

IOWA STATE UNIVERSITY

Biobased Automobile Parts Investigation

A report developed for the
USDA Office of Energy Policy and New Uses

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The automobile industry is a very large potential user of biobased products. The use of biobased products has been increasing, yet there are still many parts that may be replaced with biobased materials. This investigation has developed a collaborative list of parts in the top-selling automobiles manufactured in the United States. From this list of parts, an impending list of parts that have the potential to use biobased materials was developed.

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1. Introduction

This study is intended to provide information to a number of audiences regarding the potential application of biobased materials in the manufacture and use of component parts and subassemblies in the manufacture of automobiles and light trucks. This information is expected to be of use to public policymakers, persons and organizations researching and designing such applications, potential manufacturers and suppliers of such products, automobile manufacturers, and other interested stakeholders. Realistic constraints to the use of such materials, along with their potential for enhancing environmental sustainability of the products, are also addressed.

The study outlines the methodology used in data collection and presents some historical context on the use of biobased materials and components by the auto industry and industry sales by manufacturer and model. The study also identifies and discusses a broad range of component categories and parts with potential for biobased content. The study then discusses the constraints and opportunities faced by the automotive industry in the use of components with biobased content, importantly focused on performance in use, durability, weight, safety, cost in a highly competitive industry, and potential for enhanced environmental sustainability.

The information contained in this report was gathered in a specific time frame and subject to the most current available information on the Internet. The information in this report is time sensitive in the fact that the automotive industry is constantly changing, and may not be representative of all the industry's work being conducted with biobased parts.

Because of the proprietary nature of the research on biobased materials and parts, the current status of biobased parts will be incomplete and not comprehensive. Some companies are looking at sustainability, biodegradability, and recyclability in the biobased products they are using or developing for use, which are not addressed in this report.

Challenges in Using Biobased Parts

After discussions with the automotive industry and associations, many challenges became apparent with the use of biobased parts in the automotive industry. One of the main considerations in determining when to manufacture automotive parts from biobased materials is the cost to manufacture the part. Although cost is a major consideration, there are other factors used to determine the best material for manufacturing parts for vehicles. These considerations include the following:

- Part performance – biobased materials may offer improvements such as sound insulation or improved performance characteristics
- Weight – biobased materials may require heavier parts due to lower material strength
- Durability – biobased materials may affect durability depending on the biodegradability nature of the material
- Safety – biobased materials may require substantial testing to ensure safety standards can be met

- Biodegradability – biobased materials may provide excellent biodegradability due to the renewable nature of the source materials
- Sustainability/carbon foot print – biobased materials may or may not make improvements in this area due to being produced from renewable sources. Definitive measures of carbon foot print and broader assessments of sustainability will require utilization of formal lifecycle assessment tools
- Availability of biobased materials – biobased materials availability may improve over time due to the increased demand and research, however, current resources may be have predicted limits
- New attributes or performance characteristics – in some situations biobased lubricants provide improved lubricity and therefore reduce wear on metal parts
- Recyclability – biobased materials may impact established recycling channels

Because these considerations or attributes of the parts are related to the material they are manufactured from, the ultimate use of biobased materials is not a simple process. Switching to biobased materials is a very complex process and is many times an optimal balance of the above considerations against the cost to manufacture. The research and development in the area of biobased materials and parts takes time and money, which affects the bottom-line profits of the automotive manufacturers and their part suppliers.

The use of biobased materials has to also be sold to the customers. The ability to market the use of biobased in automotive manufacturing is important in having the customer accept or appreciate the use of biobased materials without sacrificing performance or characteristics of the automotive vehicle they choose to buy. Marketing the use of biobased materials being used in an automobile costs money and must be part of the consideration in the cost of using biobased parts.

The above challenges contribute to the complex nature of the automotive industry and its products. This complexity is increased by the proprietary nature of the research and development of biobased materials and parts. New biobased materials are being developed each year, which means that new standards to evaluate those materials need to be developed along with new processes to manufacture parts from those biobased materials.

Investigation Method

On February 10, 2010, research of the automobile industry began, the goal was to develop a list of parts in the modern consumer vehicle and, from there, determine which parts and components would be potential candidates for biobased material substitution.

To start this project, a list of all automakers with production in the United States and their contact information was developed. Then a list of car parts from a reliable source had to be developed, preferably from the automakers themselves. This proved to be a challenge because most of the companies' websites failed to have a comprehensive list—they simply suggested that one contact a local

dealer for parts and maintenance. One company, for example, had a very convenient list of parts directly on their website, while others had nothing.

Because of lack of information on the company sites, alternative methods and websites had to be employed. A search of the Internet for other sites that might provide the information needed eventually produced a site that could provide a breakdown of parts for many of the vehicles manufactured in the United States. This site, Auto Parts Center—Genuine OEM Auto Parts and Accessories (<http://www.autopartscenter.net/>), had a comprehensive list for every car from the companies that manufacture in the United States. To verify that the list of parts was reliable and accurate, the site had to be authenticated before it could be used, so questions were posed to the site owners. It was determined that this site was directly affiliated with the car companies in question; thus it was deemed a reliable source.

The next step was to compare parts lists and determine if there were any large differences between the four body types of vehicles. Based on sales and vehicle types, four types of vehicles were selected—one sedan, hybrid sedan, sport utility vehicle (SUV), and truck from each company. The companies researched included the big three automakers in the United States: Ford, Chrysler, and General Motors (GM), as well as Toyota, and Honda.

The parts on the Auto Parts Center site were categorized into HVAC (heating, ventilating, and air conditioning), Interior, Body, Lights, and Steering. A comparison of all categories for the different vehicle types for one company, GM, was then conducted. Aside from a few external body parts, little differences were found between the sedan, truck, SUV, and hybrid sedan other than the fact that the hybrid sedan contained special hybrid components. Further details can be found in the Auto Parts Data section.

The following definitions were used when differentiating between parts:

- Biobased—A product determined by the U.S. Secretary of Agriculture to be a commercial or industrial product (other than food or feed) that is either (1) composed, in whole or in significant part, of biological products, including renewable domestic agricultural materials and forestry materials; or (2) an intermediate ingredient or feedstock [1].
- Organic—Material that contains carbon and hydrogen and usually other elements such as nitrogen, sulfur, and oxygen. Organic compounds can be found in nature or they can be synthesized in the laboratory. An organic substance is not the same as a "natural" substance. A natural material means that it is essentially the same as it was found in nature, but "organic" means that it is carbon based [2].
- Recyclable (materials)—Materials that are separated from the waste stream and collected for use as a substitute for raw materials in a manufacturing process [3].

2. Background

The history of biobased automobile parts begins early in the development of automobiles themselves. During the 1930s, automobile pioneer Henry Ford began developing soy-based automobile parts. Research in the development of biobased products was short lived. A focus on production of World War II related materials limited efforts to continue research [4].

Today Ford and the other automotive manufacturers are demonstrating a commitment to create biobased car parts. Below are a few examples of what is currently in production and currently in development.

Henry Ford demonstrates the strength of his biobased trunk [4].



Examples of Biobased Parts Currently in Production

Daimler

Daimler is currently producing an air filter system that is made of 60% polyamide. It received the 2009 VDI (Verein Deutscher Ingenieure) award for the innovative application of plastics. This air filter system will replace the plastics produced from fossil fuel resources. To demonstrate its commitment to the development of biobased materials, Daimler placed this air filter in its Mercedes Benz line [5]. In addition, the door cladding, seatback linings, and package shelves of the Mercedes Benz contain process flax, hemp, and sisal. Seat bottoms, back cushions, and head restraints contain coconut fiber and caoutchouc (a source of natural latex). Under-floor body panels are made using the abaca tree [6]. These panels are used on the cover for the spare-wheel compartment in the three-door version of the Mercedes Benz A-Class model. The abaca plant fibers used have very high tensile strength [7].

Ford

Ford has also demonstrated a commitment to the biobased industry. The 2010 Ford Flex's third-row interior storage bins contained 20% wheat straw biofiller. Soy-based polyurethane foams have been placed in the seat cushions and seatbacks of the Ford Mustang, Expedition, F-150, Focus, Escape, Escape Hybrid, Mercury Mariner, Lincoln Navigator, Lincoln MKS, and, most recently, 2010 Taurus. Soy-foam headliners were put in place for the 2010 Ford Escape and Mercury Mariner. Part of the Ford Mustang GT RTD body is made of flax fiber-reinforced linseed-acrylate, which is a high-performance composite made of natural fibers embedded in a resin from the same plants (flax and linseed) [5].

General Motors

General Motors has also been utilizing natural ingredients in several of its automobiles. The Saturn L300 and European-market Opel Vectra have package trays and door panel inserts made of a kenaf and flax

mixture. Wood fiber is being used in the cargo area floor of the GMC Envoy and Chevrolet Trail Blazer as well as in seatbacks for the Cadillac DeVille [6].

Mazda

In 2007, Mazda announced the development of a new fabric made entirely from plant fibers. It was to be used for seat covers and door trim in the Premacy Hydrogen RE Hybrid car. This car also includes a bioplastic for the instrument panel and other interior fittings. Mazda is dedicated to continuing its research and development efforts for these environmentally friendly technologies [8].

Honda

Honda has developed a plant-based fabric that is used for its vehicle interiors including seat covers, door coverings, headliners, floor mats, and other fabric-covered surfaces. The material is both durable and resistant to light and has the potential to reduce energy consumption during production by 10–15%. The fabric is to be used in Honda's fuel cell vehicles [9].

Goodyear

Tires for Goodyear have been developed using Biolsoprene™ technology, which is made from a renewable resource. Biolsoprene™ is a new alternative to replace a petrochemically created ingredient in the manufacture of synthetic rubber with renewable biomass. Goodyear has already been using BioTREND technology, which replaces carbon black with a starch-based (MaterBi) reinforcement. The production of these tires uses less energy [5].

Oregon State University

Wood science researchers at Oregon State University have been testing the use of microcrystalline cellulose to partially replace silica as reinforcing filler in the manufacture of rubber tires. "Cellulose fiber is a product that can be made from almost any type of plant fiber" and "has been used for some time as reinforcement in some types of rubber and automotive products, such as belts, hoses, and insulation, but never in tires." Oregon State University researchers have found that replacing some of the silica with the cellulose fiber reduces the amount of energy needed to produce the tire [5].

Examples of Biobased Parts Currently in Development

Along with biobased products that are already produced, several biobased parts are currently in development. The list below is not inclusive of all manufacturers who are developing biobased parts or their development activities. Because of the proprietary nature of the research and development, this list is very limited and does not represent the current status of development.

Daimler

A joint development project that is funded by the German Federal Ministry of Education and Research centers its activities on biobased polyamides for automotive applications. An air filter for the new Mercedes Benz engine is being produced from polyamide 6.10 and 5.10, and soon any "automotive components that are currently made from high performance plastics produced from fossil raw materials will be made using biopolymers." In addition to the air filter, other parts are being tested and analyzed, including an accelerator pedal module, a cogwheel for the steering angle sensor, and a cooling fan. Trials

are currently being carried out on sample components that are made from biopolyamides suitable for mass production [5].

In 2005, DaimlerChrysler was developing flexible tubing for fuel and brake systems made with castor oil. The corporation has also been using coconut fiber and caoutchouc to produce seat bottoms, back cushions, and head restraints [6].

Ford

Ford Motor Company has teamed up with academic researchers to develop an environmentally friendly wheat straw-reinforced plastic. The first application of this product was in the 2010 Ford Flex, specifically used for center console bins and trays, interior air register and door trim panel components, and armrest liners [5]. Ford is also working on adding biobased content into the following parts: floor mats, gaskets, seals, splash panels, underbody panels, radiator air deflectors, cowl plugs, mounting plates, and underbody components.

Renault

A new generation BioConcept-Car, the Renault Mégane Trophy, was presented during Composites Europe 2009. This car already utilizes biofuels; however, doors, fenders, engine hood, bumpers, spoilers, and trunk lids made completely from biocomposites are currently being developed for use in this vehicle [5].

3. Industry Associations

Motor & Equipment Manufacturers Association (MEMA)*

The Motor & Equipment Manufacturers Association represents motor vehicle parts suppliers and serves members through its three affiliate associations: the Automotive Aftermarket Suppliers Association, Heavy Duty Manufacturers Association, and Original Equipment Suppliers Association. The association provides its members with seminars and conferences on industry issues, networking, a forum to address issues of concern, and vital information on market trends.

The Auto Alliance*

The Auto Alliance represents a united auto industry. It is dedicated to developing and applying constructive answers to public policy challenges that promote sustainability and benefit society in the areas of environment, energy, and motor vehicle safety. The Auto Alliance represents 77% of all car and light truck sales including the BMW Group, Chrysler Group LLC, Ford Motor Company, GM Corporation, Jaguar Land Rover, Mazda, Mercedes-Benz, Mitsubishi, Porsche, Toyota, and Volkswagen.

Clean Fuels Development Coalition (CFDC)*

The CFDC is a nonprofit organization that supports the increased production and use of fuels that can minimize air pollution and oil imports. The CFDC has worked with four presidential administrations and eight different congressional delegations to build support in industry and government to promote a healthy national energy policy.

Association of International Automobile Manufacturers (AIAM)

The AIAM represents international motor vehicle manufacturers, original equipment suppliers, and other automotive-related trade associations. The AIAM supplies its members with information and support on a wide range of legislative and regulatory issues impacting the auto sector.

Automotive Industry Action Group (AIAG)

The AIAG is a globally recognized organization that offers an open forum where members work together to develop and promote solutions that improve the success of the automotive industry. Members of the AIAG play a unique role in the development of new technologies and the standards that govern the use of these new technologies. The organization was founded by managers from Chrysler, Ford Motor Company, and General Motors.

Automotive Learning Center

The Automotive Learning Center is a division of the American Chemistry Council that provides information regarding “Plastics & Today’s Automobiles,” “Tomorrow’s Automobiles,” “Education & Seminars,” and “Automobile Recycling.”

*These associations have been contacted by USDA BioPreferred in the past.

Note: Industry association contact information is found in Appendix A.

4. Auto Manufacturers Producing in the United States

Manufacturer History

BMW

Bayerische Motoren Werke AG (BMW) (English: Bavarian Motor Works) is a German automobile, motorcycle, and engine manufacturing company founded in 1916. It also owns and produces the Mini brand and is the parent company of Rolls-Royce Motor Cars. It produces motorcycles under BMW Motorrad and Husqvarna brands.

Chrysler

Chrysler Group LLC is a U.S. automobile manufacturer headquartered in the Detroit suburb of Auburn Hills, Michigan. Chrysler was first recognized as the Chrysler Corporation in 1925. From 1998 to 2007, Chrysler and its subsidiaries were part of the German-based DaimlerChrysler AG. In 2007 Daimler AG announced the sale of Chrysler Group to American private equity firm Cerberus Capital Management, L.P.

Daimler

Daimler AG (formerly DaimlerChrysler) is a German car corporation and the world's thirteenth-largest car manufacturer. Originally founded in 1883, Benz & Company merged with Daimler Motoren Gesellschaft AG in 1926 to become Daimler-Benz AG. In 1998 there was another merger, this time with American automobile manufacturer Chrysler Corporation. From 1998 to 2007, the company was then known as DaimlerChrysler AG. In 2007, though, DaimlerChrysler AG sold the Chrysler group to the private firm Cerberus Capital Management and formally changed its name to Daimler AG.

Ford

The Ford Motor Company, based in Dearborn, Michigan, a suburb of Detroit, was founded by Henry Ford and incorporated in 1903. Ford owns the Ford, Lincoln, and Mercury brands as well as Volvo. Ford introduced large-scale manufacturing methods of cars using engineered manufacturing sequences typified by moving assembly lines. Currently, Ford is the second-largest U.S. automaker and fifth in the world based on number of vehicles sold annually.

General Motors

General Motors Company, also known as GM, is a U.S. automobile manufacturer headquartered in Detroit, Michigan. Founded in 1908, GM currently has operations worldwide and was the largest U.S. automaker in 2008. Currently, GM owns the Chevrolet, Cadillac, Buick, and GMC brands.

Honda

Honda Motor Company, Ltd., is a Japanese multinational corporation known for automobile and motorcycle manufacturing. Founded in 1948, Honda is the world's largest manufacturer of motorcycles and recently surpassed Chrysler as the fourth-largest automobile manufacturer in the United States. In addition to automobiles, Honda has been involved in artificial intelligence/robotics research. It has also ventured into aerospace with the HA-420 Honda Jet.

Hyundai

Hyundai Motor Company, a division of Hyundai Kia Automotive Group, is the world's largest automaker by profit and the world's fourth-largest automaker by units sold. Founded in 1967, Hyundai is headquartered in Seoul, South Korea, with about 75,000 employees worldwide. Hyundai entered the U.S. market in 1986 with the Hyundai Excel. After the introduction of the Excel, Hyundai soon invested more prominently in quality and design and has since been given top marks from J. D. Power and Associates, placing third overall in the Initial Quality Survey.

Kia

With headquarters in Seoul, Kia is South Korea's second-largest automobile manufacturer. Founded in 1944, Kia is now a division of the Hyundai Kia Automotive Group and employs more than 42,000 people worldwide. As of August 2009, Kia has grown to be the eighth best-selling automotive brand in the United States.

Mazda

With more than 39,000 employees, Mazda, of Hiroshima, Japan, was founded in 1920, although it did not manufacture cars until 1931. Before that Mazda was known as the Toyo Cork Kogyo Co., Ltd., and manufactured machine tools for vehicles as well as weapons throughout the Second World War. Although every automobile has used the Mazda name, it was not formally adopted until 1984.

Mitsubishi

Mitsubishi Motors Corporation is the sixth-largest automaker in Japan and the seventeenth-largest in the world. Founded in 1970, Mitsubishi now has its corporate headquarters in Tokyo, Japan, and employs more than 33,000 people worldwide.

Nissan

Nissan Motor Company, Ltd., is headquartered in Yokohama, Japan, and is the third-largest Japanese car manufacturer. Nissan Motor Company, founded in 1933, owns the Nissan brand and also the Infiniti luxury brand. Although based in Japan, all machinery, vehicle designs, and engine designs originally came out of the United States.

Subaru

Established in 1954, Subaru is the brand name of Japanese transportation conglomerate Fuji Heavy Industries. With corporate headquarters in Gunma, Japan, Subaru also owns Subaru of America headquarters in Cherry Hill, New Jersey.

Toyota

Toyota Motor Corporation, headquartered in Toyota City, Aichi, Japan, is the world's largest automobile manufacturer. Founded in 1937, Toyota also owns Lexus and Scion brands. In addition to automobile manufacturing, Toyota provides financial services and builds robots.

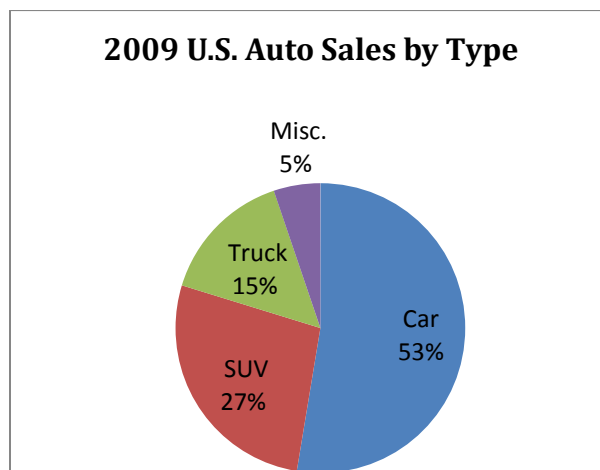
Volkswagen

Volkswagen, founded in 1937, has headquarters in Wolfsburg, Lower Saxony, Germany, and is one of the top five producers of motor vehicles in the world. Among the Volkswagen brands are Audi, Bentley Motors, Bugatti Automobiles, and Lamborghini.

Note: Manufacturer contact information is found in Appendix A.

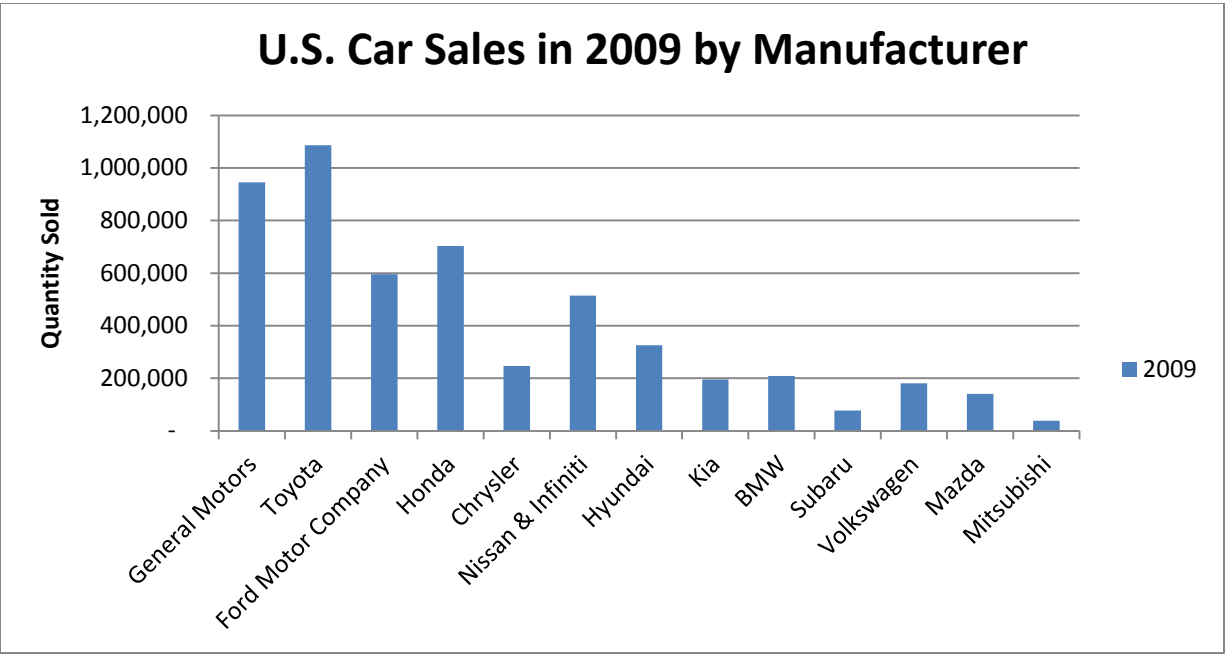
Types of Vehicles Sold in United States

To provide an idea of the size of the auto industry and major manufacturers, the following graphs are representative of available sales data for U.S. auto manufacturers. The use of the word “Car” refers to sedans, sports wagons, hatchbacks, sports cars, hybrids, and convertibles. The label of “Misc.” refers to the vehicles that do not fall into the other three categories, such as vans or semis/commercial delivery vehicles. Because of the unavailability of U.S. sales data, Daimler sales were omitted from the graph. Material from references [10]–[33] was used in compiling the graphs.

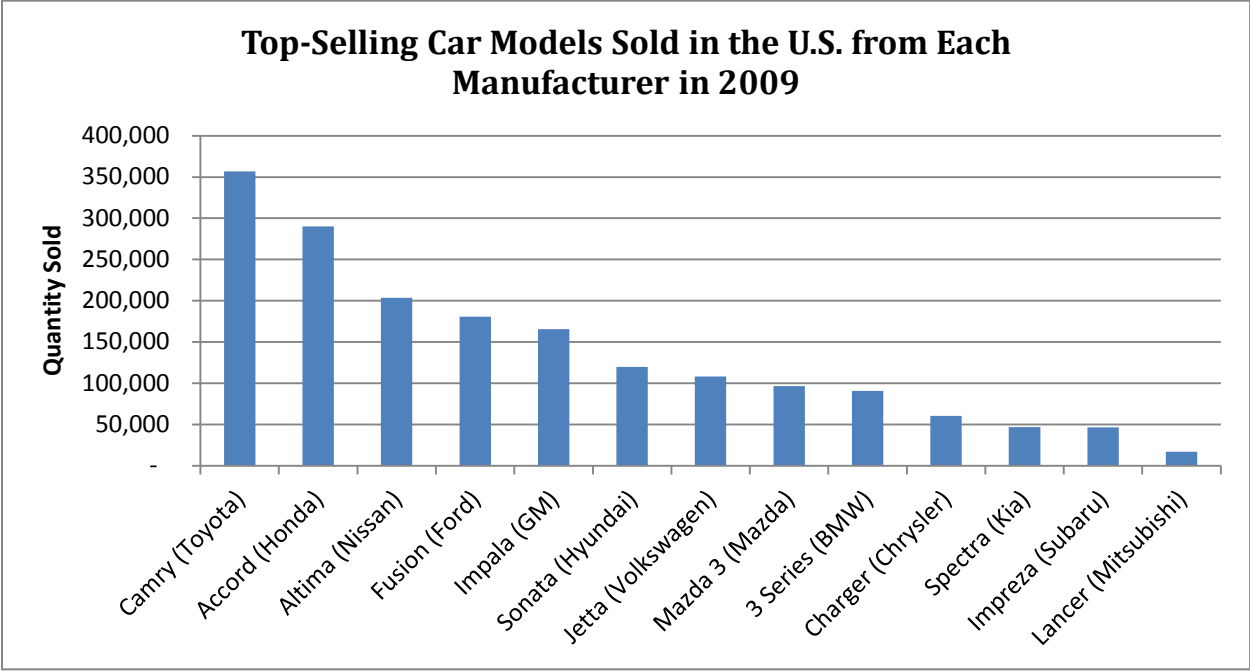


The above graph demonstrates the dominance of car sales in the automobile market. The car sales consistently hold the majority of the automobile industry.

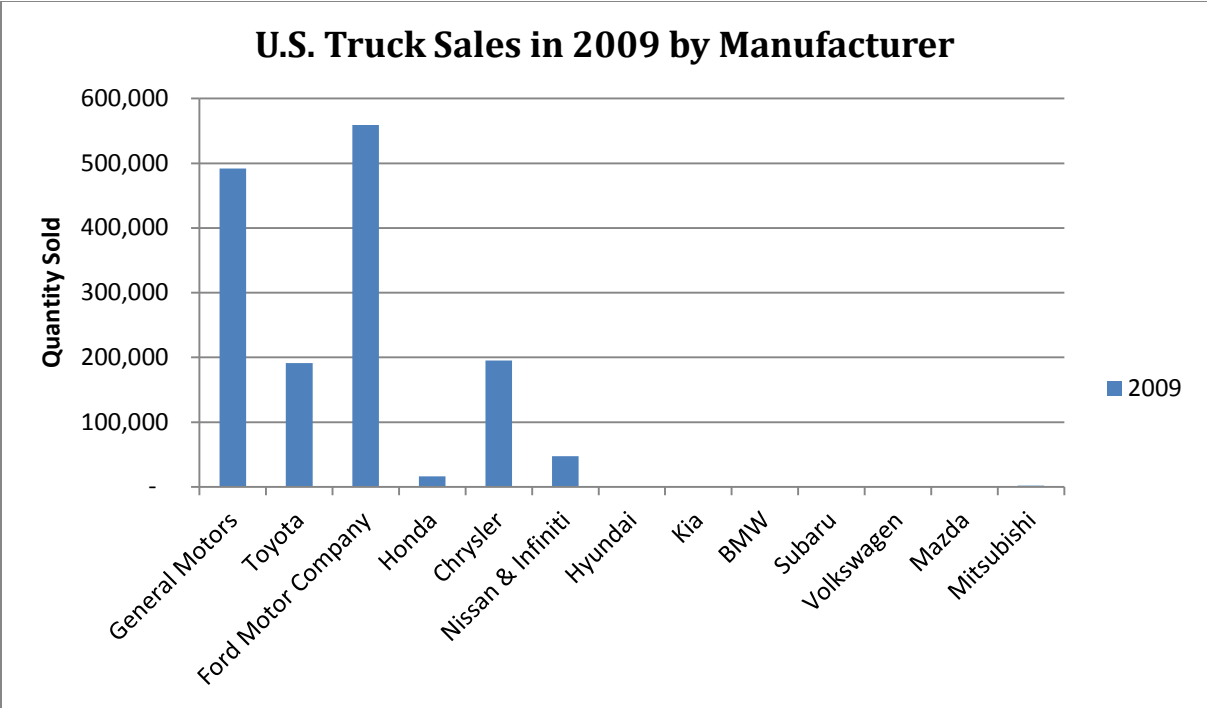
The following eight graphs demonstrate an analysis of the car, truck, SUV, and miscellaneous vehicles, respectively. The graphs display information of both manufacturing companies and year the data were taken. These data were used to determine the vehicles that were emphasized in the part analysis.



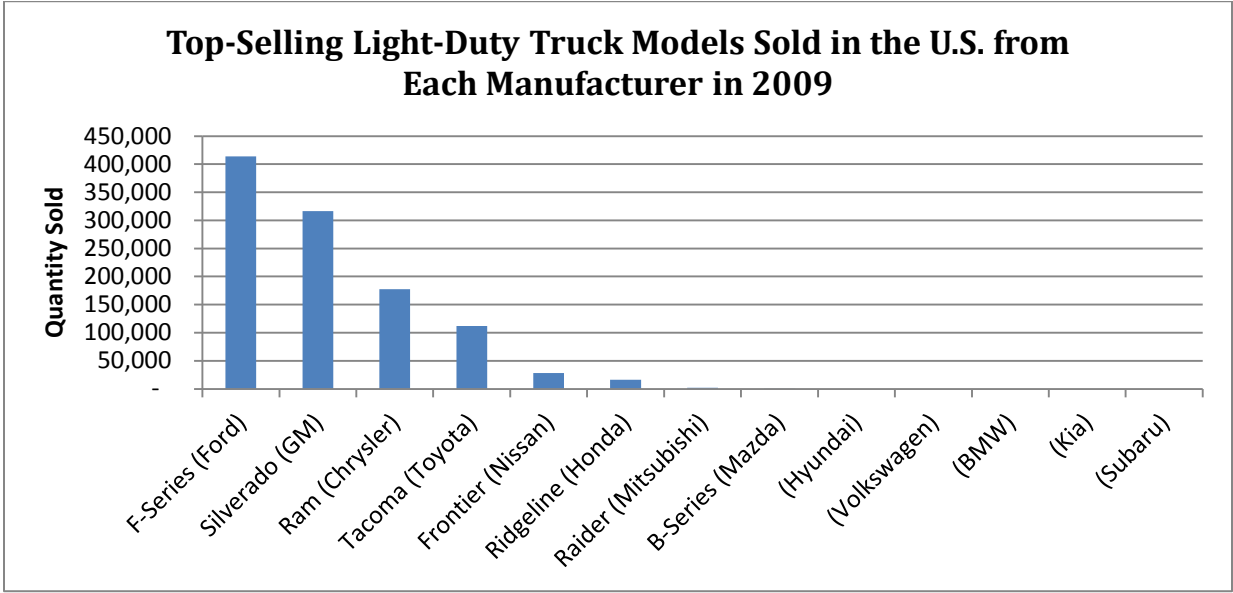
The above graph displays the quantity of cars sold by each automobile manufacturer in 2009. As shown, Toyota, General Motors, Honda, Ford, Nissan Motor Company, and Chrysler were the top-selling companies in the United States.



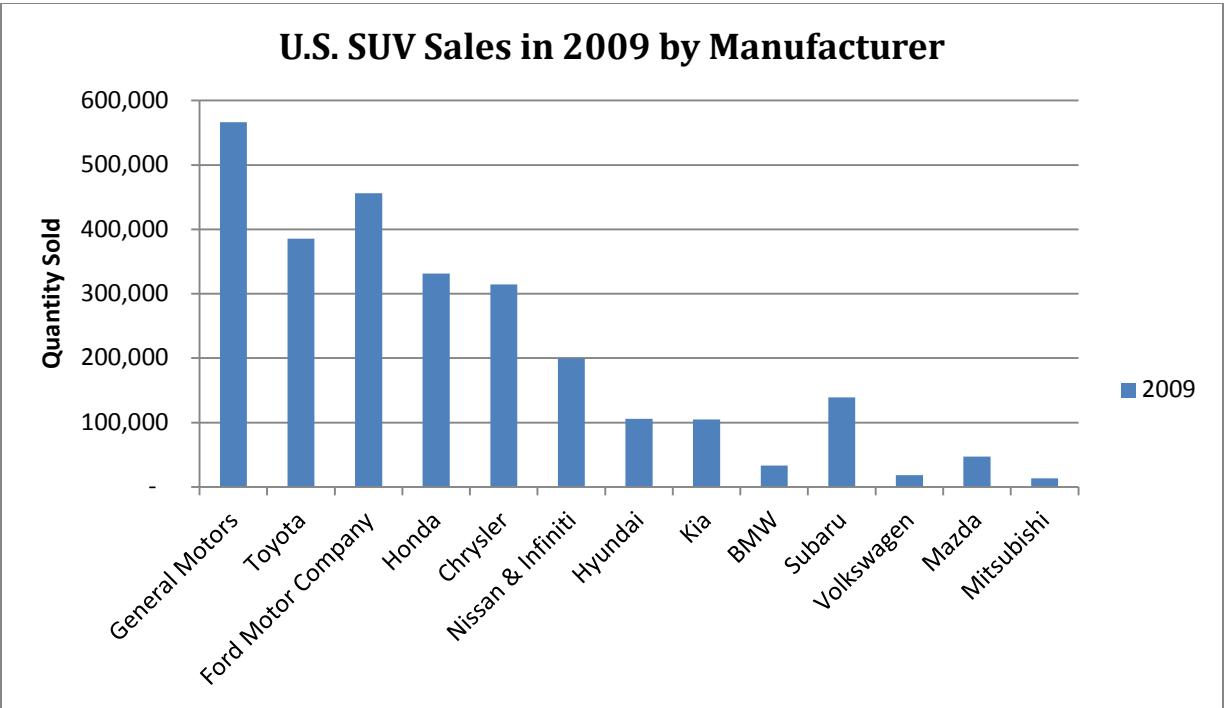
The graph above displays the top-selling individual cars with respect to manufacturer in 2009. The sedans chosen for emphasis were Toyota Camry, Honda Accord, Ford Fusion, Chrysler Dodge Charger, and GM Chevy Malibu (similar to GM Chevy Impala).



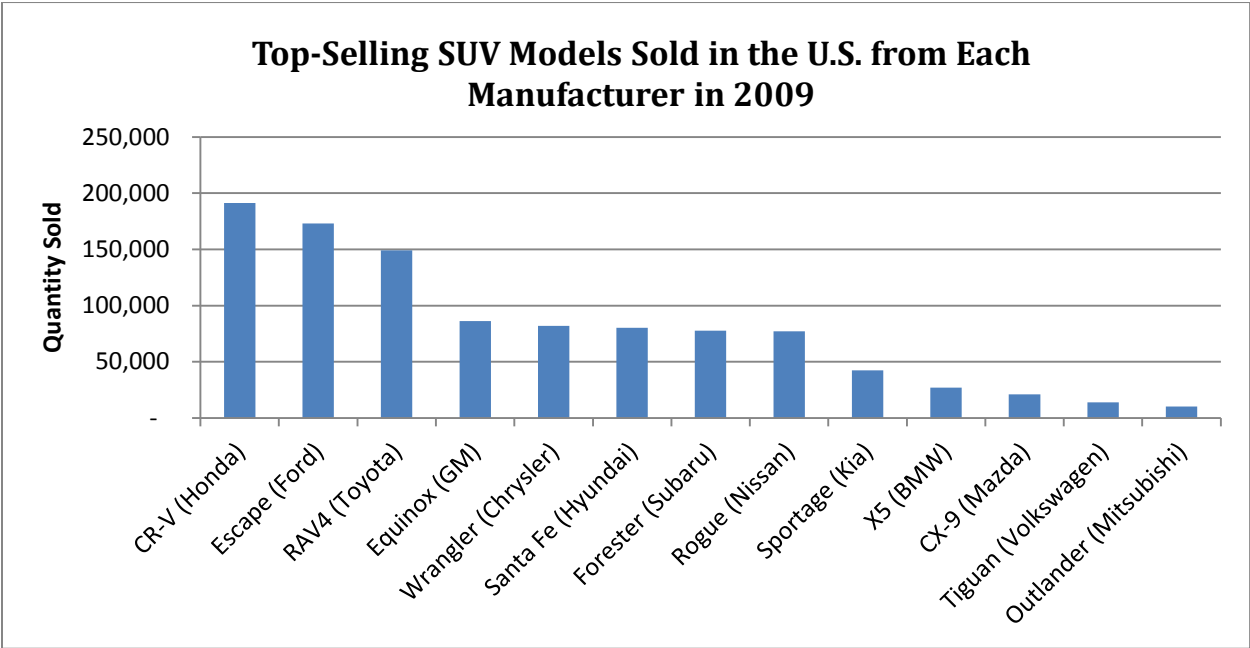
The graph shown above displays the quantity of trucks sold by each automobile manufacturer in 2009. This graph shows that only about half of the manufacturers produced trucks.



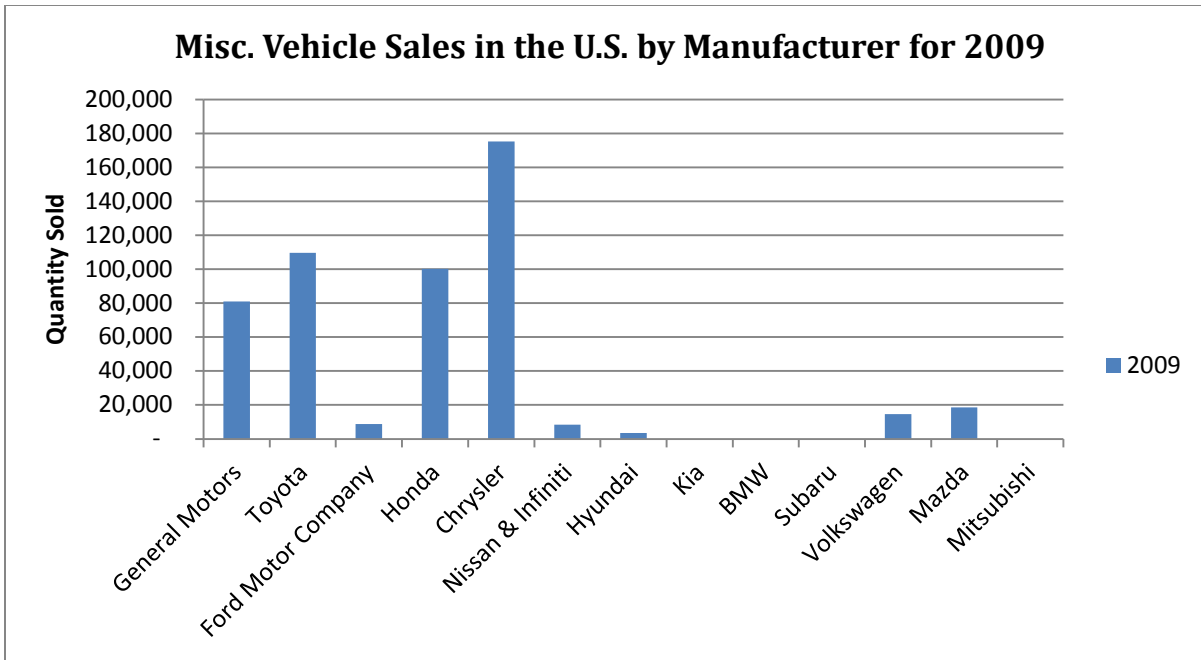
Above is a graph that displays the top-selling trucks with respect to manufacturer in 2009. The trucks chosen for emphasis were the Ford F-150, Chevy Silverado, Chrysler Dodge Ram, Honda Ridgeline, and Toyota Tundra (similar to Toyota Tacoma).



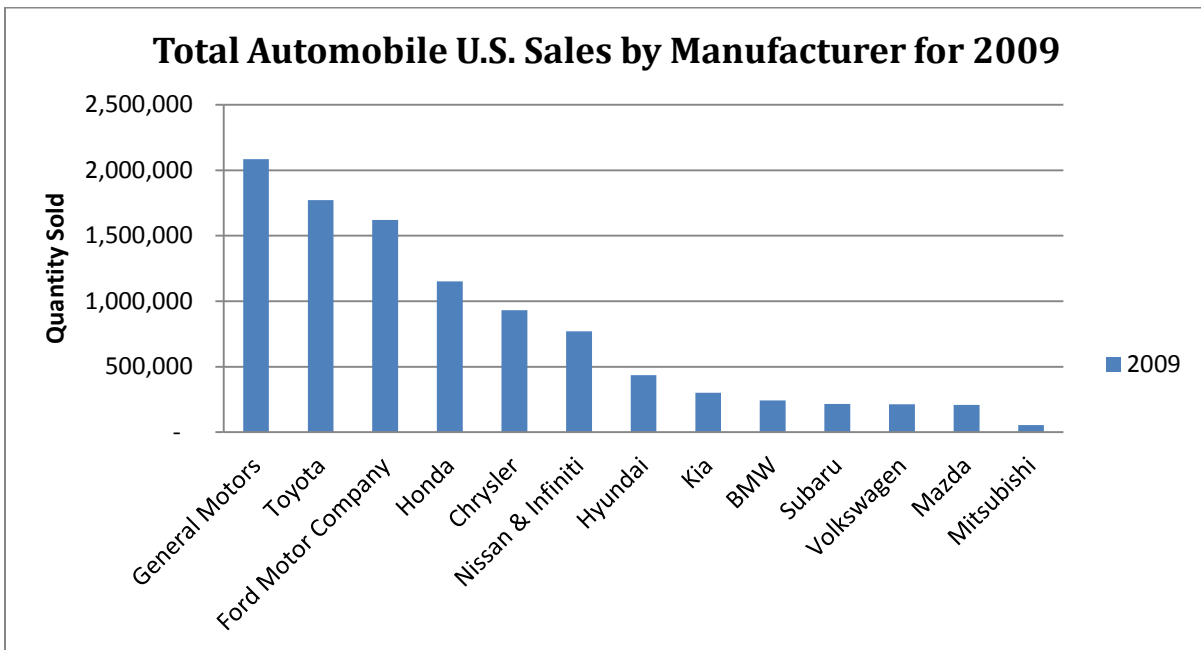
The graph above displays the quantity of SUVs sold by each manufacturer in 2009.



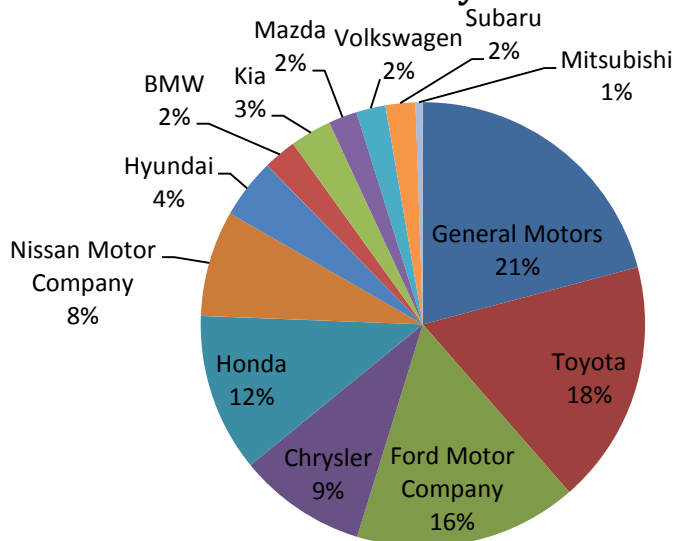
Above is a graph that displays the top-selling individual SUVs with respect to manufacturer in 2009.



The graph above displays the quantity of vehicles not included in the other categories sold by each manufacturer in 2009. For the most part, these include vans or commercial vehicles such as semi trucks.



Total Automobile U.S. Sales by Manufacturer for 2009



The above graphs display the total sales analysis with data from 2009. Based on these graphs, there is a definitive difference in the market share of the top six companies (General Motors, Ford Motor Company, Nissan Motor Company, Toyota, Honda, and Chrysler) when compared to the others. These top six companies dominated a combined 84% of the market in 2009. It is for these reasons that we concentrate our efforts on these companies for the majority of this report. Nissan Motor Company was excluded from our parts analysis due to the unavailability of parts lists for their vehicles.

Note: Data tables with specific figures are found in Appendix B.

5. Auto Parts Data

A comprehensive parts list from selected models of five of the top six U.S. automotive manufacturers was extracted from the Auto Parts Center [34] to provide an awareness of how many parts comprise a vehicle and an indication of the possible use of biobased components. A sales volume analysis was used to determine the top-selling vehicle, which was then selected as the vehicle to be examined for component parts. A summary parts comparison of each of the four types of vehicles (sedan, SUV, truck, and hybrid) from five of the top six U.S. automotive manufacturers can be found in Appendix C, with a detailed list in Appendix D (located online at xxx).

An early observation was that the truck and SUV were built with a different frame than that of the sedan or sedan hybrid, and therefore they contained different exterior body parts. The truck was the only vehicle to contain a cab, pick-up box, frame, and additional engine category. It lacked the parts of the pillar rocker and floor, cowl, front suspension, quarter panel, rear body and floor, and roof.

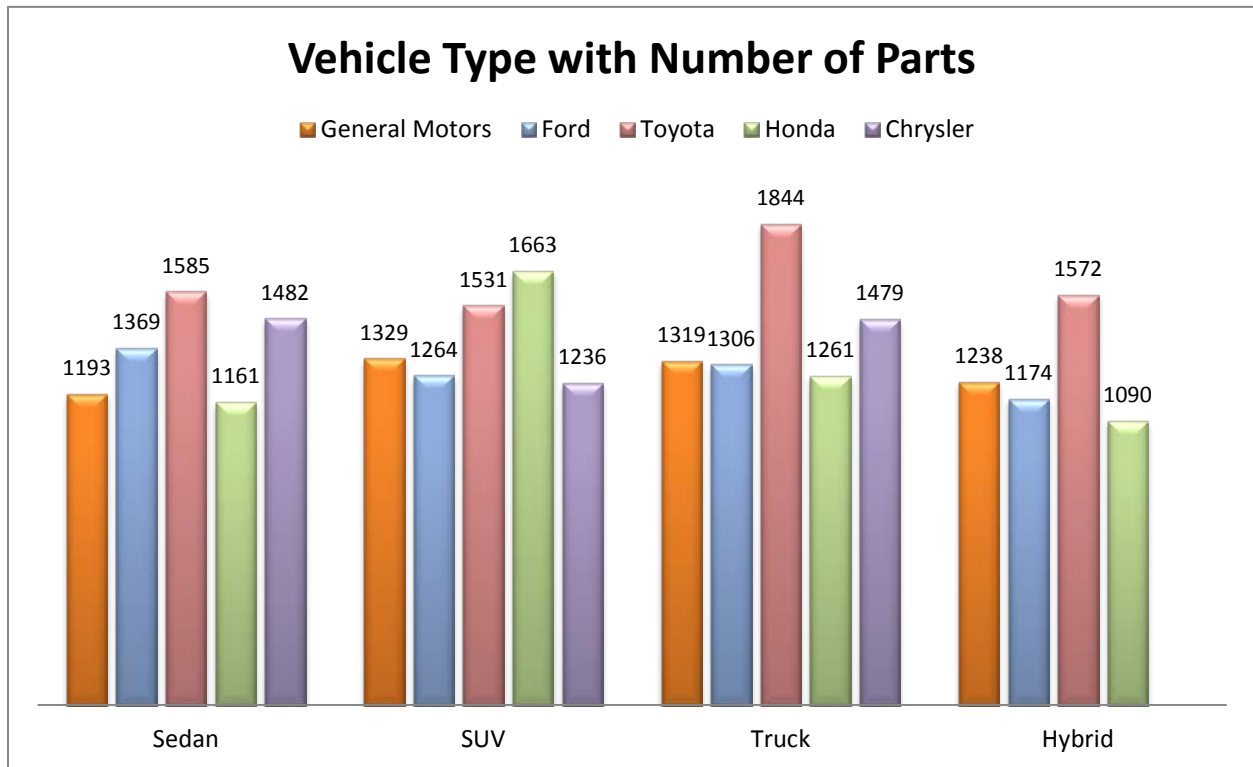
There were instances of different category names of the same parts. An example of this was with the categories Engine/Transaxle and Engine in the case of the truck; for instances such as these, both categories were treated as one.

All vehicles, cars, SUVs, hybrids, and light-duty trucks, contained a list of components for the air conditioner and heater, but only the hybrid contained an additional HVAC category of parts. The hybrid also contained some specific hybrid components. It was the only vehicle type to contain an additional category for the cooling system. It also contained parts for maintenance and lubrication.

All vehicles contained an electrical system, instrument panel, air conditioner and heater, fuel system, wheels, console, seats and tracks, information labels, windshield, front and rear bumpers, front and rear doors, fender, hood, steering column, wheel, gear and linkage, emission system, exhaust system, cooling, radiator support, and front and rear lamps.

The graph below displays the differences found in the number of parts per vehicle. The SUV and truck contained a significantly larger number of parts than the other vehicle types, with an average number near 1,400. The hybrid contained a lower number than any other vehicle type, with an average number of parts near 1,250. The sedan contained an average number of near 1,350 parts per vehicle.

The company with the largest average number of parts was Toyota, with an average number per vehicle type of 1,600. Chrysler had an average number of parts per vehicle type of 1,399. The average number of parts per vehicle for General Motors, Ford, and Honda was from 1,270 to around 1,290.



The summary of potential biobased parts, shown below, contains categories found from all vehicle types from the top five U.S. manufacturers included in the research. Each category has been described in the second column. The third column of the table contains an impending list of potentially biobased parts.

The parts selected were parts currently made of biobased materials or of materials considered to be potentially replaced with biobased materials. It should be noted materials listed as biobased also have the potential to be recyclable.

Category	Description	Biobased Content Potential
HVAC		
Air Conditioner and Heater	Heater, condenser, and evaporator components	Fans, lines, filter, case, vents, tubes, vent valves, levers
HVAC	System that heats and cools the inside of the vehicle	Discharge line, switches and sensors, dash control unit
Electrical		
Electrical	System that includes the battery, starter, alternator, and wiring and cables	Electrical wire insulation, horn, battery case, battery cover, battery tray, fuse cover, switches, display units
Alternator	Unit that converts mechanical energy into electrical energy	-
Starter	Electrical device used to start internal-combustion engines	Shield
Interior		
Instrument Panel	Set of instruments mounted in the front of the vehicle	*Instrument panel (Mazda), switches, blank cover, cluster assembly, air distributor, ducts, defroster nozzle, glove box assembly, latch, carrier housing, liners, molding, storage compartment, trim, radio cover, speaker covers
Console	Storage compartment	Center console bins and trays, armrest, cup holders, harness, liners, trim, buttons, dome lamp switch, release switch, ashtray, power outlet cover, switches
Cab	Driver and passenger compartment	Luggage carrier, seal, filler cap, cowl grille, cowl side panel, dash panel, water deflector, roof molding, dome lamp, map lamp, corner trim, headliner, grip handle, sun visor, running board pad, air deflector, drain tube, drip channel, weather stripping
Rear Body and Floor	Parts that compose the flooring of the vehicle	*Under-floor body panels (Daimler), *cargo area floor (GM), *floor mats (Honda), anchor cover, cargo net, trim, tray cover, seat belt bezel, storage box, package tray, rear body panel, carpet, upholstery
Seats and Tracks	Driver and passenger seats and parts that allow seat repositioning	Head restraints (Daimler), armrest liners (Ford), cushion cover, head rest, heater control, recline handle, cushion assembly, cushion padding, trim bezel, seat cover
Cowl	The part of the automobile in which the windshield, hood, and dashboard are attached	Reservoir, reservoir cap, hose, cowl grille, dash panel, water deflector
Pillars Rocker and Floor	Interior and exterior framing and support components	Moldings, interior trim
Restraint System	Parts, including seat belts and air bag components,	Air bags, seat belt, belt assembly

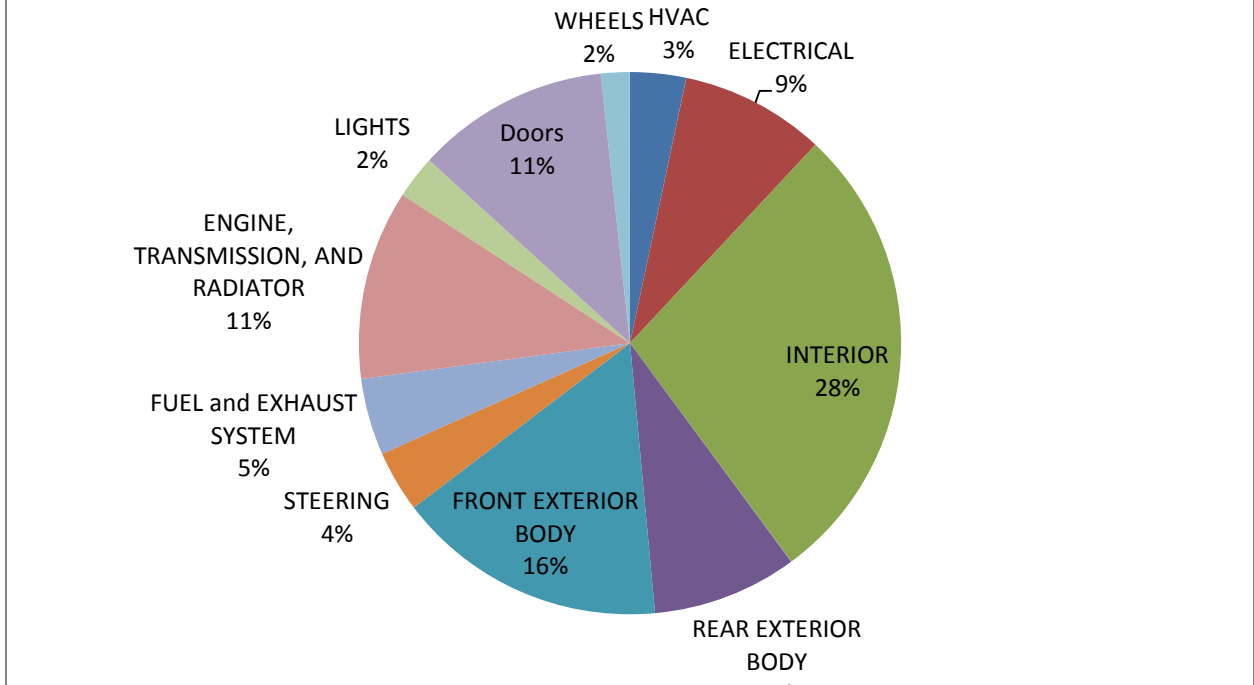
	whose purpose is to restrain the driver and passengers during a collision	
Information Labels	Safety, information, and VIN number labels	Labels
Convertible/Soft Top	Retractable fabric roof	Top fabric
Removable Top	Retractable fabric roof	Hardtop, knob, top panel
Roll Bar and Components	Framing components for a convertible/soft top	Bezel, cover, dome lamp, molding, sun visor
Roof	Interior and exterior components of the top covering of the vehicle	Roof molding, bezel, dome lamp cover, garage door opener, lamp bezel, map lamp assembly, sunroof switch, sun visor, drain tube, front hose, sunroof stripping, sunshade, headliner
Rear Exterior Body		
Back Glass	Glass in the rear of the vehicle	Reveal moldings
Rear Bumper	Part at rear of car “designed to absorb crash energy during minor and low-speed collisions”	*Bumper (Renault), bumper cover, license molding
Rear Suspension	System at rear of vehicle that absorbs energy from roadway imperfections to deliver a smoother ride for the vehicle and passengers	Brake hose, sealer, hose, housing, cover, bumper
Tailgate	Hinged door at the rear of a truck that can be laid flat or dropped down during loading and unloading	Bumper, handle outside, hinge cover
Trunk Lid	Part that opens and closes, allowing access to the trunk	*Trunk lid (Renault), emblem, trunk lid trim, pull strap, weather strip
Liftgate	See Tailgate	Exterior and interior trim, handle, lock assembly, washer hose, pivot cap, wiper blade, hinge cover, weather strip
Pick-Up Box	Assembly and trim of the rear box of trucks	Box assembly, exterior trim, decal, molding, pad, rear shield, splash shield, wheelhouse panel, storage box, bumper, access cover, step, remote-control casing, spare-tire carrier, handle
Universals and Rear Axle	Shaft on which the wheel revolves	Gasket
Front Exterior Body		
Windshield	Piece of glass and associated parts that protect passengers and the vehicle interior from external conditions	Reveal moldings, windshield wipers, adhesive, filler tube, reservoir cap, reservoir
Front Bumper	Part at front of car “designed to absorb crash energy during minor and low-speed collisions”	*Bumper (Renault), bumper cover, lower vent, outer grille, upper filler
Fender	Corner part that surrounds each wheel	Splash shields, *fender (Renault), mud guard, front and rear panels, fender liner
Front Suspension	System at front of vehicle that absorbs energy from roadway imperfections to deliver a smoother ride for the vehicle and passengers	Brake hose, splash shield
Grille	Grated component at front of car near bumper that protects the inner parts of the vehicle from roadway debris	Grille
Hood	Large steel cover protecting and allowing access to the engine compartment	*Engine hood (Renault), hood bumper, seal, insulation
Quarter Panel	Part that covers section between the rear door and trunk	Mud guard, trim, wheelhouse liner
Front Drive Axle	Shaft on which the front wheels rotate	-
Frame	Supporting structure of the vehicle to which all other	Paint, upper insulator

	components are attached	
Body Hardware	Door, hood, liftgate or tailgate, and various similar components of the vehicle	Hood, tailgate, handle
Collision Repair Kit	Repair kit that contains the front components of the vehicle	Seat belts
Steering		
Steering	System of components that allows the wheels of the vehicle to change direction	*Cogwheel for the steering angle sensor (Daimler)
Steering Column	System connecting the steering wheels to the steering rod that allows the wheels to turn	Combo switch, signal switch, wiper switch, tilt level
Steering Gear and Linkage	See Steering	Hoses, tubes, reservoir, reservoir cap, seal kit
Steering Wheel	Component that allows the driver to control the direction of the vehicle wheels	Cruise switch, horn contact, paddle switch, radio switch, steering wheel
Fuel and Exhaust System		
Emission System	System that monitors and controls the gases created when the vehicle is running	Air pipe, hose and tubes, seals, vapor canister
Exhaust System	System that carries away gases created when fuel and air are burned in the combustion chamber	Insulator, shroud
Fuel System	Various fuel system components, including fuel induction and fuel supply	*Fuel cap, hoses, tubing (Daimler), *accelerator pedal module (Daimler), tank shield
Engine, Transmission, and Radiator		
Engine	System that uses air and fuel to propel the wheels of the vehicle	Clamps, hose, inlet duct, seal, spacer, engine front and rear cover, access cover, oil tube, cap, valve cover
Maintenance and Lubrication	Various maintenance components for engine, transmission, and transaxle	*Air filter (Daimler), belts and pulleys, lubricants
Cooling	See Cooling System	Belts, fan, hoses, tubes, recovery tank, reservoir cap, thermostat housing, gasket, expansion tank
Cooling System	System that removes heat from the engine to keep it operating in its optimal temperature range	Cap, cooling fan, belts and pulleys, gasket
Radiator Support	An assembly that keeps the radiator secure by attaching it to the upper and lower rails and the left and right sides of the engine assembly frame	Splash shields, air shields
Automatic Transaxle	Unit that combines the functionality of the transmission and associated components	Lubricants
Clutch	Mechanism that connects the engine shaft to the transmission shaft	-
Transfer Case	Part that connects and transmits power from the transmission to the front and rear axles	Shaft seals
Transmission	Set of gears and shafts that transmits power from the engine to the wheels	Filter, gasket
Back Door	Door above rear bumper	Exterior trim, wiper and washer components
Brakes	Braking components that allow the vehicle to decelerate	*Tubing (Daimler)
Rear Lamps	Parts on the rear of the vehicle that serve as signals including signal lamp, backup lamp, and license lamp	Lamp assembly
Lights		
Front Lamps	Parts that light the roadway for the vehicle including the headlamps and fog lamps	Headlamp assembly, housing
Rear Lamps	Parts on the rear of the vehicle that serve as signals including signal lamp, backup lamp, and license lamp	Lamp assembly

Doors		
Front Doors	Doors that give access to the front seats of a vehicle	*Door panel inserts (GM), front seal, emblem, upper molding, belt, stripping, handle inside, lock knob, lock switch, mirror switch, trunk lid switch, window switch, mirror assembly, mirror cover
Rear Doors	Doors that give access to the rear seat of a vehicle	*Door panel inserts (GM), belt, molding, window stripping, handle inside, switch bezel, water deflector, window switch, handle base, handle bezel, latch, lock knob
Back Door	Door above rear bumper	Exterior trim, wiper and washer components
Wheels		
Wheels	Parts that rotate on the road to allow the vehicle to move	*Reinforcing filler in rubber tires (Goodyear), tire, tire pressure cap
Spare Tire Carrier	Compartment that contains spare tire	Carrier assembly, bumper
Hybrid Components		
Hybrid Components	Components specific to hybrid vehicles, specifically in the cooling system	Battery cover, fan

*These items are known to be biobased [5].

Average Percentage of Parts Found in Each Category from All Vehicle Types and All Manufacturers



Nearly one third of the parts of the automobile were found in the interior of the vehicle. These parts included the instrument panel, console, dashboard, seats, and other parts typically found inside the automobile. A comprehensive breakdown of each vehicle can be found in Appendix E. The next largest percentages were the exterior components. The exterior body included the frame, tailgate or trunk, bumpers, fenders, and various other body components. The engine, transmission, and radiator held 11% of the automotive parts. These parts included parts found under the hood. The next largest percentage of parts was found in door parts. Electrical parts, such as the battery, navigation, and entertainment components were the next largest percentage of parts. The last 16% of automotive parts was made up of steering, fuel and exhaust, lights, wheels, and heating, ventilating, and air conditioning components.

*Data tables and charts with part quantities are found in Appendix C, Appendix D, and Appendix E.

6. Conclusion

This report is a snapshot in time of the data and information available on the automobile industry. The research into biobased parts and the use of biobased materials is ongoing, constantly changing, and in many cases proprietary.

The automotive industry is complex and the incorporation of new materials, specifically biobased materials, into automotive parts is primarily based on cost. Determining if a biobased material is acceptable for use to make an automotive part is driven by goals established by the automotive industry and based on a number of characteristics and attributes including, but not limited to, the following:

- The components used must be cost competitive
- Part performance – biobased materials may offer improvements such as sound insulation or improved performance characteristics
- Weight – biobased materials may require heavier parts due to lower material strength
- Durability – biobased materials may affect durability depending on the biodegradability nature of the material
- Safety – biobased materials may require substantial testing to ensure safety standards can be met
- Biodegradability – biobased materials may provide excellent biodegradability due to the renewable nature of the source materials
- Sustainability/carbon foot print – biobased materials should make improvements in this area due to being produced from renewable sources
- Availability of biobased materials – biobased materials availability may improve over time due to the increased demand and research, however current resources may be limited due to their emerging nature
- New attributes or performance characteristics – in some situations biobased lubricants provide improved lubricity and therefore reduce wear on metal parts
- Recyclability – biobased materials may impact established recycling channels

Some examples of how these characteristics and attributes can be put in context with industry goals are: (1) a goal of improved mileage could be affected by the characteristics and attributes of weight, performance, and availability of biobased materials; (2) a goal of performance might include the characteristics and attributes of part performance, weight, durability, safety, new attributes, or performance characteristics; (3) a goal of improved safety might include the characteristics and attributes of weight, part performance, safety associated with the parts and their design, and new attributes or performance characteristics; (4) an environmental goal might include the characteristics and attributes of biodegradability, sustainability/carbon footprint, availability of biobased materials, recyclability, and new attributes or performance characteristics; and (5) a goal of lower manufacturing cost would probably include all the listed characteristics and attributes.

Purchase decisions are rarely, if ever, based solely on biobased content of the product the above mentioned examples represent only a limited number of possible scenarios and due to the complex nature of material selection makes a simple decision or explanation impractical.

An optimal balance of cost, performance, and environmental attributes will determine if biobased parts can be substituted into the automotive vehicle. This decision will take research and development along with evaluation to determine if it is possible and economically feasible.

Our research has determined that the automotive industry has a very large potential to utilize biobased materials. The list of industry associations, along with contact information for automobile manufacturers in the United States, enables discussions to begin on expanding the current automotive parts made from biobased materials with the assistance of a champion from the industry.

To create the largest impact, emphasis should be placed on the largest producers of vehicles. The five largest producers of automotive vehicles in the United States are General Motors, Ford, Toyota, Chrysler, and Honda. Out of these five, General Motors sells the largest volume of vehicles, based on the information available during 2009. The prominent vehicle type sold in the United States is the sedan. It contributes to more than half of all automotive sales in the United States.

The SUV and truck have a large number of parts. This makes them good candidates to be the vehicle types with the largest amount of biobased material on a part number basis. A summary table of automotive parts thought to have the greatest potential to be made of biobased material was compiled. This list of potential biobased parts may be expanded with emerging biobased advances. A majority of biobased parts currently being used was found to be in the interior of the vehicles.

References

- [1] Farm, Conservation, and Energy Act of 2008
- [2] Computer Desktop Encyclopedia 2010
- [3] Solid Waste Management Coordinating Board—2010 Rethink Recycling Campaign
- [4] <http://baggyparagraphs.wordpress.com/2009/07/21/henry-ford%E2%80%99s-beloved-bean/> (accessed April 14, 2010)
- [5] Bioplastics Magazine [01/10] Vol. 5
- [6] <http://www.edmunds.com/advice/alternativefuels/articles/105341/article.html> (accessed April 14, 2010)
- [7] <http://www.baby-benz.com/portal/new-a-class-w169-/daimlerchrysler-uses-a-natural-fiber-component-in-the-exterior-of-the-mercedes-benz-a.html> (accessed October 29, 2011)
- [8] <http://green.autoblog.com/2007/09/13/frankfurt-2007-mazdas-100-percent-biofabric/> (accessed October 29, 2011)
- [9] <http://green.autoblog.com/2006/09/06/honda-develops-bio-fabric/> (accessed October 29, 2011)
- [10] <http://www.autoeducation.com> (accessed October 29, 2011)
- [11] <http://www.car-stuff.com> (accessed October 29, 2011)
- [12] http://www.hyundainews.com/Corporate_News/Sales_Releases/01_05_2010_3384.asp (accessed October 29, 2011)
- [13] <http://www.kiamedia.com/secure/corporate010510a.html> (accessed October 29, 2011)
- [14] <http://www.kiamedia.com/secure/corporate040110b.html> (accessed October 29, 2011)
- [15] <http://www.prnewswire.com/news-releases/mazda-reports-december-and-full-year-2009-sales-80720852.html> (accessed October 29, 2011)
- [16] <http://www.theautochannel.com/news/2010/04/01/471745.html> (accessed October 29, 2011)
- [17] Dan Irvin, General Manager, Corporate Communications & Public Relations, dirvin@mmsa.com

- [18] <http://www.nissannews.com/newsrelease.do;jsessionid=C75341768F8DC84ADFC53819DD20A09A?id=1009> (accessed October 29, 2011)
- [19] <http://www.nissannews.com/newsrelease.do?id=1397> (accessed October 29, 2011)
- [20] http://www.subaru.com/company/news/2010_january.html (accessed October 29, 2011)
- [21] http://www.subaru.com/company/news/2010_april.html (accessed October 29, 2011)
- [22] http://pressroom.toyota.com/pr/tms/document/December_2009_PR_Sales_Chart.pdf (accessed October 29, 2011)
- [23] http://pressroom.toyota.com/pr/tms/document/March_2010_Sales_Chart.pdf (accessed October 29, 2011)
- [24] <http://media.vw.com/index.php?s=43&item=546> (accessed June 17, 2010)
- [25] <http://media.vw.com/index.php?s=43&item=595> (accessed June 17, 2010)
- [26] https://www.press.bmwgroup.com/pressclub/p/us/pressDetail.html?outputChannelId=9&id=T0076741EN_US&left_menu_item=node__5308 (accessed October 29, 2011)
- [27] <http://www.media.chrysler.com/newsrelease.do?id=9330> (accessed October 29, 2011)
- [28] <http://media.ford.com/images/10031/december09sales.pdf> (accessed October 29, 2011)
- [29] <http://media.ford.com/images/10031/March10sales.pdf> (accessed October 29, 2011)
- [30] http://www.gm.com/corporate/investor_information/docs/sales_prod/09_12/deliveries_0912.pdf (accessed June 17, 2010)
- [31] <http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9MzkwMzh8Q2hpbGRJRDR0tMXxUeXBIPtM=&t=1> (accessed October 29, 2011)
- [32] <http://www.hondanews.com/search/release/5350?q=december+2009+sales&s=honda> (accessed June 17, 2010)
- [33] <http://www.hondanews.com/search/release/5409?q=march+2010&s=honda> (accessed June 17, 2010)

[34] <http://www.autopartscenter.net/> (accessed October 29, 2011)

Appendix A
Contact Information

U.S. Auto Manufacturers General Information

Company	U.S. Headquarters Location	Website
BMW		www.bmwusfactory.com
Chrysler Group LLC	Auburn Hills, Michigan	
Ford Motor Company	Dearborn, Michigan	www.ford.com
General Motors	Detroit, Michigan	www.gm.com
Honda		www.corporate.honda.com
Hyundai	Montgomery, Alabama	www.hmmausa.com
Kia	West Point, Georgia	www.kmmgusa.com
Mazda	Irvine, California	www.mazda.com
Mitsubishi	Normal, Illinois	
Nissan		
Subaru	Cherry Hill, New Jersey	www.subaru.com
Toyota Motor Corporation	Erlanger, Kentucky	
Volkswagen	Chattanooga, Tennessee	www.volkswagengroupamerica.com

U.S. Auto Manufacturers Contact Information

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Clean Fuels Development Coalition*	4641 Montgomery Avenue, Bethesda MD	http://www.cleanfuelsdc.org/

	20814	
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Association of International Automobile Manufacturers	2111 Wilson Blvd., Suite 1150, Arlington, VA 22201	http://www.iam.org/public/aiam/
Government Affairs Department	govaffrs@aiaam.org	703-525-7788
Automotive Industry Action Group	26200 Lahser Rd., Suite 200, Southfield, MI 49033	http://www.aiag.org/scriptcontent/index.cfm
Supply Chain Institute	sci@aiag.org	248-358-3570
Automotive Learning Center	1800 Crooks Rd., Troy, MI 48084	http://www.plasticscar.com/s_plasticscar/
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*These persons have been contacted by BioPreferred in the past.

Appendix B
Automotive Sales Data

Types of Vehicles Produced

U.S. automobile sales by volume

Company	Car Sales '09	Truck Sales '09	SUV Sales '09	Misc. Sales '09
General Motors	945,112	491,807	566,606	80,967
Toyota	1,086,710	191,209	385,700	109,528
Ford Motor Company	595,671	559,196	456,187	8,834
Honda	702,857	16,464	331,330	100,133
Chrysler	246,624	195,112	314,442	175,224
Nissan & Infiniti	514,328	47,457	199,881	8,437
Hyundai	325,667	-	105,964	3,433
Kia	195,166	-	104,897	-
BMW	208,589	-	33,138	-
Subaru	77,585	-	139,067	-
Volkswagen	180,478	-	18,295	14,681
Mazda	141,466	573	47,240	18,488
Mitsubishi	38,529	1,944	13,513	-
Total	5,258,782	1,503,762	2,716,260	519,725

Total U.S. sales by volume for each manufacturer

Company	2009
General Motors	2,084,492
Ford Motor Company	1,620,888
Toyota	1,773,147
Honda	1,150,784
Chrysler	931,402
Nissan & Infiniti	770,103
Kia	300,063
Mazda	207,767
BMW	241,727
Volkswagen	213,454
Mitsubishi	53,986
Hyundai	435,064
Subaru	216,652

Top-selling car in the United States by volume for each manufacturer

Company	Car	Quantity Bought	Truck	Quantity Bought	SUV	Quantity Bought
Ford Motor Company	Fusion (Ford)	180,671	F-Series (Ford)	413,625	Escape (Ford)	173,044
General Motors	Impala (GM)	165,565	Silverado (GM)	316,544	Equinox (GM)	86,148
Chrysler	Charger (Chrysler)	60,651	Ram (Chrysler)	177,268	Wrangler (Chrysler)	82,044
Toyota	Camry (Toyota)	356,824	Tacoma (Toyota)	111,824	RAV4 (Toyota)	149,088
Nissan & Infiniti	Altima (Nissan)	203,568	Frontier (Nissan)	28,415	Rogue (Nissan)	77,222
Honda	Accord (Honda)	290,056	Ridgeline (Honda)	16,464	CR-V (Honda)	191,214
Mitsubishi	Lancer (Mitsubishi)	17,034	Raider (Mitsubishi)	1,944	Outlander (Mitsubishi)	10,283
Mazda	Mazda 3 (Mazda)	96,466	B-Series (Mazda)	573	CX-9 (Mazda)	21,132
Hyundai	Sonata (Hyundai)	120,028	(Hyundai)		Santa Fe (Hyundai)	80,343
Volkswagen	Jetta (Volkswagen)	108,427	(Volkswagen)		Tiguan (Volkswagen)	13,903
BMW	3 Series (BMW)	90,960	(BMW)		X5 (BMW)	27,071
Kia	Spectra (Kia)	47,114	(Kia)		Sportage (Kia)	42,509
Subaru	Impreza (Subaru)	46,611	(Subaru)		Forester (Subaru)	77,781

Appendix C
Part Comparison Table

Table 1: Composition of Vehicles with the Number of Parts per Category.

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge- line	Insight
HVAC	38	57	35	41	50	42	57	38	25	29	51	50	67	45	60	45	64	50	42
Air Conditioner and Heater	38	45	35	28	50	42	43	38	25	29	35	33	50	31	43	45	46	50	42
Blower motor and fan		2				1			6	9		9				10	10		
Condenser compressor and lines	18	19	13	14	15	18	21	12	9	10	13	9	26	17	30	13	14	6	7
Condenser fan																	3	19	15
Heater components											9							4	3
Evaporator components						23		26			13							21	
Evaporator and heater components	20	24	22	14	35		22		10	10		15	24	14	13	22	19		17
HVAC		12		13			14				16	17	17	14	17		18		
Air conditioner		7		6			10				8	8	10	10	10		13		
Controls		4		6			6				7	7	6	3	6		4		
Heater		1		1			1				1	2	1	1	1		1		
ELECTRICAL	91	139	101	184	111	106	227	115	85	64	178	114	181	73	157	48	153	64	97
Electrical	91	138	101	184	111	106	225	115	85	64	165	114	179	72	157	48	142	64	97
Abs components	8	6	10	4	8	1	8	8	7	6	12	15	7	7	6	5	6	3	7
Alarm system					3	1	1	3	4	2	3	3		6					
Alternator	6	3	8		7	8	9		2	2	2		5	5	7	4	4	3	
Antenna	6	4	8	3	5	7	3	5	4	7	3	4	10	6	12	6	10	3	4
Battery	9	12	16	9	10	12	8	27	6	13	8	21	9	6	6	13	8	6	7
Body electrical				33			26				29	38	21		25		27		
Chassis electrical		24		37			33		38		44		30		29		32		
Communication system components	8	9	7	8											1				
Cruise control system										1								5	
Electrical components	3	5	13	26	11	5	8	13	4	6	5	38			7		7	26	53

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Entertainment system components		2	7							4	4		5		4				
Fuse and relay	33	26	15	27	32	52	67	36		7	3		22	19	13				
Horn	4	2	2	4	2	1	2	2	3	3	4	3	4	4	1	1	2	1	1
Ignition system	8	6	9	9	19	9	26	10	7	7	7	10	15	9	18	12	11	8	9
Instrument and gauges				1			4				6		4	1			3		
Keyless entry components		6													3				
Navigation system components			3		7	1	2	6	2		4	14		2	2	6	8	8	9
Power train control				10			11				10		8		9		10		
Restraint systems				8			10				10		8		7		11		
Ride control components	1			1															
Starter	2	2	3	1	4	5	5		2	1	3		6	4	3	1	3	1	1
Tire pressure monitor components	3	3		3	3	3	2	3	5	4	6			1	4				
Traction control components						1													6
Wiring harness		1						2	1	1	1	6		2					
Alternator		1					1				7		1	1			6		
Starter							1				6		1				5		
Armature											1						1		
Brush holder											1						1		
Drive											1								
Frame											1								
Housing																	1		
Reduction gear																	1		
Shield																			
Solenoid											1								
Yoke											1						1		

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge- line	Insight
INTERIOR	337	407	404	280	394	336	397	380	452	496	483	481	310	306	388	353	473	415	316
Instrument Panel	59	61	65	55	80	48	79	73	74	79	87	96	56	85	61	58	84	79	64
Cluster and switches	15	5	15	11	14	11	21	13	12	22	28	19	8	8	11	10	15	25	17
Console													9	23					
Ducts	13	11	10	11	17	6	9	15	15	12	13	13	7	9	6	5	4	6	4
Glove box	5	8	9	2	5	6	6	5	9	5	5	11		4	6	5	9	8	6
Instrument panel components	21	20		7				23	20	11	13	23				13	16	10	19
Instrument panel		7	23	20	27	19	28		7	19	15	27	24	29	29	15	28	19	10
Sound system	5	10	8	4	17	6	15	17	11	10	13	10	8	12	9	10	12	11	8
Console	25	13	37	22	37	39	47		27	23	31	17	24		33	29	49	32	17
Center console	25		23	22		22									28	29	39	30	17
Console					25			28	22	23	31	17	18						
Front console							43										2		
Shifter housing					6	12		2											
Overhead console		13	14		6	5	4	6	5				6		5		8	2	
Cab			185				152				234	40			160				
Back panel			4				10				8			4					
Cab assembly			8																
Center pillar and rocker											16								
Components on dash panel			14				10				7	13			11				
Cowl			24				13				22	27			11				
Exterior trim			3				3				9				2				
Floor			21				3				31				12				
Interior trim			49				45				14				62				
Jack and components			13				6				72								
Luggage carrier			4																
Rocker											4								
Roof and components			12				9				25				7				
Roof lamps			3																
Running board			2				37								2				
Side panel											15								

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Sunroof			23				16				11				14				
Uniside			16												35				
Rear Body and Floor	54	53		45	40	27		36	71	34		52	33	18		33	53	57	47
Floor and rails	20	25		15	18	19			34	17		18	10	9		15	15		20
Glass and hardware																		12	
Interior trim	23	10		20	20	8		21	34	12		33	11	9		13	32	23	16
Jack and components	5			4															9
Rear body and rails																			
Rear body and floor								15										19	
Trailer hitch components																		3	
Rear body	6	18		6	2				3	5		1	12			5	6		2
Seats and Tracks	20	86	65	41	102	63	93	94	77	141	86	75	59	58	100	84	122	85	58
Front seat components			50		38	25	37	32		62		40	23	15	63	24	39	26	20
Second row seats										44									
Third row seat										35									
Rear seat components	20	25	15	21	29	28	28	32	29		27	35	18	32	37	20	55	32	25
Rear bench seat																			
Rear seat																			
Tracks and components					35	10	28	30					18	11		40	28	27	13
Driver seat components		35		20					26		27								
Passenger seat components		26							22		32								
Cowl	23	29		19	26	34		32	30	25		40	25	22		14	29	19	20
Components on dash panel	10	14		10	10	13		16	7	7		13	11	11		6	6	6	10
Cowl	13	15		9	16	21		16	23	18		27	14	11		8	23	13	10
Pillars Rocker and Floor	62	68		33	44	60	18	44	63	78		81	39	53		47	47	59	43
Aperture panel						2	18						4			2			
Carpeting																3			
Center pillar	6	4		6		7			11	9		9		2		7	6	4	4
Exterior trim	10	2		6	2	11		2	9	2		8	1	6			8		
Floor					7			6											

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Floor and rails	13	6				12			21	23		28	13	14		1	1	9	3
Hinge pillar	4	12		3	12	9		12	10	14		12		5		9	4	9	11
Interior trim	18	32		13	21	21		22	21	28		24	21	22		19	18	30	23
Rocker														4		6	6	5	
Rocker panel	9	9		3						2									
Uniside	2	3		2	2			2									4	2	
Running board																			
Restraint System	21	28	28	18	28	24	24	29	39	34	34	36	23	24	22				
Air bag components	11	8	13	7	14	12	13	15	16	13	12	15	10	8	9				
Front seat belts	5	10	9	6	7	4	5	7	7	7	11	10	8	8	9				
Second row seat belts										8									
Third row seat belts										6									
Rear seat belts	5	10	6	5	7	8	6	7	16		11	11	5	8	4				
Information Labels	12	9	24	13		7	2	2	20	16	11	23	16	12	12				
Labels	12	9	24	13		7	2		20	16	11	23	16	12	12				
Removable Top														7					
Glass														2					
Top and components														5					
Roll Bar and Components														27					
Interior trim														23					
Roll bar														4					
Roof	61	60		34	37	34		34	51	66		21	35			47	47	52	24
Exterior trim	2	2		2	2	2		2	4	5		3	2			2	14	3	2
Interior trim	28	19		24	16	7		13	22	24			14			18	10	19	21
Luggage carrier		7				5				11									
Roof and components	10	16		8	5	9		5	14	15		18	3			4	3	5	1
Sunroof	21	16			14	11		14	11	11			16			23	20	25	
REAR EXTERIOR BODY	50	131	137	84	125	147	205	104	132	96	174	123	115	90	179	82	134	100	89
Back Glass	4		11	1	2		9	2	4		14		1		3	7			
Glass	2		2	1	2		9		4		3		1		3	7			

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Reveal moldings	2										1								
Glass and hardware			9								10								
Rear Bumper	28	29	19	24	20	20	25	20	32	27	27	24	14	14	11	7	11	16	11
Trailer hitch components		3	1			4	3												
Bumper and components	28	29	18	24	20	16	22	20	32	27	27	24	14	14	11	7	11	16	11
Rear Suspension	34	38	34	43	80	71	51	59	65	69	32	41	69	56	67	44	65	67	24
Axle housing							8							24					
Axle and differential		15			7	7							21		25		22	13	
Brake components	11	13	11	11	19	21	19	16	21	18	13	13	15	11	10	11	15	21	11
Driver axle										11									
Carrier and front axles			13																
Crossmember				1											1		1		
Lower control arm		1												1	1				
Ride control													2						
Rear axle		2												1					
Shocks and components	4	3		4	12			12					10						
Stabilizer bar				2								3	5	3	3		4	4	
Stabilizer bar and components	4	5		4	8	6		8	5	5				17	8	5	3		
Upper control arm				1													1		
Struts and components																14		13	
Suspension components	15	1	10	20	34	37	24	23	39	35	19	25	16	9	18	14	19	16	13
Tailgate																		17	
Gate and hardware																		13	
Interior trim																		1	
Exterior trim																		3	
Trunk Lid	18			16	23			23	31				22			24			
Exterior trim	2			2	5			5	5				2			4			
Interior trim	3			2	2			2	2				6			4			
Lid and components	12			12	15			15	19				13			14			
Spoiler	1				1			1	5				1			2			
Liftgate		64				51						58		13			43		54

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge- line	Insight
Exterior trim		10				4						7					6		8
Gate and hardware		16				5						7					13		15
Glass		1				15						10		6			7		14
Interior trim		12				1						10					6		7
Lock and hardware		6				12						12							
Spoiler		5										3					1		
Wiper and washer components		13				14						9		7			10		10
Pick-Up Box			73			5	101				80				98				
Box assembly							1				2				5				
Box rails			13												3				
Exterior trim			9				40				17				17				
Floor											5				7				
Front and side panels							34				38				50				
Pick-up box components			28																
Spare tire carrier			8			5									2				
Tailgate			15				26				18				14				
Universals and Rear Axle							23				21		9	7			15		
Rear axle							23				21		9	7			15		
FRONT EXTERIOR BODY	212	225	181	210	212	187	257	183	270	288	279	261	223	205	275	173	239	228	167
Windshield	22	20	22	18	26	19	24	26	26	33	27	27	17	18	24	21	25	37	29
Glass	3	4	6	2	7	7	9	7	6	6	4	6	2	8	5	5	5	13	7
Reveal moldings	1		4				3		1	4	1	1	3		3	1	3	3	1
Wiper and washer components	18	16	12	16	19	12	12	19	19	23	22	20	12	10	16	15	17	21	6
Front Bumper	56	31	58	29	21	19	22	21	30	36	42	23	16	12	42	11	16	19	16
Bumper and components	24	29	58	24	21	19	22	21	20	36	42	21	16	12	39	11	16	19	16
Exterior trim																			
Grille and components	8	2		5					3						3				
Spoiler									7			2							
Fender	45	43	14	45	31	29	24	31	77	66	41	54	24		27	24	39	29	32
Exterior trim	1	5	1	1		1	6			11	8				10	1	6	3	3

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge- line	Insight
Inner components							6				22				2				
Fender and components	14	17	13	14	16	11	12	16	23	25	11	19	7		15	8	13	8	8
Splash shields																	1		
Structural components and rails	30	21		30	15	17		15	54	30		35	17		15	19	18	21	
Front Suspension	49	60	49	64	73	50	80	73	69	52	83	59	87	81	122	82	75	65	50
Brake components	13	8	15	11	17	13	16	17	19	16	23	15	21	19	16	13	12	12	12
Carrier and front axles			13				21				6								
Cross member		1															1		
Drive axles	4	6		4	9	9		9	12	10		9	5			18	14	14	10
Front axle and carrier														12	47				
Lower control arm				3			3				4		2	5	4			3	
Stabilizer bar				4			4				4		4		1			3	
Stabilizer bar and components	4	5	3	4	6	6	7	6	5		1	4	9	9	12	6	3	3	3
Struts and components	13	9		13	20			19		11	10		14			23			
Suspension components	15	26	18	25	21	22	29	22	33	15	34	31	31	36	39	11	38	26	
Suspension mounting																11	1	10	22
Upper control arm											1		1						
Grille			4		9	6		9		14	13	3	5	2			12	5	5
Grille panel						6													
Grille and components			4		9			9		14	13	3	5	2			12	5	5
Hood	15	22	24	15	25	20	26	25	22	15	22	21	26	17	21	15	13	17	13
Exterior trim			5											1					
Hood and components	15	22	19	15	25	20	26	25	22	15	22	21	26	16	21	15	13	17	13
Quarter Panel	25	49		23	27	44		29	46	72		44	30	21		20	39	56	22
Exterior trim	1	1		1		9				10			1	2		1	6	4	
Glass		2				3				2				1			8		
Inner structure	11	21		10	4	9		4	25	33		18	10			7	9	19	6
Interior trim	4	17		3	5	14		7	4	17		4	6			1	4	15	4
Side panel and components																		18	

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Quarter panel and components	9	8		9	18	9		18	17	10		22	13	18		11	12		12
Front Drive Axle				3			23				24	8	7	15			9		
Drive axles				3			23				24	8	7	15			9		
Frame			10				13				13			20	30				
Frame and components			10				13				13			20	30				
Body Hardware				13			21				14	22	11	19	9		11		
Door				4			15				8	11	3	10	4		3		
Fuel door												2					1		
Hood				6			3				1	3	3	2	3		2		
Instrument panel											1		1	4			1		
Liftgate												6					4		
Trunk				3									4						
Tailgate							3				4			3	2				
Collision Repair Kits																			
Front components																			
STEERING	52	57	66	33	54	28	70	33	52	32	56	50	51	60	45	61	81	47	47
Steering				4			8				5	7	7	12	7		17		
P/s pump and hoses							4						5	3	4		6		
Steering gear and linkage				4			4				5	7	2	9	3		11		
Steering Column	17	21	28	17	18	15	30	18	24	18	29	18	19	19	15	11	18	16	15
Bracket											1								
Bushings																			
Coupling													1						
Cover																	1		
Dust shield																			
Intermediate shaft				1							1			1	1				
Jacket																			
Lower boot																			
Lower components			3																
Lower shaft											1								

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge- line	Insight
Lower shroud				1							1						1		
Motor				1															
Shaft assembly		1																	
Shroud		1											1		1				
Shroud switches and levers	8	14	24	7	11	7		11	10	13	13	8	10		7	8	11	13	11
Steering column assembly	9	5	1	3	7	8		7	13	5	10	10	7	16	6	3	3	3	4
Steering wheel				2							1		1	1			1		
Tilt lever				1										1					
Upper shaft																			
Upper shroud									1		1						1		
Wire Harness				1															
Steering Gear and Linkage	24	27	30	5	30	10	27	10	18	7	8	11	17	23	12	34	31	16	15
Pump and hoses	12	9	15		10		13		10				9	6	7	18	12	16	
Steering gear and linkage	12	18	15	5	20	10	14	10	8	7	8	11	8	17	5	16	19		15
Steering Wheel	11	9	8	7	6	3	5	5	10	7	14	14	8	6	11	16	15	15	17
Steering wheel and trim	11	9	8	7	6	3	5	5	10	7	14	14	8	6	11	16	15	15	17
FUEL and EXHAUST SYSTEM	62	59	53	44	90	85	81	29	69	45	73	45	107	75	71	68	73	42	46
Emission System	24	14	9	10	23	29	22	12	9	8	13	4	42	27	23	20	22	14	15
Exhaust Gas Recirculation System							3						5	1	3		3		
Air Injection Reaction System											2								
Emission components	24	14	9	7	23	29	22	12	9	8	9	4	33	21	17	20	15	14	15
Gasket														1					
PCV valve													1	1	1		1		
Tube														1					
Vapor canister				3			2				2		3	2	2		3		
Exhaust System	24	25	21	13	46	36	26		33	22	25	12	34	23	27	33	24	15	17
Catalytic converter				1									1	1	1		1		
Center pipe																	1		
Exhaust components	18	23		6	19	36	23		23	11	16	6	21	8	22	20	16	15	11
Exhaust manifold			16	2	27		3		10		2		1	3	2		2		
Exhaust pipe														1					

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Front pipe											1								
Manifold	6	2	5	3						11	4	6	9	10	2	13	3		6
Muffler				1							1			1			1		
Muffler and pipe assembly													1						
Tailpipe											1								
Resonator and pipe assembly																			
Fuel System	14	20	23	21	21	20	28	17	27	15	35	29	31	25	21	15	27	13	14
Cruise control		1		1			1				1		1	1	1		1		
Fuel induction		1		7			7				11		10	2	7		7		
Fuel supply		2		2			3				3		3	4	2		4		
Fuel system components	14	16	23	11	21	20	17	17	27	15	20	29	17	18	18	15	15	13	14
ENGINE, TRANSMISSION, AND RADIATOR	169	149	164	160	139	168	204	96	143	149	228	195	236	147	131	145	177	104	91
Engine		44	70	41	58	58	113	52			125	37	154	86	59		62		
Air intake			14		11		10	10			9		12	4					
Camshaft and timing		17		16			19				25	7	17	9	19		21		
Crankshaft and bearings		6		5			11				8	5	7	5	6		9		
Cylinder block							1				1	1		19			1		
Cylinder head and valves		11		13			17				18	13	25		19		20		
Engine appearance cover			3					2			2		13						
Engine and trans mounting			6		24	58	13	20			7		1	8	15				
Engine parts			29		17		30	17			29		67	30					
Lubrication		4		1			4				7	6	6	3			2		
Mounts		3		2			3				3	3	1	3			2		
Overhead gasket set											1	1	1	5					
Pistons, rings, and bearings		3		4			4				14	4	4				6		
Transaxle parts					6			3											
Turbocharger and components			18																
Valve grind gasket kit								X											
Short block							1				1	1	1				1		

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Chrg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Engine/Transaxle	96	86		43	4	49		6	71	80		59	0		40	90	45	57	46
Air intake	24	17		9		13			12	11		14			12	23	17	16	15
Engine appearance cover	8	7							1	10					3	16	7	8	6
Engine mounting	18	29		6					15	1		8				10	3	4	4
Engine parts	36	27		23		36			36	39		37			25	19	18	28	17
Valve and timing covers					4			6		7						22			
Transaxle parts	10	6		5					7	12								1	4
Maintenance and Lubrication		6		5			7				8	7	10	8			7		
Engine service		5		3			5				6	4	5	6			6		
Transaxle				2								3					1		
Transmission		1					2				2		5	2					
Cooling	59	52	76	41	62	55	56	29	57	39	49	49	51	30	16	49	36	37	33
Belts and pulleys	5	4	9	4	7	6	8	3	6	1	6	2	6	4		5	5	5	5
Cooling fan	1	7	10	1	1	3	4		11	12	12	13	6	4		7	3	4	4
Intercooler			9																
Inverter cooling components								6											
Engine oil cooler									7		8								
Oil cooler													4						
Power steering oil cooler			1												1				
Radiator and components	48	34	40	24	33	25	14	15	22	11	13	27	23	15	15	21	18	18	16
Trans oil cooler			4		6	6	15		5	6	5		4	3				4	
Water pump	5	7	3	12	15	15	15	5	6	9	5	7	8	4		16	10	6	8
Cooling System		14		9			11				16	13	10	10	12		16		
Cap		1		2															
Cooling fan		3					3				6	6	2	2	5		3		
Gasket				3			2				1	1					2		
Inlet tube											1								
Radiator		3		1			4				3	3	2	5			3		

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Chrg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Reservoir		1		1									1				3		
Reservoir cap		1											1				1		
Water inlet		1		1							1						1		
Thermostat		1		1			1				1	1	1	1			2		
Thermostat housing		1		1							1	1	1	1					
Water pump		2		2			1				2	1	2	1	7		2		
Radiator support	14	11	15	13	15	6	10	15	15	30	27	28	7	2	4	6	7	10	12
Radiator support	5	11	15	3	15	6	10	15	x	24	26	18	4	2	4	5	7	10	12
Splash shields	9			10					x	6	1	10	3			1			
Automatic Transaxle				4								2		6			4		
Automatic transmission																			
Drive plate				1								1		1			1		
Drive torque																			
Extension housing seal														1					
Shift control cable				1										1			1		
Torque converter				1										1					
Transmission														1					
Vehicle speed sensor														1					
Transaxle				1								1							
Clutch																			
Clutch and flywheel																	2		
Transfer Case							1						1	2			1		
Input shaft seal														1					
Output shaft seal														1			1		
Transmission			3				6				3		3						
Transmission components			3				6				3		3						
Automatic transmission																			

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Charg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Brush and holder																			
Frame																			
Front bearing																			
Rear cover																			
Retainer																			
Rotor																			
Manual Transmission														3					
Extension housing seal														1					
Flywheel														1					
Transmission														1					
LIGHTS	35	30	26	30	27	31	34	27	86	52	61	53	20	28	20	31	27	31	28
Front Lamps	13	15	8	12	16	16	17	16	38	30	33	33	12	22	10	16	16	15	17
Daytime running lamp components														3				4	
Fog lamps	2	2	2		2	4	7	2	6	8	8	4	2	3	4	4	4	4	
Headlamp components	11	13	6	11	10	12	10	10	32	22	25	29	6	9	6	12	12	7	14
Side marker								4					4						
Side marker and signal lamps					4									4					
Side repeater lamps														3					
Signal lamps				1															3
Washer components																			
Rear Lamps	22	15	18	18	11	15	17	11	48	22	28	20	8	6	10	15	11	16	11
Combination lamps			7				9		21		13	13		2					7
High mount lamps					3			3		6	11			1	2			5	1
High mounted stop lamp	4	2	4	4		4	5		3			3	2			4	3		
Backup lamps	2			1					18										
Identification lamps			4																
Side marker lamps	4			4															
License lamps	4	1	3	4	1	2	3	1	6	5	4	4	3	3	3	3	4	4	3
Tail lamps	8	12		5	7	9		7		11			3		5	8	4	7	

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Chrg	Jeep Wrangler	Ram Series	Accord	CR-V	Ridge-line	Insight
Doors	131	70	141	143	159	126	185	163	211	244	215	162	140	167	146	143	185	170	157
Front Door	62	38	78	82	84	66	102	88	100	91	114	93	83	93	82	81	103	95	89
Door and components	8	10	8	7	8	5	8	8	13	18	25	18	15	11	11	6	11	11	13
Exterior trim	12	11	5	11	6	4	4	8	12	8	1	5	7		5	7	15	2	5
Glass and hardware	9	8	10	8	8	7	11	8	16	10	20	15	7	37	13	11	10	13	17
Interior trim		20	32	28	20	12	16	22	19	19	31	19	25	10	12	22	13	22	14
Lock and hardware	24	22	14	22	32	31	38	32	30	20	30	29	25	30	36	20	38	33	24
Outside mirrors	9	8	9	6	10	7	25	10	10	16	7	7	4	5	5	15	16	14	16
Back Door										70									
Door and components										4									
Exterior trim										14									
Glass and hardware										7									
Interior trim										18									
Lock and hardware										12									
Spoiler										3									
Wiper and washer components										12									
Rear Door	69	65	63	61	75	60	83	75	111	83	101	69	57	74	64	62	82	75	68
Body side molding																	1		
Door and components	11	11	11	9	11	7	9	11	21	16	22	13	11	10	12	5	11	13	12
Exterior trim	10	9	6	8	6	8	9	6	12	18	1	5	11		4	7	10	2	7
Glass and hardware	11	8	8	9	14	7	11	14	24	16	18	14	8	25	10	12	8	11	15
Interior trim	16	18	21	14	16	9	16	16	18	16	25	12	18	6	9	16	16	16	13
Outside mirrors							25												
Lock and hardware	21	19	17	21	28	29	38	28	36	20	35	25	9	33	29	22	36	33	21
WHEELS	6	5	11	33	8	8	37	6	60	36	46	36	32	40	7	12	57	10	10
Wheels	6	5	11	4	8	8	7	6	60	22	6	6	8	7	7	12	22	10	10
Covers and trim	2		5	1	2	1	1		8	8	1	1	2	2	1		2	1	2
Alloy wheels																	1		

Parts Category	General Motors				Ford				Toyota				Chrysler			Honda			
	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Hybrid	Sedan	SUV	Truck	Sedan	SUV	Truck	Hybrid
	Malibu	Equinox	Silverado	Malibu Hybrid	Fusion	Escape	F-Series	Fusion Hybrid	Camry	RAV4	Tundra	Prius	Dodge Chrg	Jeep Wrangler	Ram series	Accord	CR-V	Ridge-line	Insight
Tire pressure monitor components					x														
Wheels	4	5	6	3	6	7	6	6	56	14	5	5	6	5	6	12	19	9	8
Spare Tire Carrier							3			14				5					
Carrier and components										14				5					
Brakes				29			27				40	30	24	28		35			
Anti-lock brakes				4			4				9	7	6	3		8			
Brake components				6			8				12	8	6	7		8			
Hydraulic system				16			10				14	11	9	15		14			
Parking brake				3			5				5	4	3	3		5			
HYBRID COMPONENTS				2								2	0						
Hybrid Components				2								2							
Battery												1							
Blower motor												1							
Cooling system				2															
Total Number of Parts	1193	1329	1319	1238	1369	1264	1306	1174	1585	1531	1844	1572	1482	1236	1479	1161	1663	1261	1090

Appendix D

Detailed Part Comparison Spreadsheet

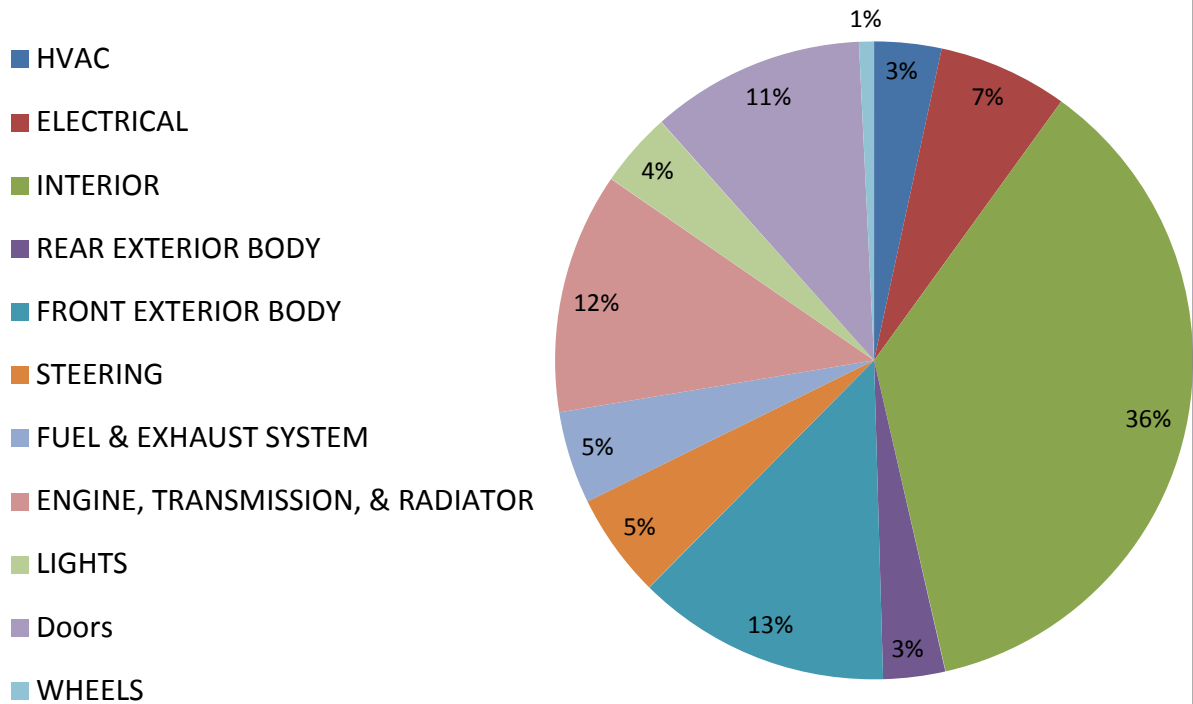
(located online at

http://www.ciras.iastate.edu/publications/Automotive_Industry_Parts_Investigation_Appendix_D.xlsx)

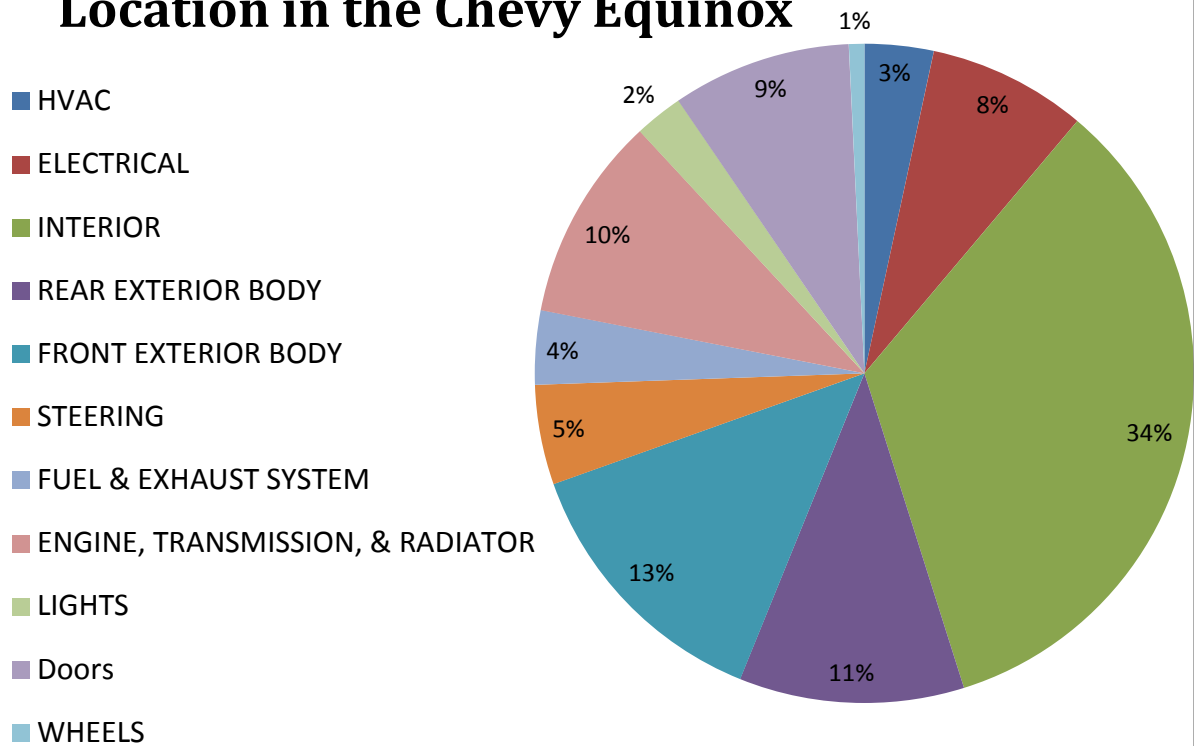
Appendix E

Comprehensive Part Lists and Additional Part Graphs

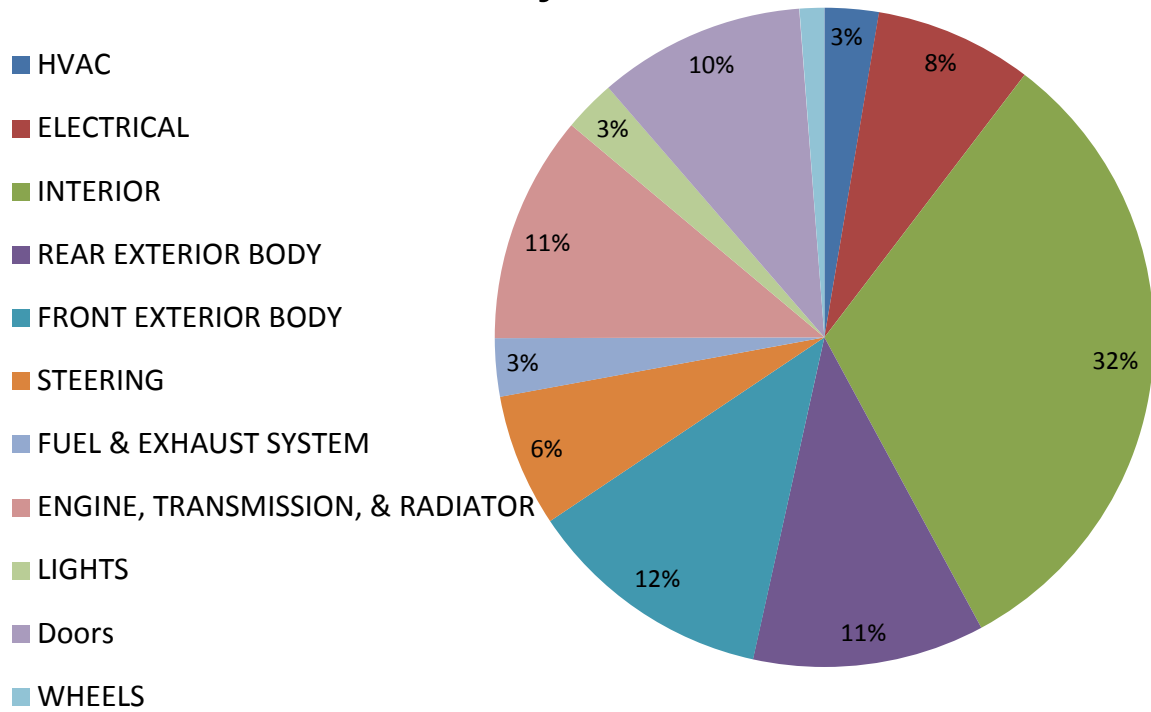
Percentage of Parts Based upon Location in the Chevy Malibu



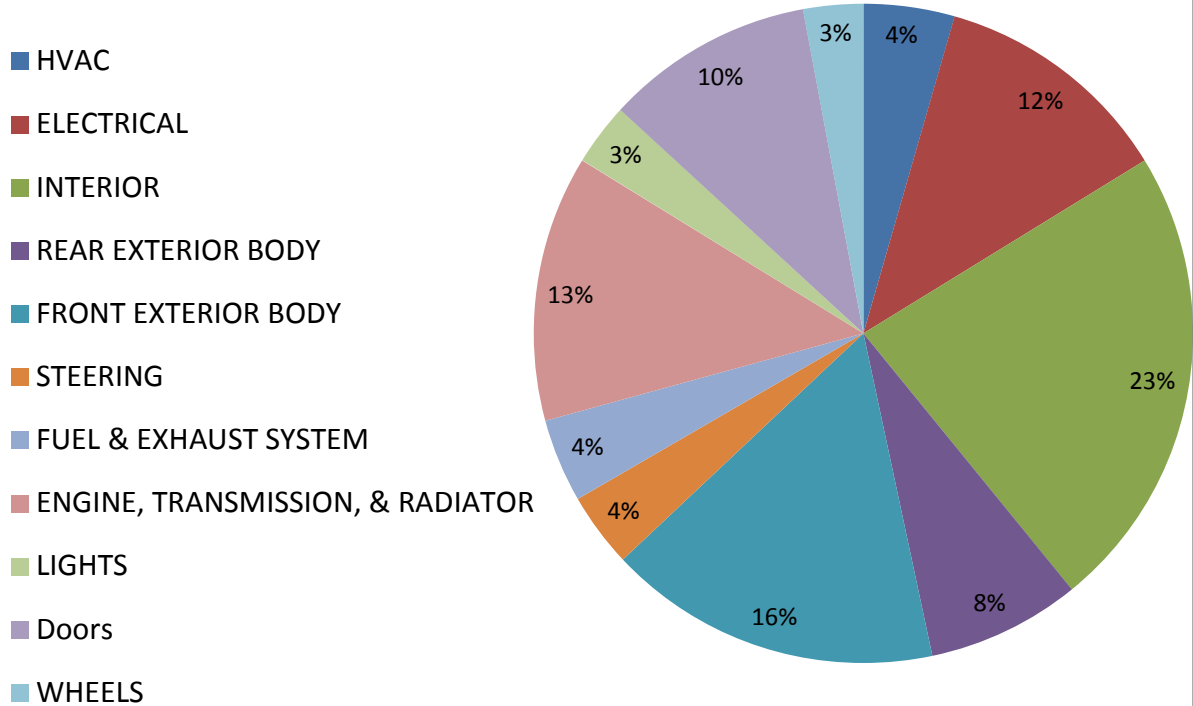
Percentage of Parts Based upon Location in the Chevy Equinox



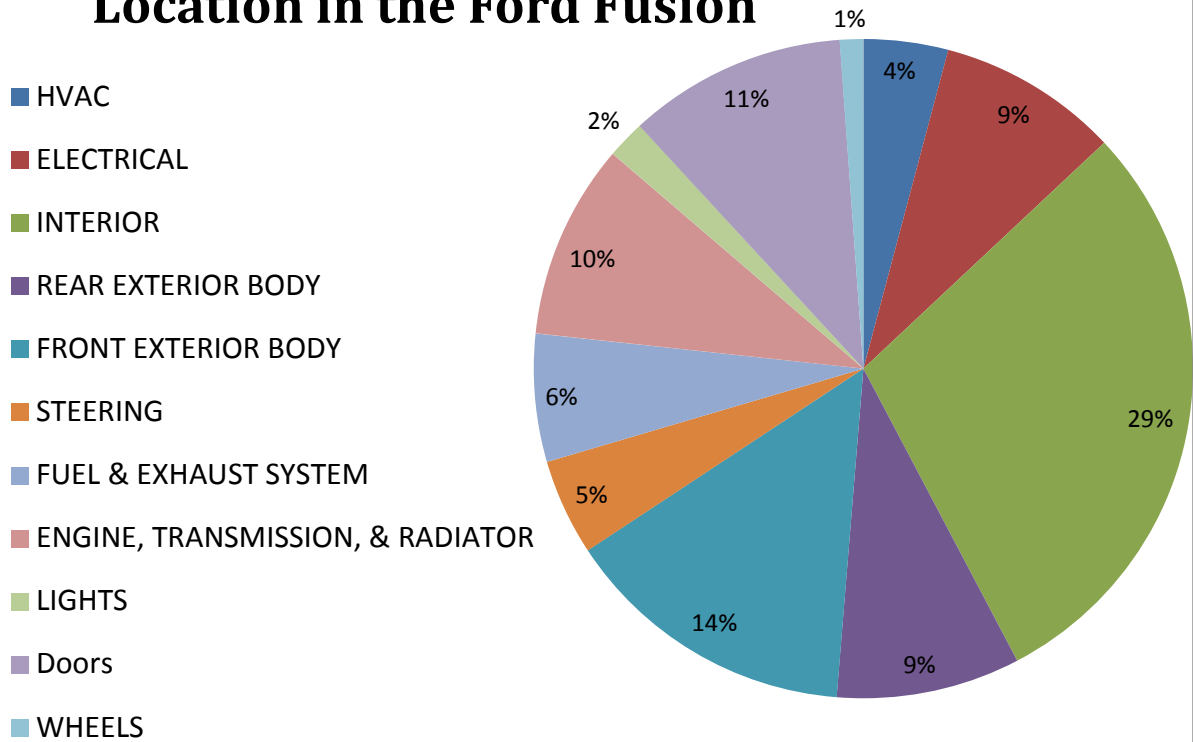
Percentage of Parts Based upon Location in the Chevy Silverado



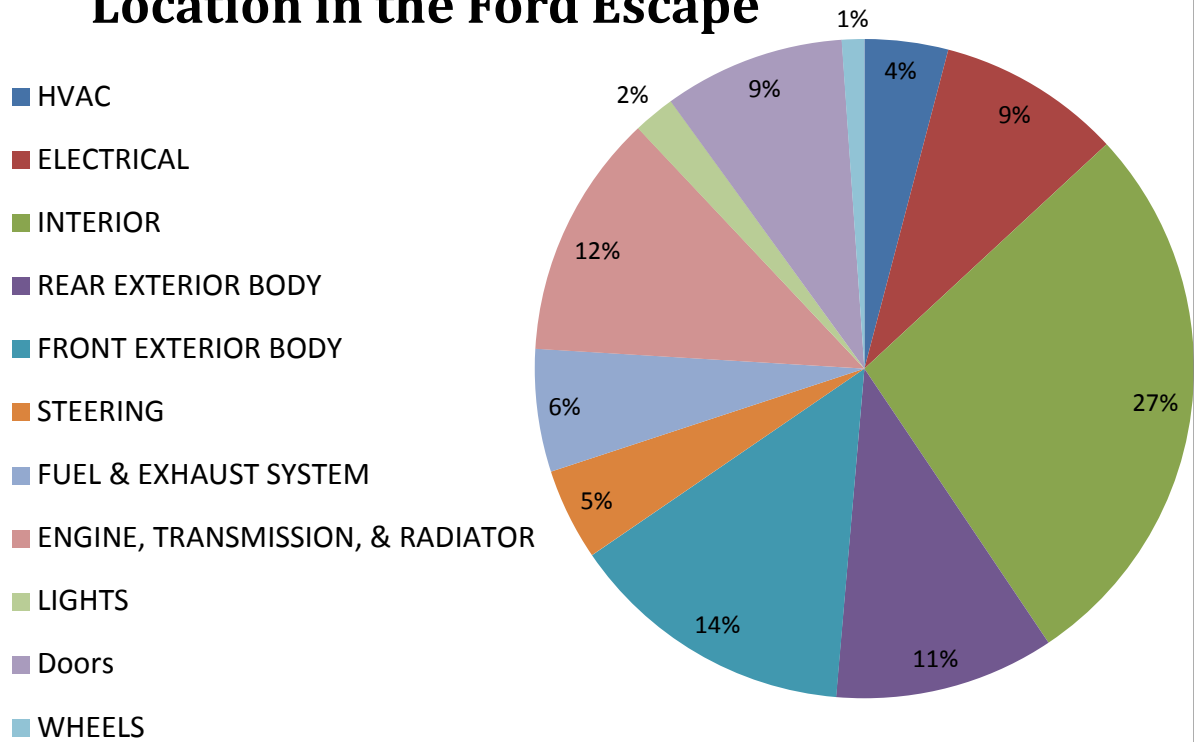
Percentage of Parts Based upon Location in the Chevy Malibu Hybrid



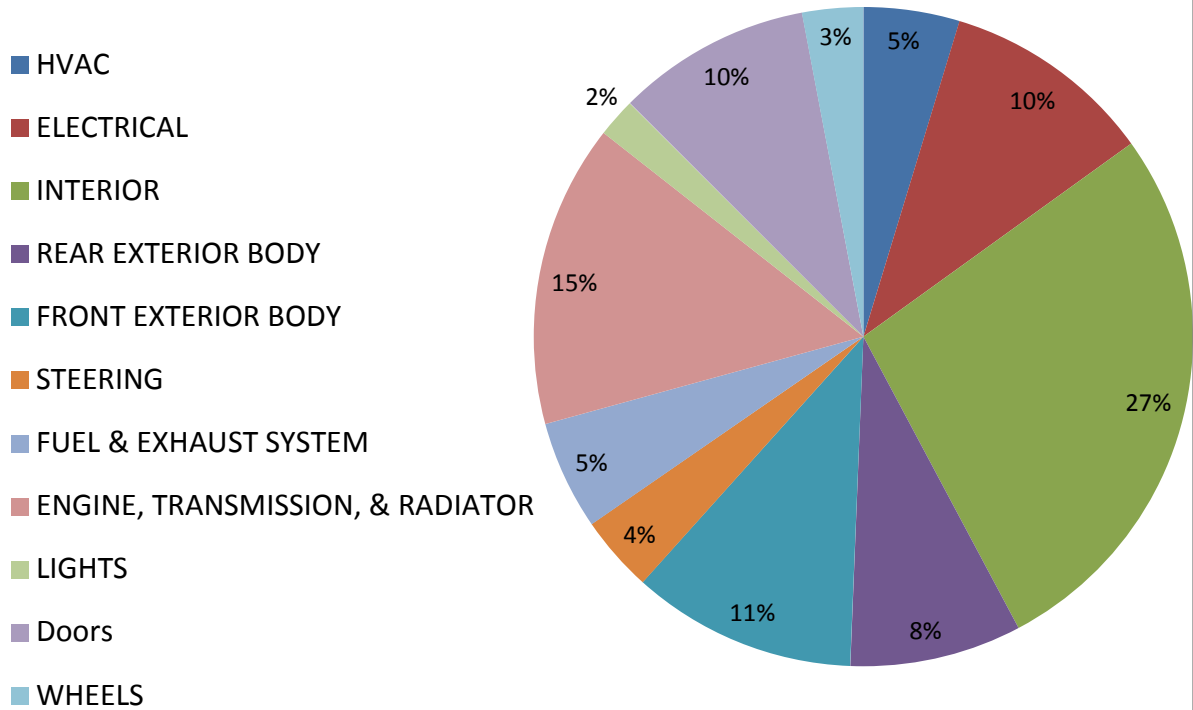
Percentage of Parts Based upon Location in the Ford Fusion



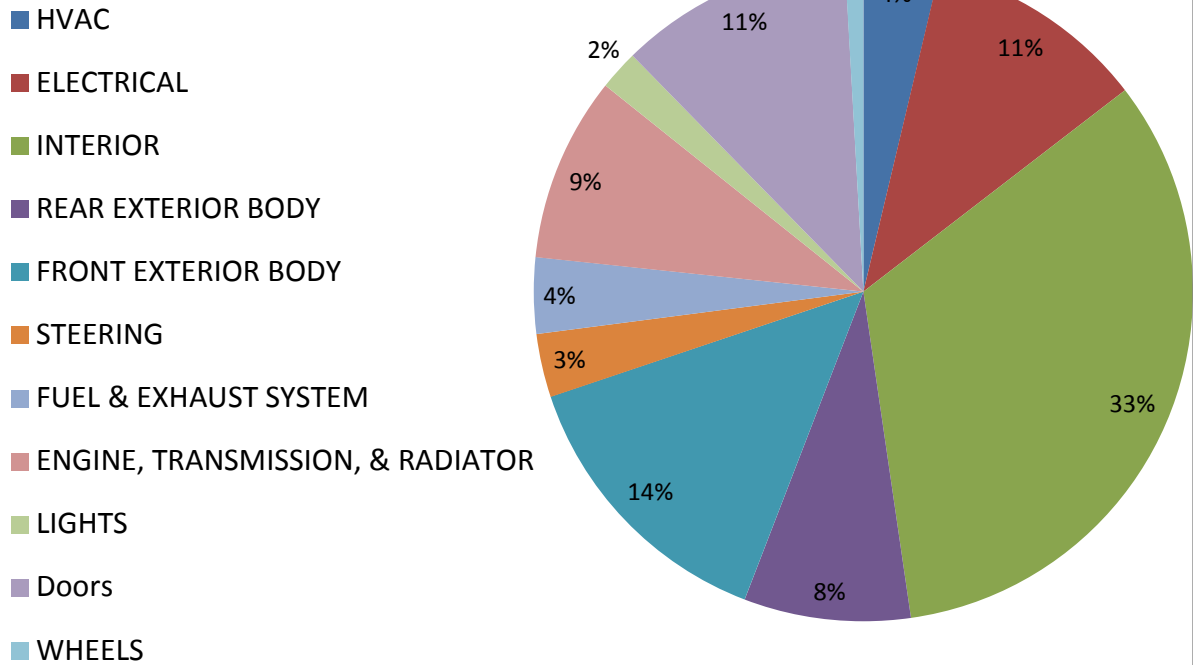
Percentage of Parts Based upon Location in the Ford Escape



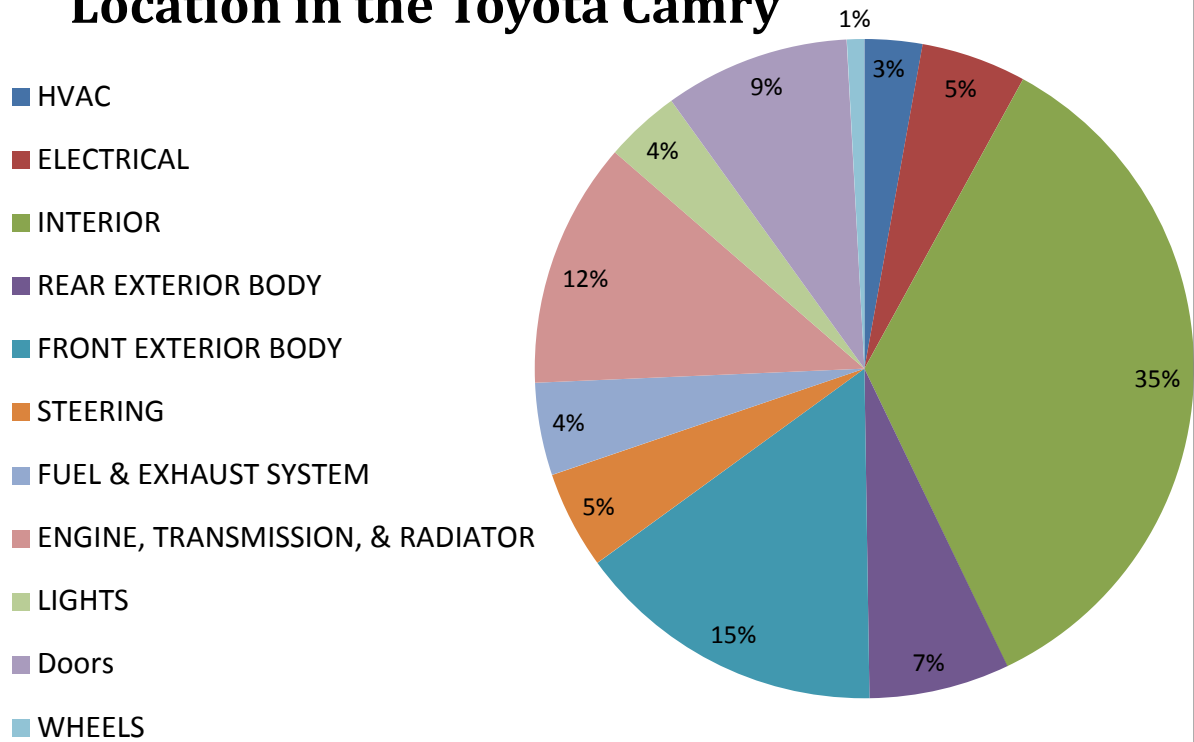
Percentage of Parts Based upon Location in the Ford F-150



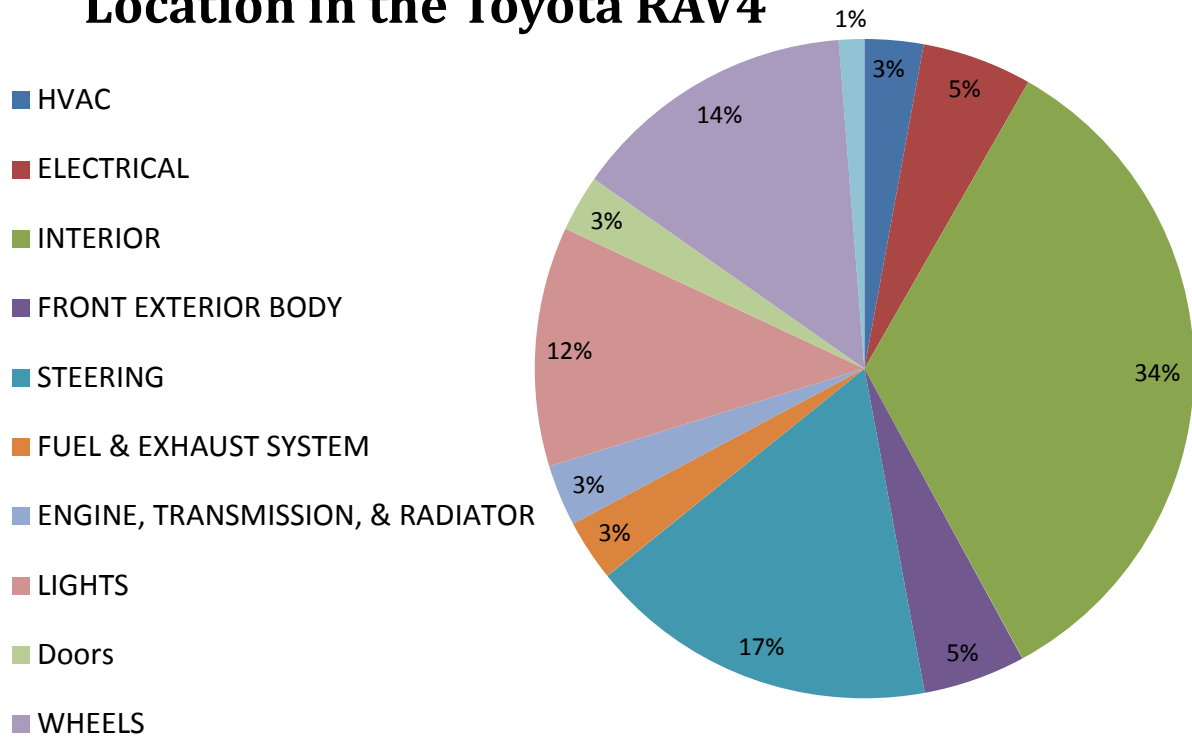
Percentage of Parts Based upon Location in the Ford Fusion Hybrid



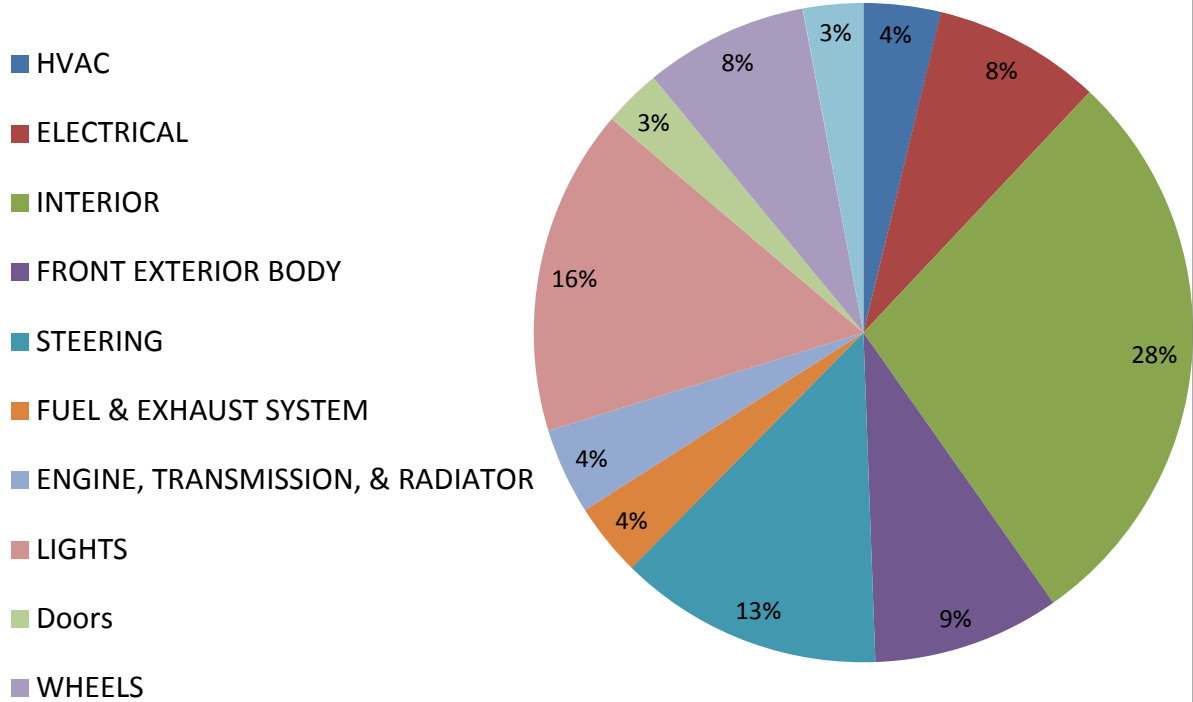
Percentage of Parts Based upon Location in the Toyota Camry



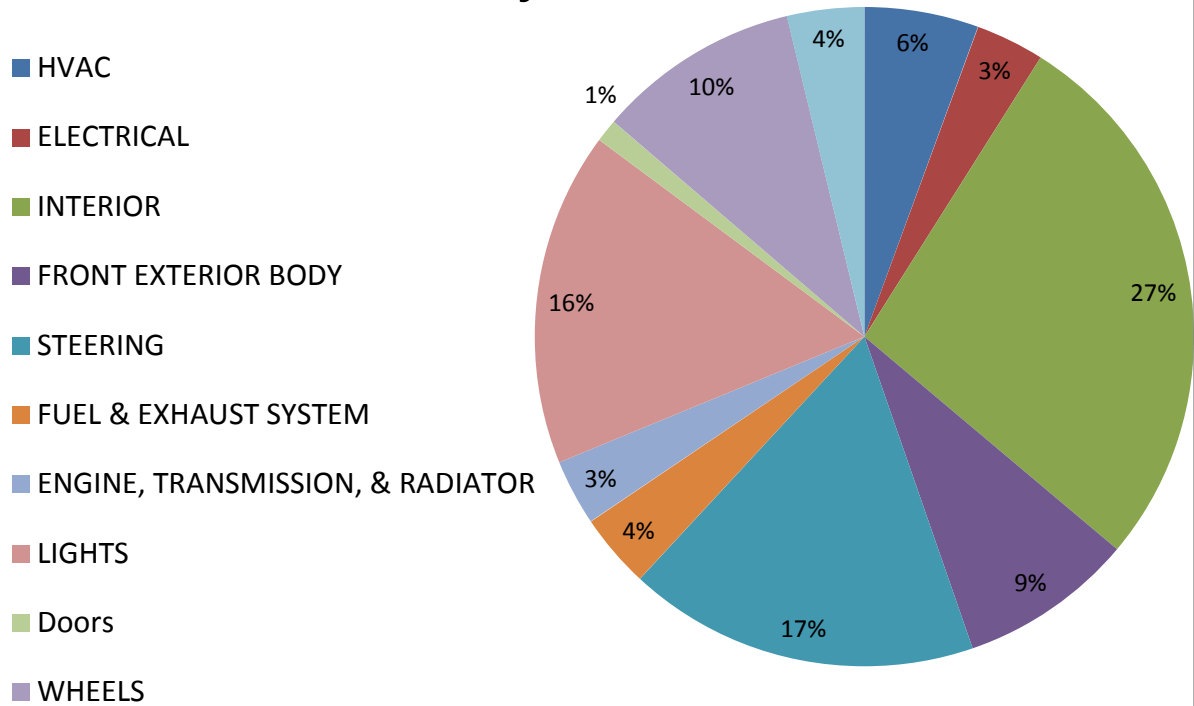
Percentage of Parts Based upon Location in the Toyota RAV4



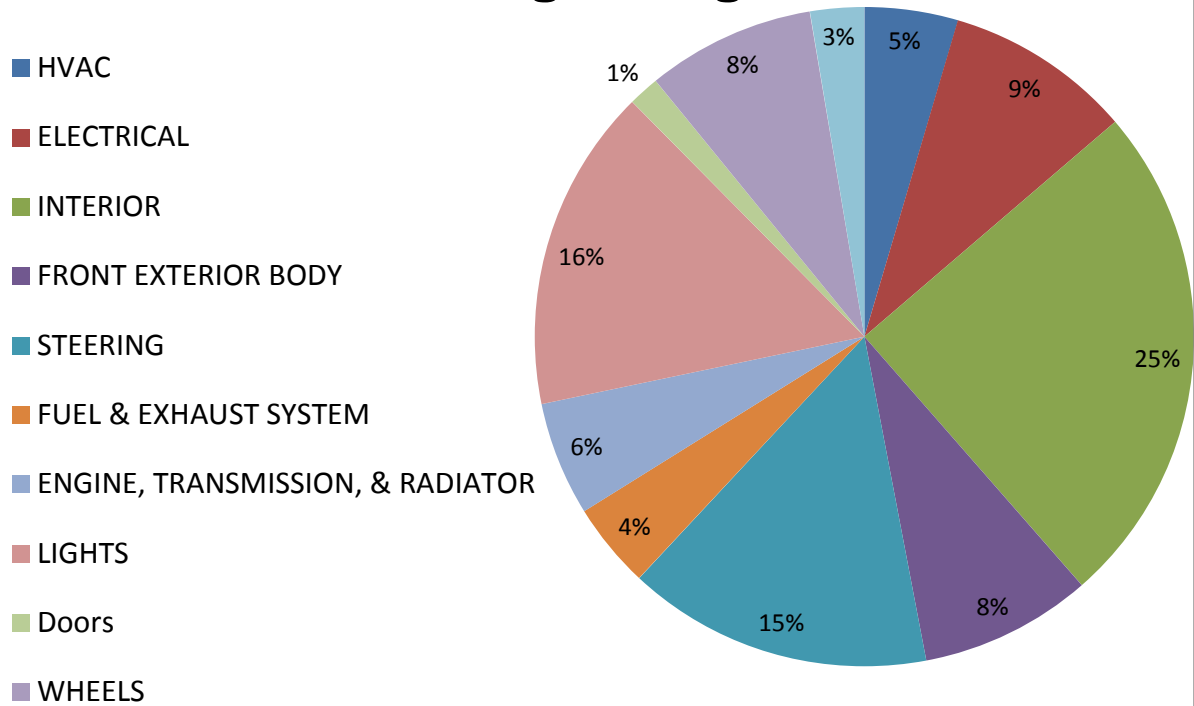
Percentage of Parts Based upon Location in the Toyota Tundra



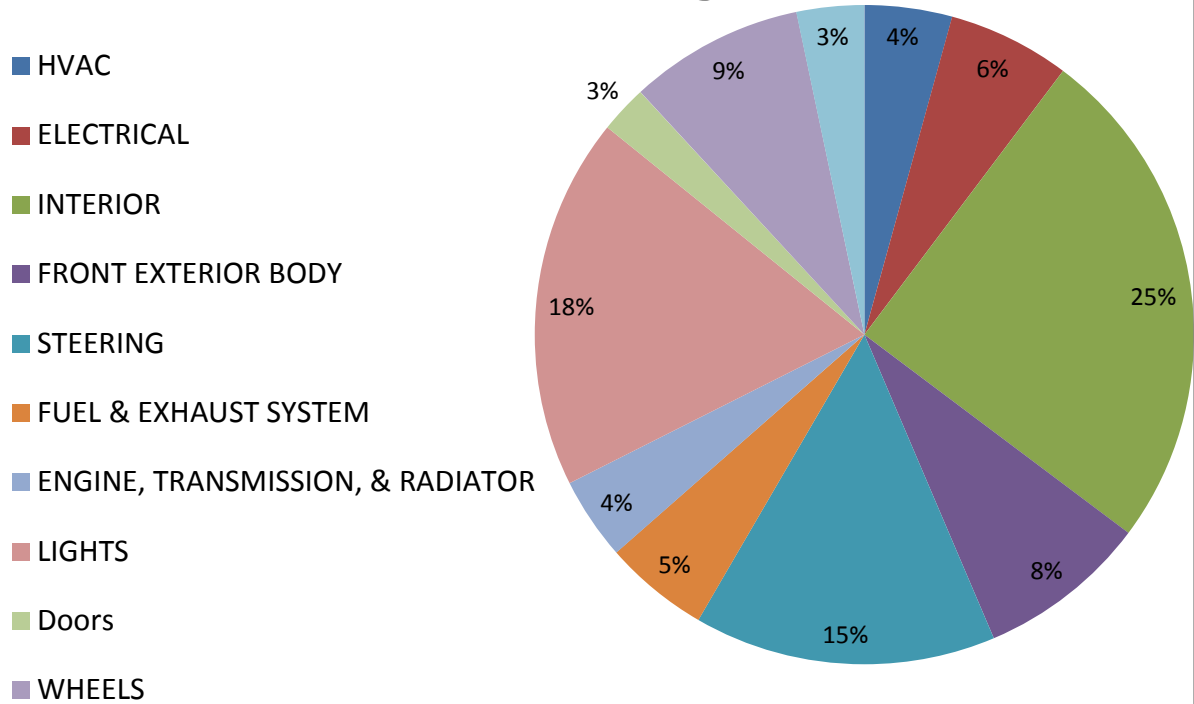
Percentage of Parts Based upon Location in the Toyota Prius



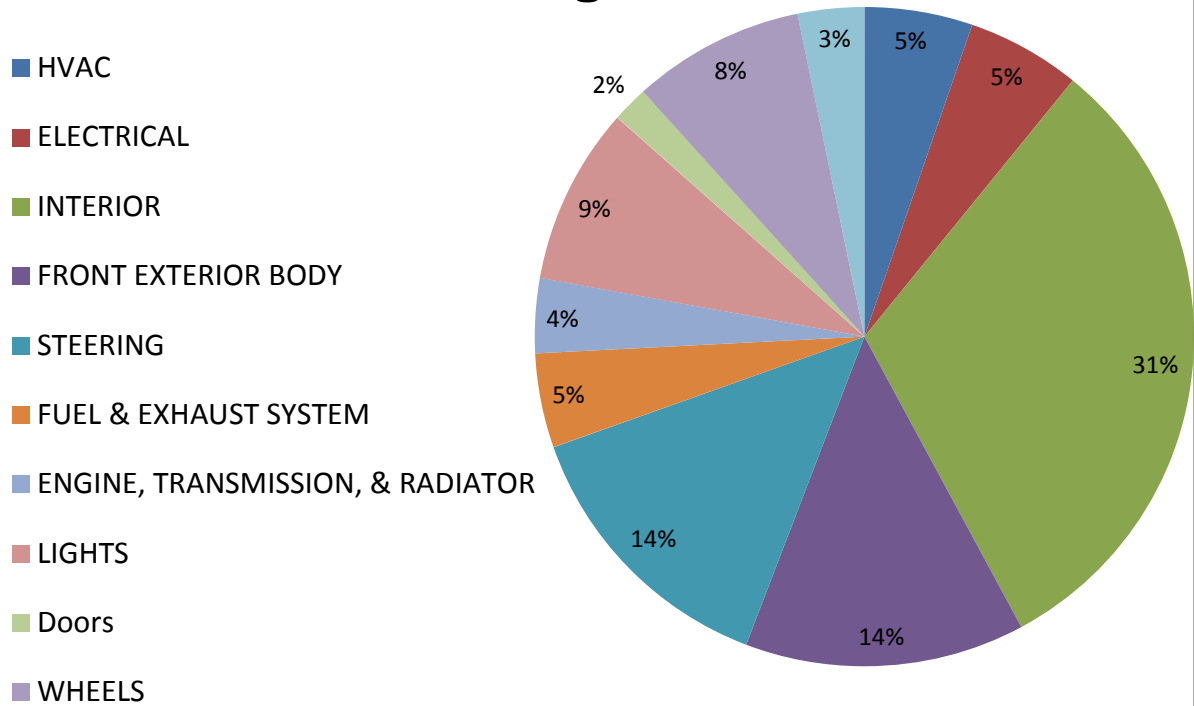
Percentage of Parts Based upon Location in the Dodge Charger



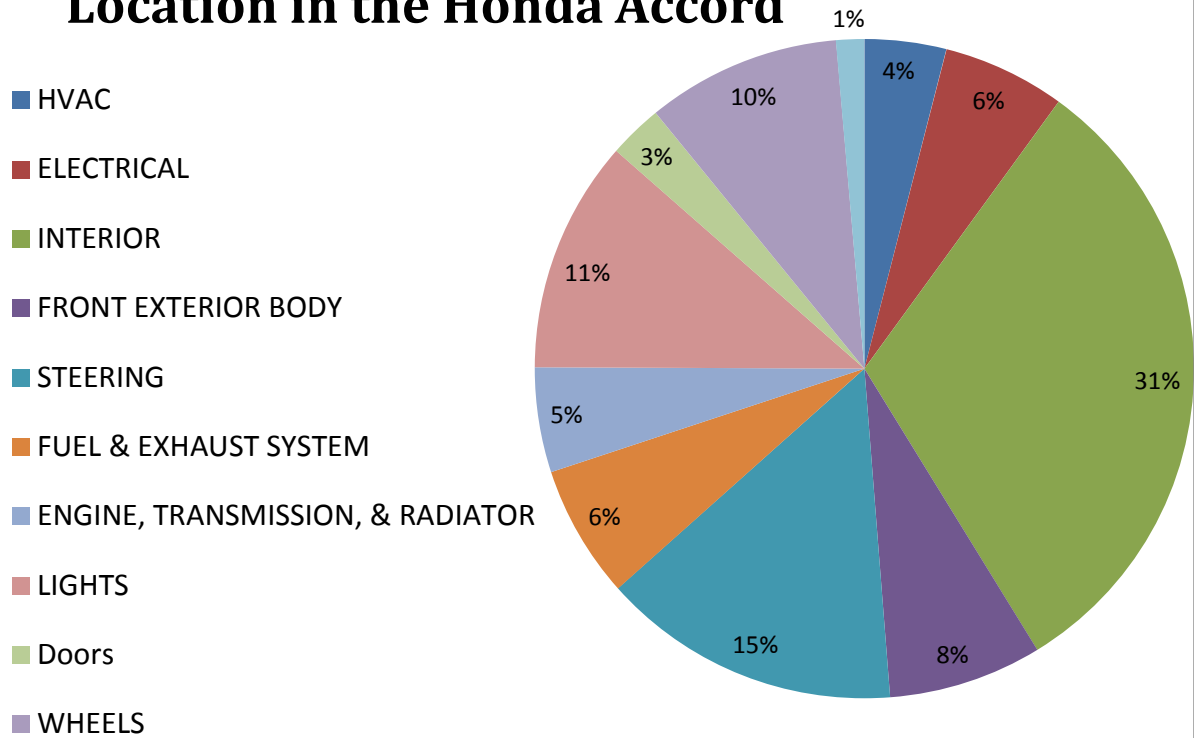
Percentage of Parts Based upon Location in the Jeep Wrangler



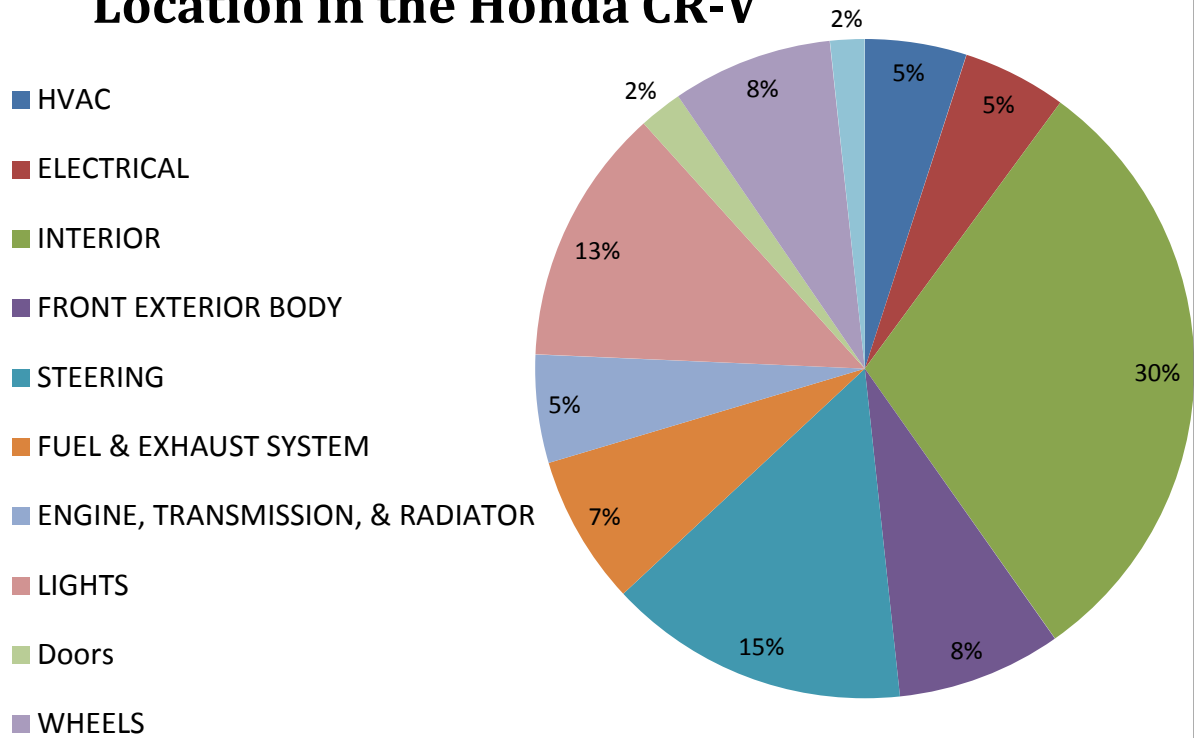
Percentage of Parts Based upon Location in the Dodge Ram



Percentage of Parts Based upon Location in the Honda Accord

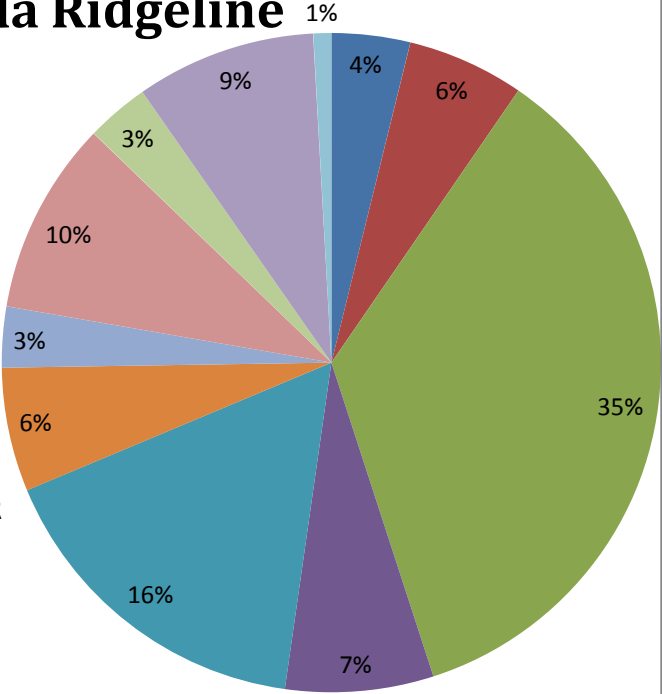


Percentage of Parts Based upon Location in the Honda CR-V



Percentage of Parts Based upon Location in the Honda Ridgeline

- HVAC
- ELECTRICAL
- INTERIOR
- FRONT EXTERIOR BODY
- STEERING
- FUEL & EXHAUST SYSTEM
- ENGINE, TRANSMISSION, & RADIATOR
- LIGHTS
- Doors
- WHEELS



Percentage of Parts Based upon Location in the Honda Insight

