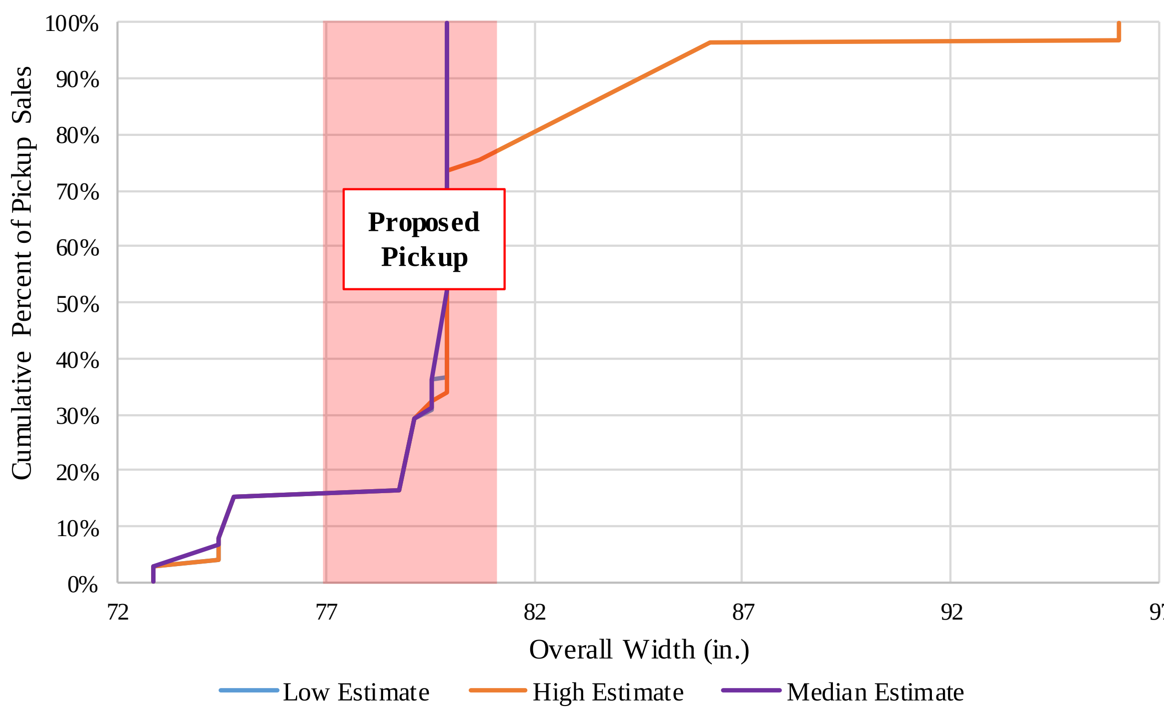

Figure E-16. Pickup Truck Overall Width Distribution

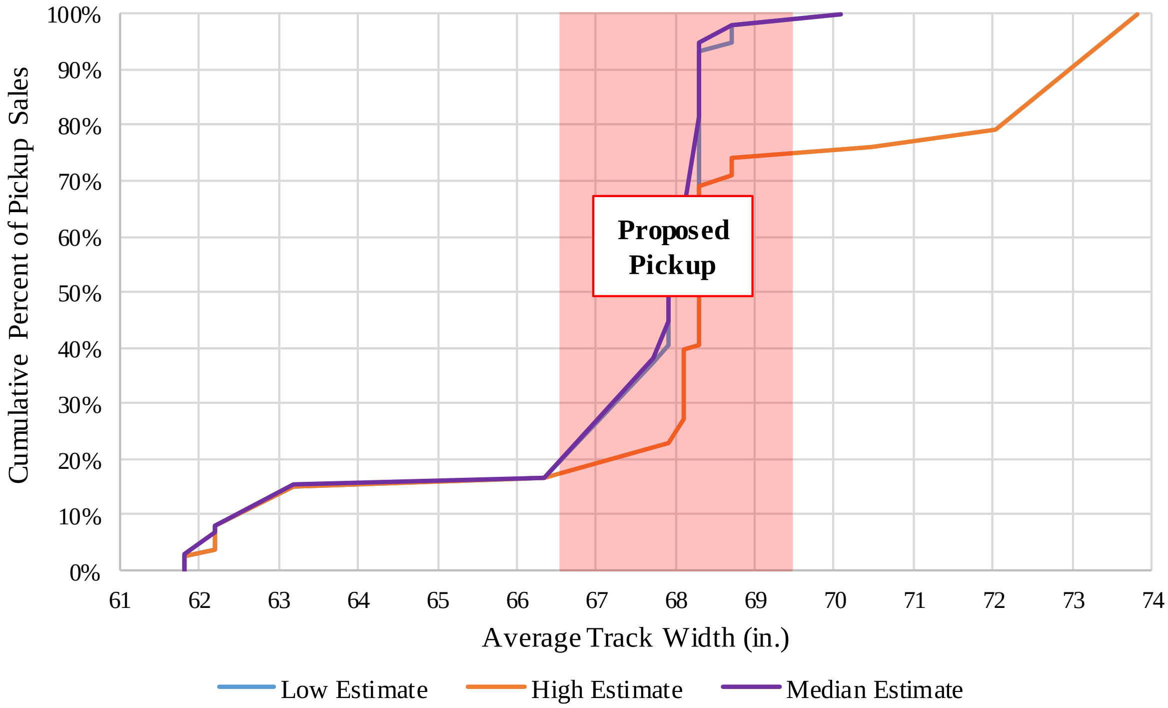

Figure E-17. Pickup Truck Average Track Width Distribution

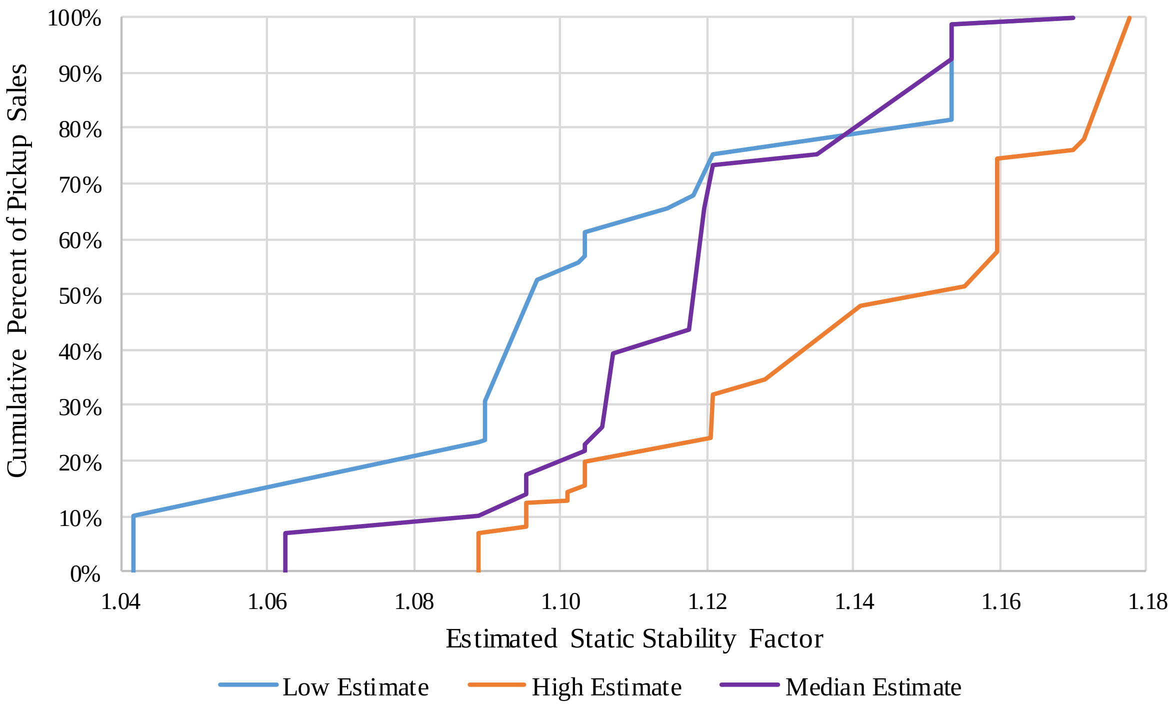

Figure E-18. Estimated Pickup Truck SSF Distribution

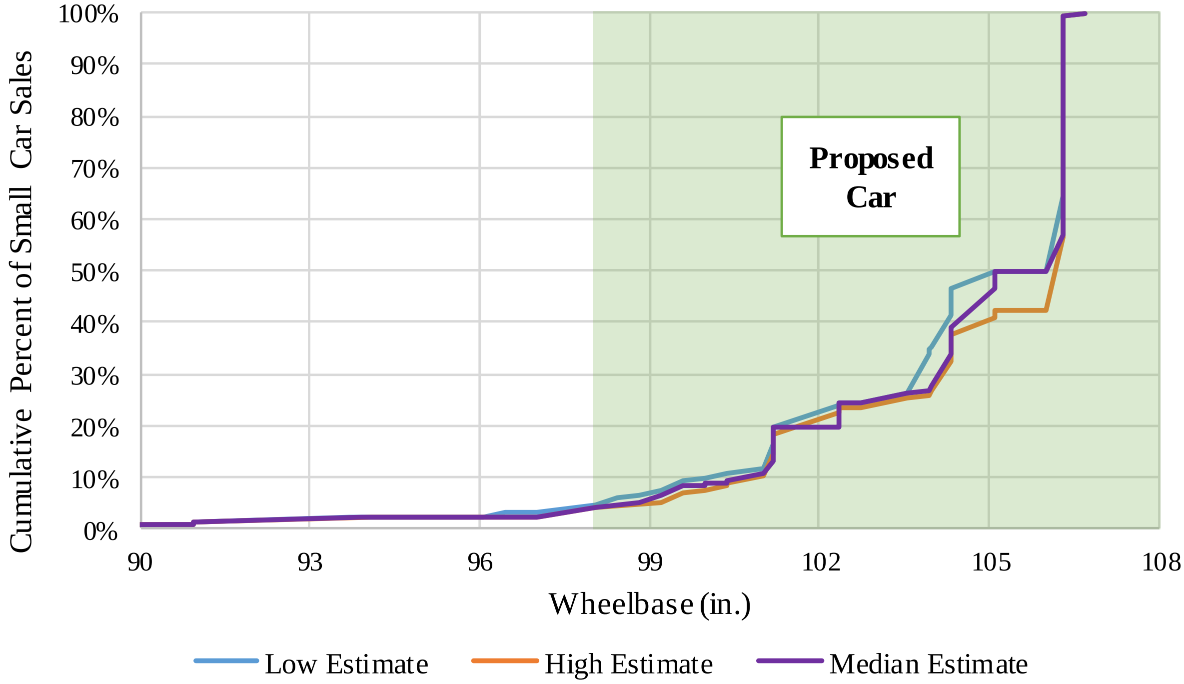

Figure E-19. Small Car Wheelbase Distribution

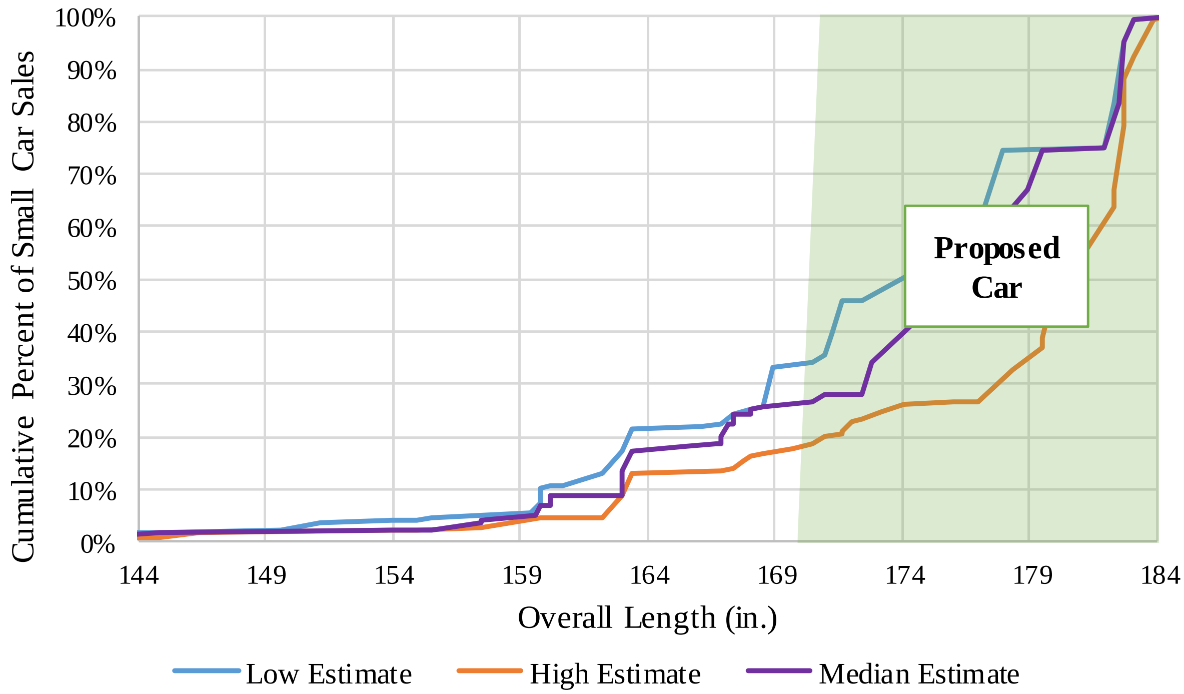

Figure E-20. Small Car Overall Length Distribution

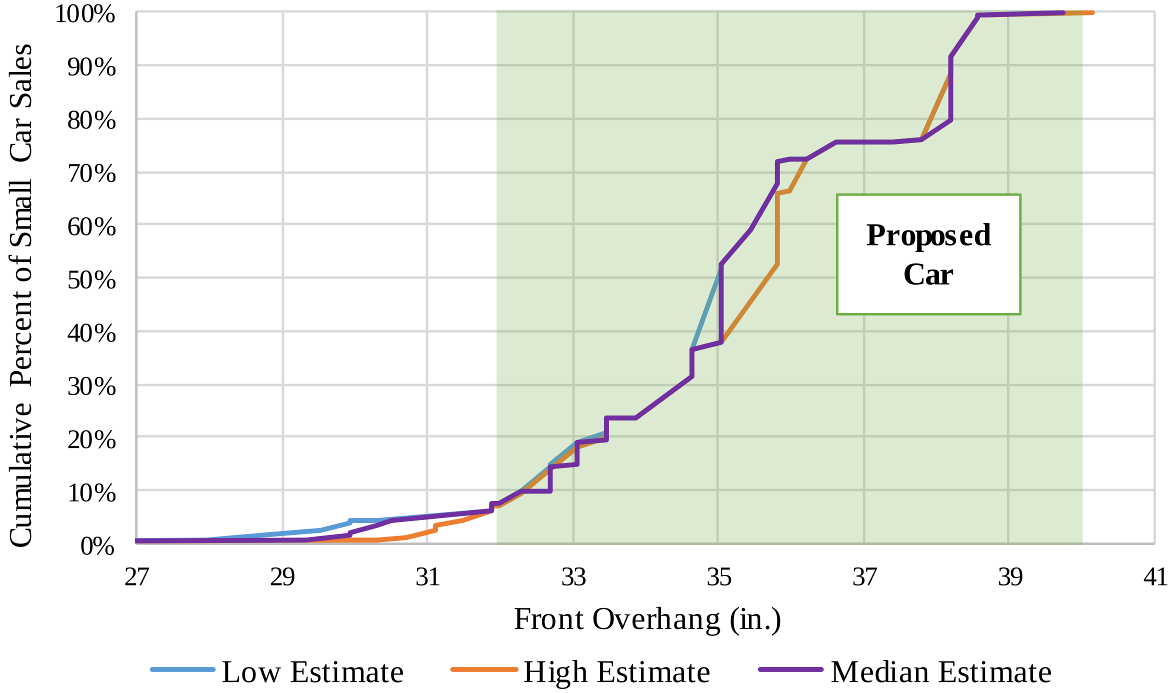

Figure E-21. Small Car Front Overhang Distribution

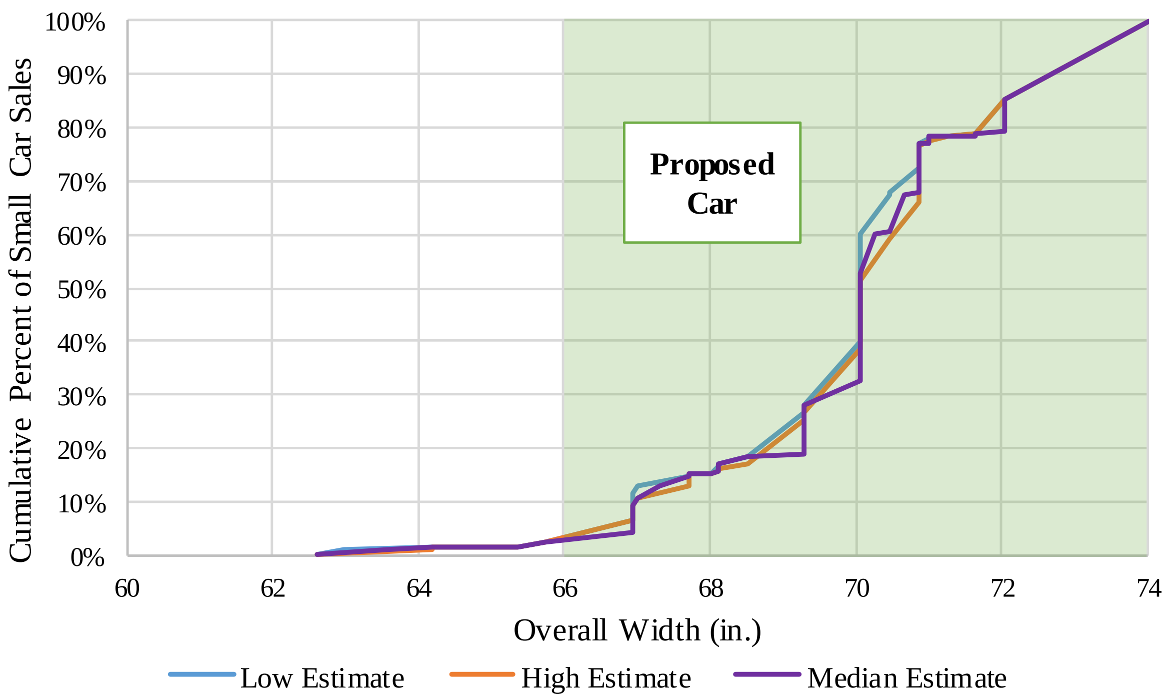

Figure E-22. Small Car Overall Width Distribution

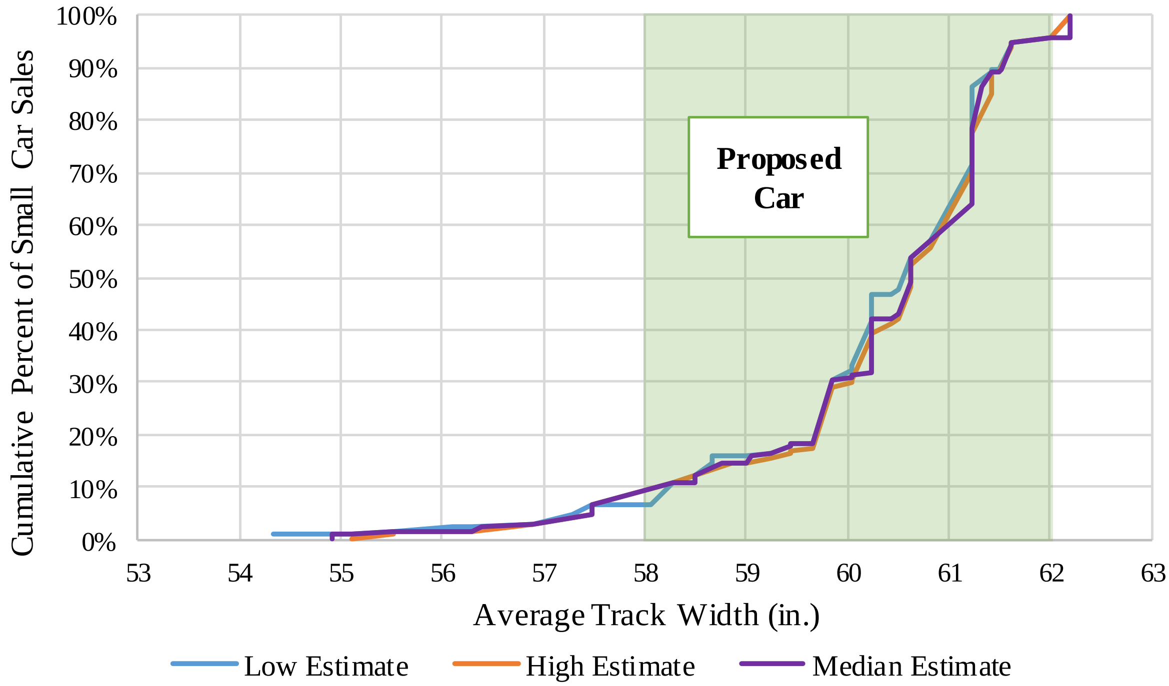

Figure E-23. Small Car Average Track Width Distribution

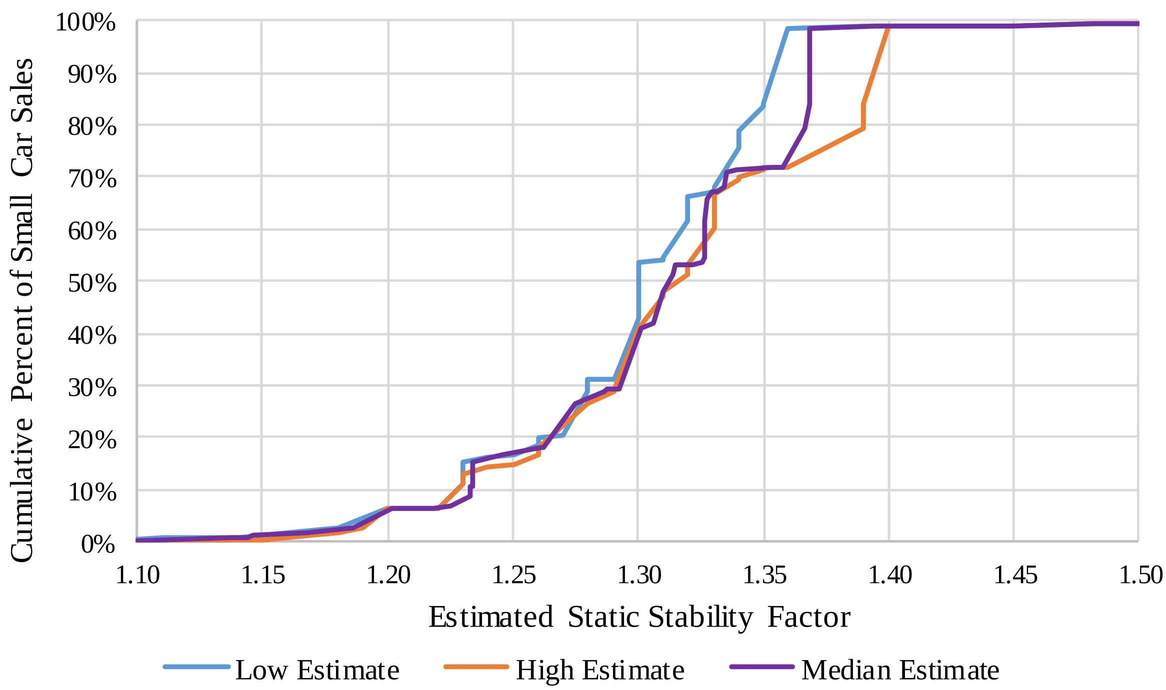

Figure E-24. Estimated Small Car SSF Distribution

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