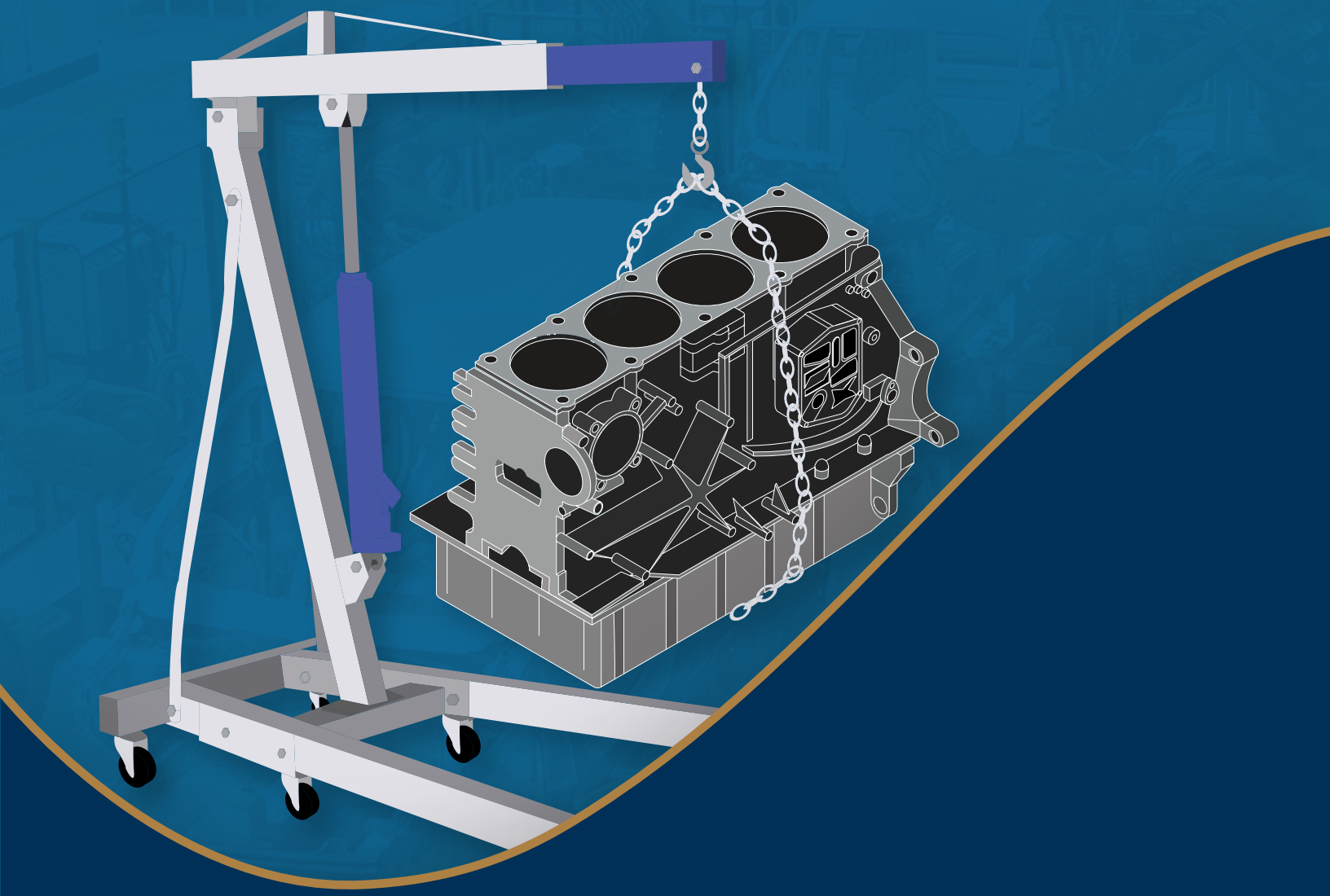
Georgia Tech Panama
Logistics Innovation & Research Center

Regional Hub for the
Automotive Industry



Driving Efficiency: The Supply Chain for Automotive Components

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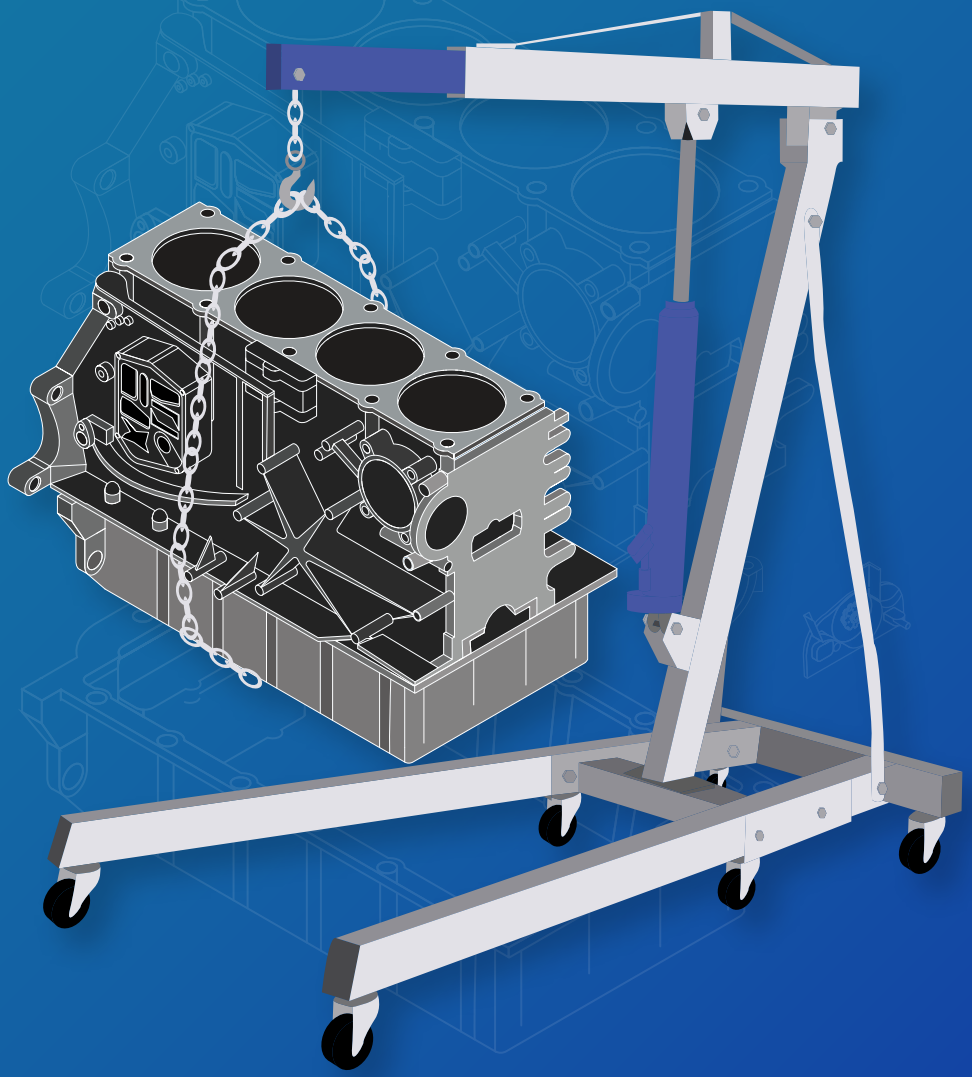

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A. Overview

Auto parts play an essential role in the constantly shifting environment of the automotive industry. As vehicles become more specialized to cater to the diverse needs of various sectors—ranging from personal transport to commercial logistics—the demand for high-quality, reliable components surges.
This growing market is not only vital for maintaining the operational efficiency of existing fleets but also for fostering innovation and economic growth in the face of emerging technologies and shifting consumer preferences. The automotive industry is made up of two main sectors [1]:

- **Auto parts**, which supplies components and spare parts for the production and repair of products in the finished vehicle sector.
- **Finished Vehicle Sector**, which provides personal vehicles, commercial vehicles, trucks, buses, specialized agricultural and construction equipment.

The size of the global auto parts market was $2,325.16 billion in 2023, and is projected to grow from $2,411.19 billion in 2024 to $3,241.4 billion by 2032. [2] The expected growth of the industry opens the doors to a growing generation of jobs in areas of production, logistics, and jobs derived from them. This projection is based on growing emerging markets, technological advancements, and the industry's recent recovery from the impact of COVID-19.

Auto parts are parts, components, or accessories of systems that are used in the construction, repair, or improvement of vehicles. [2] These can be [3]:

- **OEM (Original equipment manufacturing)**. distributed by official dealers and authorized representatives of the brands.
- **Generic manufacturing (aftermarket)**. generally produced by manufacturers that are not associated with the original groups, and generate the parts mostly through reverse engineering. These parts seek to be universal, so they work in a wide number of vehicles regardless of the model or brand.

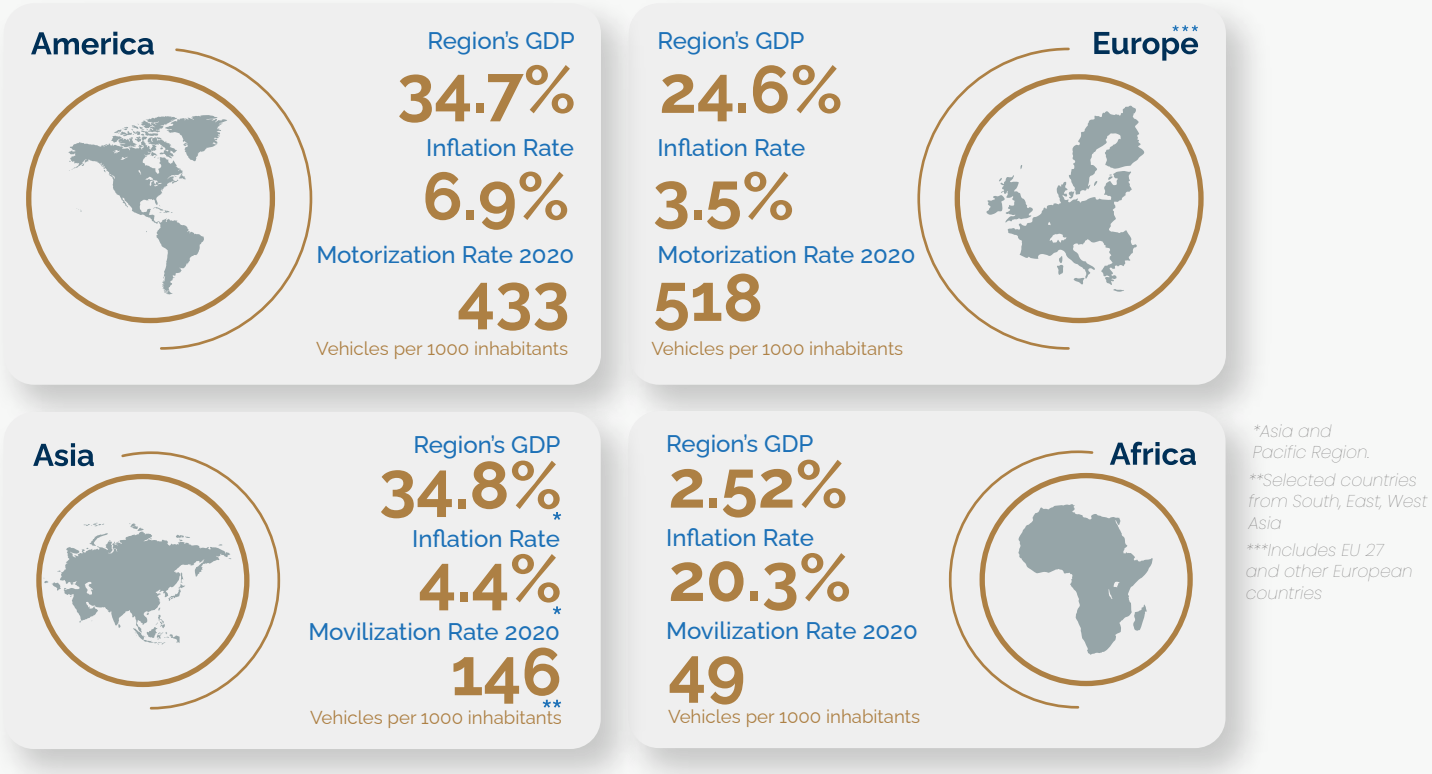
While certain Latin American countries manufacture OEM auto parts for light and heavy vehicles, their production is limited to specific models and brands, resulting in significant market gaps due to the variety of vehicles, predominantly manufactured in Europe and Asia. Additionally, heavy machinery auto parts must be imported from producing nations, resulting in prolonged wait times for repairs when vehicles require servicing.

It should be noted that in Latin America countries possess legislation to guarantee consumer protection, mandating that all manufacturers, producers, distributors and/or importers must ensure the regular supply of components, spare parts, parts and technical parts during the period in which they are manufactured, assembled, imported, distributed and sold in the country and, subsequently, for an extended period. For instance, Panama stipulates a minimum duration of ten years, while Costa Rica and Colombia require five years. [4][5]

In light of these challenges, exploring the establishment of an auto parts hub in Panama emerges as a strategic solution. This paper aims to demonstrate how such a center could significantly reduce storage costs and enhance supply chain efficiency, benefiting industry participants and their customers alike.

Global Economic Trends

The global economy is undergoing significant changes as countries recover from recent recessions driven by political and social upheavals, as well as natural disasters. With a continuous growth in Gross Domestic Product (GDP) and a decline in inflation rates, projections suggest a favorable economic climate by 2025. This optimistic outlook is expected to stimulate new constructions, major infrastructure projects, and an increase in consumer purchasing power, all of which will drive up the demand for vehicles and auto parts.



Adapted from OICA & IMF [6][7][8]

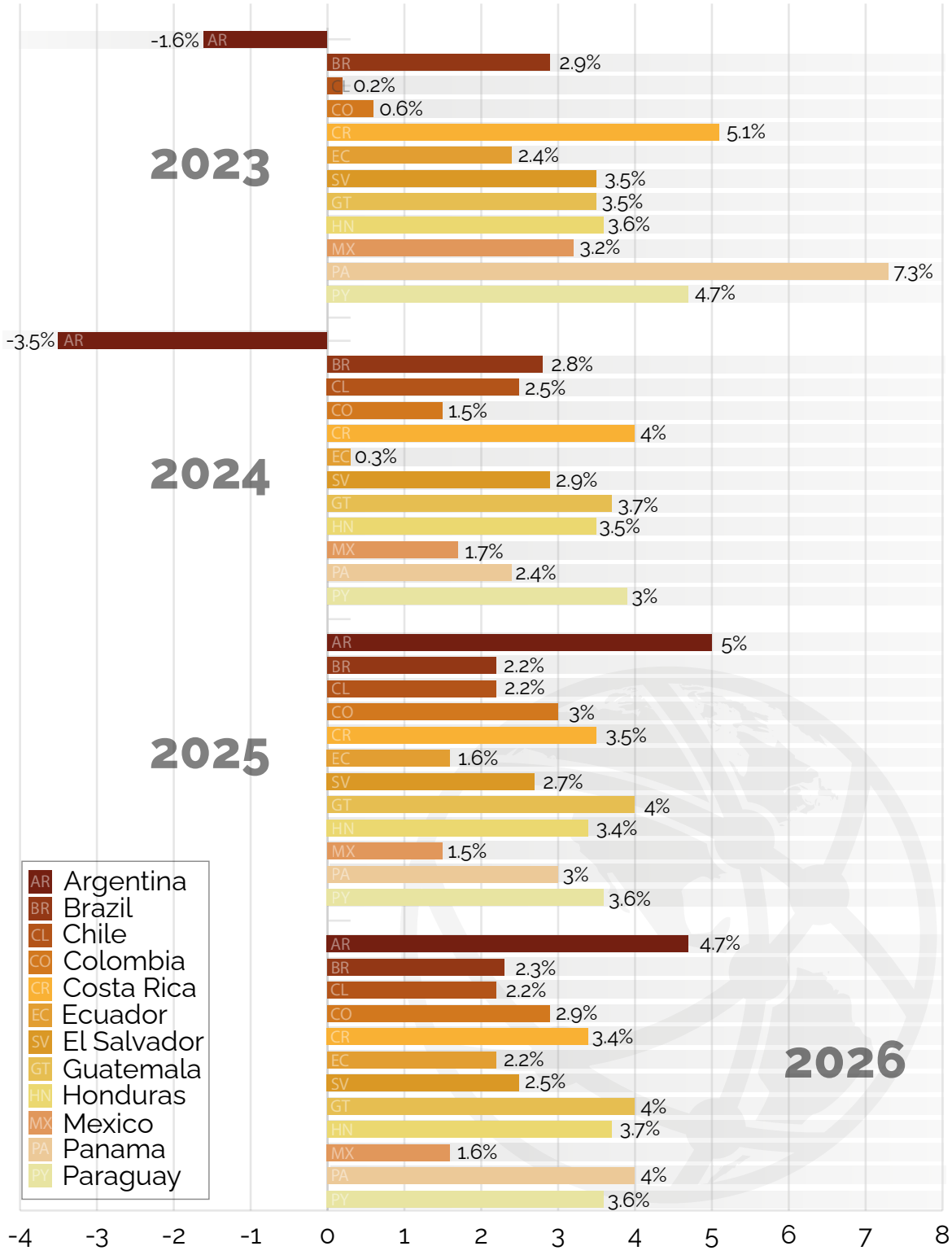
Europe leads with over 500 vehicles per 1,000 inhabitants, supported by a high GDP per capita and a controlled inflation rate of 3.5%. [6][7][8] These favorable conditions have enabled growth at a moderate rate of 2% between 2015 and 2020. [8]

In the **Americas**, motorization reaches 433 vehicles per 1,000 inhabitants, driven by steady GDP growth of over 2% in key sectors like technology and trade [8][10][11] Despite higher inflation rate (6.9%) compared to Europe, similar motorization growth of 2% reflects a reliance on automotive transportation. [6]

Asia, with a lower GDP per capita, recorded an 8% increase in motorization from 2015 to 2020, reaching around 140 vehicles per 1,000 inhabitants, with a total of 50.5 million vehicles registered in 2023. [7][8][9] Moderate inflation at 4.4% supports this rapid growth. [6]

Africa faces the greatest economic challenges, with the lowest GDP per capita and a high inflation rate. [7] These factors limit vehicle adoption, reflected in a rate of just 49 vehicles per 1,000 inhabitants. [8] Nevertheless, a 4% increase since 2015 suggests gradual progress through better infrastructure and vehicle access. [8]

Expected GDP Growth for some Latin American countries



Source: "Economic Outlook | Latin America and the Caribbean October 2024," World Bank[10].

Classification of Vehicle Components

Auto parts are essential to achieving optimal vehicle performance, as they play an important role in ensuring safety and reliability. We should remember that auto parts are parts, components, or accessories of systems that are used in the construction, repair, or improvement of vehicles. [2] Auto parts in optimal condition increase fuel efficiency and vehicle handling. [12]

Original parts offer greater reliability, quality and safety to consumers due to their custom manufacture with clear specifications depending on the model and brand of the vehicle. **Generic parts**, on the other hand, may not meet the technical specifications of the manufacturers. This mismatch can cause the parts not to conform to the technical requirements of the model.

Generic parts are of lower quality than OEM and can reduce the performance of the vehicle by not working in harmony with the other parts. The use of them leaves the vehicles without a warranty before the manufacturer or dealer. However, aftermarket parts are more accessible to consumers in terms of time and price, compared to OEMs that may have higher prices by having to import them from other regions; either because the model is not produced or because of the lack of stock in the region. [3]

A typical vehicle has about 70,000 parts and components that are then assembled or put together with others to form the systems. Examples of components include oil filter, brake pads, bodywork, interior and exterior parts, suspension, shock absorbers, batteries, wheels, specialized equipment parts. Examples of systems include powertrain, transmission, brake system, electrical system, fuel systems, and exhaust system. [13]

Powertrain

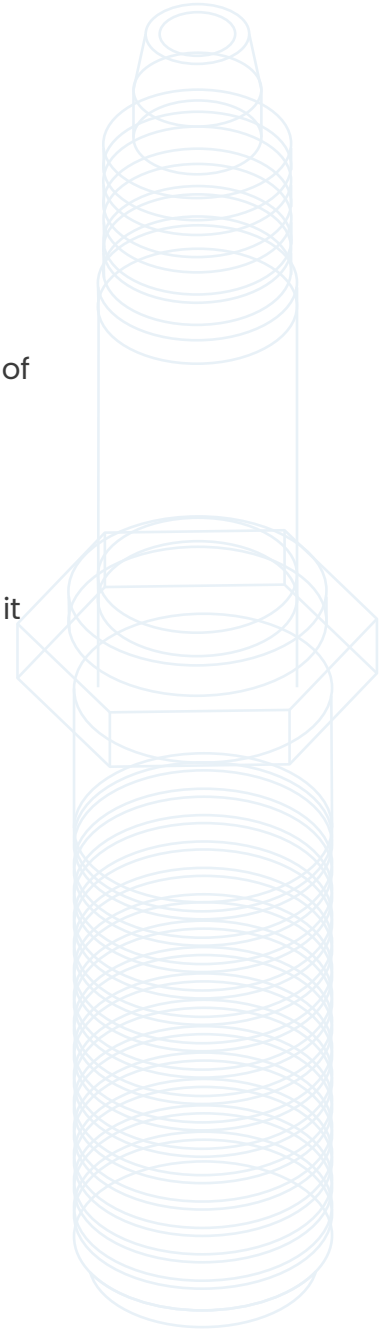
Also known as the propulsion system, it propels the car into motion. It includes the engine block, transmission, driveshaft, differentials and axles. The engine generates the energy necessary to start the vehicle and allows its correct operation. It is composed of [14]:

- **Engine block.** It has several holes to contain the cylinders and provide flow routes for water and oil to cool and lubricate the engine. All other engine parts, like pistons, cylinder, crankshaft, camshaft, engine valves, combustion chambers and crankcase are bolted to it.
  - Pistons are responsible for transferring the energy generated during combustion to the crankshaft to move the vehicle; these move up and down inside the cylinder twice during each rotation.
  - The crankshaft converts the up and down motion of the piston into simultaneous displacement at engine speed.
  - The camshaft regulates the opening and closing time of the valves.
  - Valves allow air to enter and exit; the more air in and out of the engine, the more efficient it will be, thus generating more power.
  - The combustion chamber is the area inside the engine where the combination of air and fuel is ignited.
  - The crankcase is the most complex part of an engine, as it has numerous oil and cooling passages that are necessary to cool and lubricate it.

There are five types of engines:

- Gasoline Engine (Internal Combustion). Petrol engines are internal combustion engines that convert chemical energy into mechanical energy, operating on the four-stroke Otto cycle. During the first stroke, the engine piston moves downwards to make room for a mixture of gasoline and air (intake); from the reaction of this mixture, the chemical energy is extracted. In the second stroke, the mixture is compressed, and a spark plug injects the energy necessary for the combustion of the mixture (compression). After combustion, the heat released increases the pressure, which presses the piston downwards and creates the power output (explosion). Finally, the burnt gases are removed through a valve (exhaust), completing the cycle. [15][16]

  The fuel for this type of engine is gasoline, one of the most widely used fuels. Because petrol engines require fewer parts than



diesel engines, they are considered easier to maintain and repair. It is mainly composed of hydrocarbons and is extracted from crude oil through refining. During refining, crude oil is distilled in a furnace at elevated temperatures, where gasoline, diesel and other petrochemical products are separated. [17]

Depending on its resistance to detonation and combustion, gasoline is classified as regular (87 octane), medium grade (89 to 91 octane) and premium or first level (93 octane).

Petrol engines can also use ethanol as a fuel source. Ethanol is an alcohol produced naturally from the fermentation of plant-based sugars such as corn or sugarcane, it is used as an additive to gasoline, either in 5% or 10% blends. These ethanol-gasoline mixtures make fuel more natural and decrease its environmental impact. [8]

- Diesel Engines (Internal Combustion). This type of internal combustion engine works due to the elevated temperatures that result from the compression of the air in the cylinder, eliminating the need for a spark. Instead, the energy needed to initiate combustion is obtained by spark plugs that raise the temperature in the combustion chamber. [15]

  Diesel, due to its higher flash point and lower volatility than gasoline, is more commonly used in trucks, allowing higher mileage performance. Diesel engines compress the air in the cylinder and then inject fuel, which initiates ignition. These engines do not usually reach high speeds. [16]

  In recent years, a way has been discovered to create biodiesel a diesel from organic waste. Biodiesel sources include [19]:
  - Vegetable oils, extracted from rapeseed, sunflower, palm, soy and plants of marine origin.
  - Animal fats such as those extracted from pork, cattle and poultry.
  - Used cooking oils.

- Electric engines. Electric motors are those that transform electrical energy into mechanical energy through magnetic fields. Unlike the other engines, these do not have an internal combustion engine; they have an electric motor that is powered by batteries that can be lithium or NCM (Nickel, Cobalt, Manganese). These batteries must be connected to a charging station for recharging. [16]

- Hybrid engines. Hybrid vehicles that have an internal combustion engine and an electric motor. This type of vehicle integrates the two engines so that the use of one recharges the other; that is, by using the combustion engine to drive the vehicle at high speeds, the electric motor is recharged, not requiring to plug in the batteries to recharge the engine. [16]

  There are several types of hybrid vehicles. Among the most common are:

  - Parallel hybrids. In these vehicles, both engines are connected.
  - Hybrid as standard. Here, the electric motor is the one that directly drives the wheels of the car, and the petrol engine is used only to charge the car's battery.
  - Combined hybrid. They use both systems to provide more fuel efficiency. [20]

  In this type of engine, not only gasoline or diesel are the source of fuel, but there is also hydrogen. This type of vehicle has a filling process like gasoline or diesel. In the fuel cell, a chemical reaction takes place between the hydrogen stored in the vehicle's tanks and the oxygen that arrives from the outside air. This reaction generates electricity to move the vehicle and water steam, so it is considered a clean alternative, with lower pollution levels than vehicles powered by conventional fuels. [21]

- Gas engines. Gas engines are similar in structure and operation to gasoline engines. Depending on the type of vehicle, the differences lie in the fact that some require the adaptation of a pressure regulator. The fuel types for this engine are:
  - Compressed natural gas (CNG). Considered a fossil energy source, composed of methane produced from the decomposition process of organic waste. It is commonly used in commercial vehicles, such as vans and light trucks. [22]
  - Liquefied petroleum gas (LPG). Becomes liquid when subjected to low temperatures and low pressures. LPG is based on propane, butane and gases from the distillation of petroleum. This is most used in heavy vehicles and pickup trucks. [19]

The other elements within the powertrain are:

- **Transmission.** The transmission transfers power from the engine to the wheels. This regulates the gear by connecting with the gearbox, which can be automatic, manual or continuously variable transmission (CVT).

  The manual transmission requires the driver to manually engage and deactivate the gears using the clutch pedal and gear level (shift). The parts of the manual transmission are: clutch, flywheel, gear selector, input and output axles, synchronized gears and a gear lever. These parts work together to enable gear changes and power transfer in vehicles. [23]

  An automatic transmission is the most common type today. It consists of a complex system of planetary gear assemblies, hydraulic torque converters, and a series of clutches and belts. CVT, instead of fixed gears, employs a belt or chain system that smoothly and continuously adjusts the gear ratio, allowing for infinite gear ratios. [24]

- **Driveshaft, differential, axles.** The driveshaft plays a crucial role in transferring torque from the transmission to the wheels. It is designed to operate at various angles and adjust its length to accommodate the movement of the suspension. The differential allows the rear wheels to rotate at different speeds, a function essential during cornering, as the outer wheel needs to turn faster than the inner wheel. Axles, positioned between the wheels, serve two primary purposes: (1) supporting the vehicle's weight and (2) transmitting power from the engine to the wheels, ensuring effective rotation and movement. [25]

Brake system

Brakes are an essential system that allows the car to slow down and stop. The process begins when the driver presses the brake pedal, transmitting hydraulic pressure to the brake mechanism. This pressure squeezes the brake pads against the rotating brake disc attached to the wheels. The friction created by this action slows down the car. [26] [27]

Suspension system

The car's suspension system ensures constant contact between the car's tires and the road, ensuring proper traction. This allows proper handling, control, and stability of the vehicle, providing a smooth and comfortable ride for the driver and passengers. The parts of the suspension are: shock absorbers, arms, ball joints, axles and links that connect the vehicle to its wheels. [28]

Electric system

It primarily consists of the battery and alternator. The battery stores energy in chemical form and releases it as electricity to power the vehicle's electrical components. The alternator is an electricity-generating device that converts mechanical energy into electrical energy in the form of alternating current. It also recharges the battery using mechanical energy generated by the movement of vehicle parts. [25]

Fuel system

In this system, the fuel tank stores gasoline or diesel, which is then pumped to the engine by the fuel pump. To start the car, the fuel injector sprays fuel into the combustion chamber.

Exhaust system

It is the system that allows all the gas produced by the engine, to leave the engine system. It includes:

- **Catalytic converter.** Responsible for reducing harmful emissions.
- **Silencer.** Reduces the noise produced by exhaust gases.
- The **exhaust manifold** of the engine cylinders.

Other important components

The automotive industry comprises a wide variety of components that play vital roles in the functionality, safety, and performance of vehicles. These components range from essential systems that enable operation, to specialized parts designed for specific purposes:

- **Steering system.** It comprises the steering wheel, steering system, axles, ball joints, racks and columns.
- **Specialized equipment parts.** It includes parts for specific machinery equipment, such as: lifting arms, loader, or bucket, crane cables, teeth, undercarriage, among others.
- **Chassis.** It is the skeleton of the car. The chassis absorbs energy and supports the weight of all the components of the vehicle.
- **Internal and external parts.** It corresponds to seats, airbags, door moldings, floor mats, luggage compartment, vehicle roof, bumpers, upper consoles, lamps, internal lighting systems, among others.

Automotive parts supply chain

The supply chain of auto parts involves several links. Depending on the nature, function and characteristics of the part or component, more or less links or stages are involved.

Some parts such as windshields can involve four links. First, the acquisition of the raw material, silica sand and other materials. It involves mining companies. Secondly the processing plants that transform the mixture into glass by melting and then molding it and giving it the necessary finish. Third distribution, and finally, sales. Other more elaborate parts and components require more links and involve a larger number of suppliers.

In general terms, the stages of the auto parts chain, can be grouped as follows[29]:

1. Design and testing - involves specialized companies.
2. Acquisition of raw material - could take various suppliers of raw materials.
3. Manufacturing - involves factories, groups or manufacturing companies.
4. Distribution and sales.

It should be noted that, on many occasions, automobile manufacturing groups obtain vehicle parts from different suppliers. These suppliers have OEM auto parts lines, designed under the order specifications of the groups and generic auto parts lines. The OEM groups tend to custom manufacture the heaviest or most specific parts such as engines, transmission systems, some interior parts, batteries, among others.

In vehicle manufacturing, globalization has driven the production and/or assembly of some models in certain countries to establish proximity to their target markets. This shift prompted the search for suppliers and specialists in parts that were closer to their production, to comply with the just-in-time strategy. Some of the participants in the

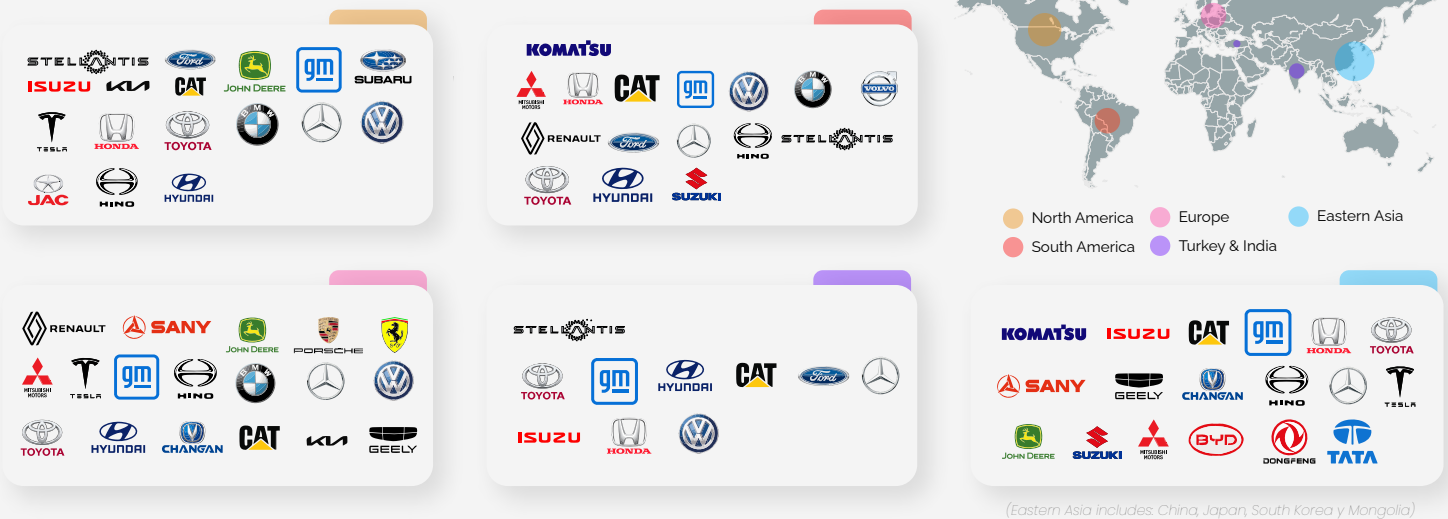
vehicle supply chain are affiliates or subsidiaries of the main group based in the manufacturing countries or regions. These entities are responsible for producing and supplying the parts for assembly, fostering the development of clusters in countries such as: China, the United States, Japan, Germany and Mexico. [30][31]

Although there are suppliers of parts close to the manufacturing region, it must be remembered that they specialize in only some models. This means that the **parts and auto parts of Original Equipment Manufacturers are closer or farther from the final consumer, depending on location and vehicle model**. [32]

The location of the suppliers of the parts also depends on their specialty. **The heaviest and most specific parts**, such as engines, transmission systems, tires and interior parts, **are usually produced close to the point of assembly.** On the other hand, **lighter parts** such as: cables, electrical system, mechanical components, brake system, among others, **are usually produced far from manufacturing regions.** This is because these parts tend to have their multi-use nature, which means they are compatible with a large part of the brand's models or varied brands. Producing these components in regions far from manufacturing hubs allows companies to reduce costs by taking advantage of volume production and scale economies. [33]

Vehicle Production Regions of the main manufacturing groups

According to sales volume in 2023



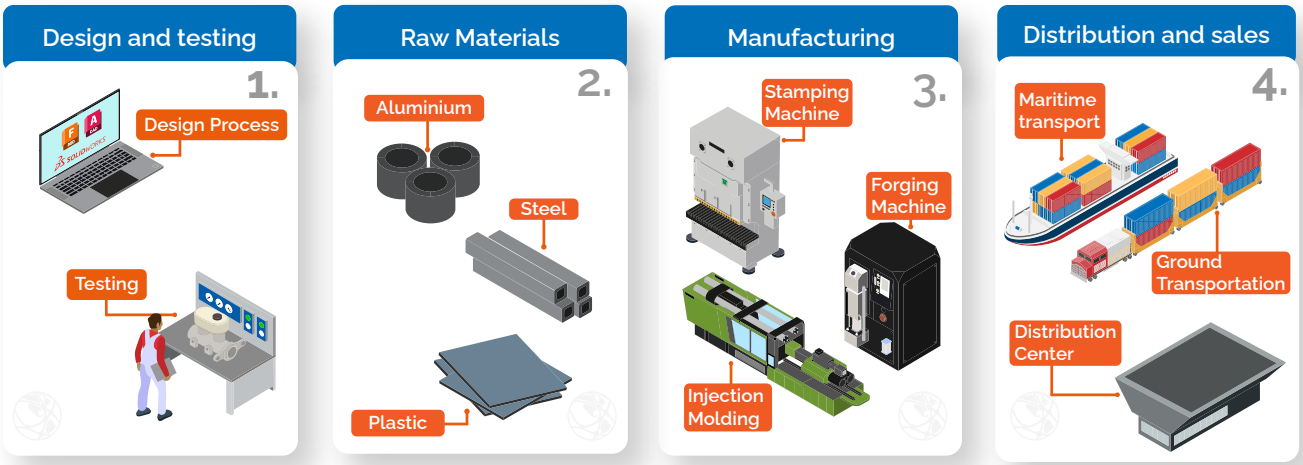
(Eastern Asia includes: China, Japan, South Korea y Mongolia)

Source: OEM official pages & Statista [43]

The following are major suppliers and OEM manufacturers of auto parts: Denso, Robert Bosch GmbH, ZF Friedrichshafen, Faurecia, Autoliv, Valeo, HELLA, Lear Corporation, Magna International, Hyundai Mobis, OPmobility, Continental, Aptiv, Aisin, Brembo, ACDelco, among others. They have production subsidiaries in vehicle manufacturing countries to ensure just-in-time delivery of parts.

Other large entrants with significant market share in generic production are: BASF SE, Thyssenkrupp AG, Continental AG (Germany), Hitachi, Ltd., Eaton Corporation, Tenneco, TRW Automotive, The Pep Boys, Pioneer Corporation, Covercraft Industries LLC, Lear Corporation, Garmin Ltd. (USA), Pecca Group Berhad (Malaysia), CAR MATE MFG, CO., LTD., NTN Corporation (Japan), AB SKF (Sweden). [33]

Supply chain description



1. Design, development and testing

Each vehicle model is designed with unique features that offer the market innovative features. Each vehicle manufacturer designs parts that adapt to the planned model, considering dimensions, mounting points and performance characteristics. In the design, the aim is to solve a need or improve the existing parts in some aspect; based on earlier analysis and studies, the idea of the auto part is conceptualized.

The most used materials are: **metals** (steel, aluminum, copper), **plastics, composites**, and **alloys**. [29] In the choice of the material, the specific characteristics required by the part, resistance, cost, durability, among others, must be considered. For example: parts that need to be light and resistant to corrosion are mainly made of plastic, parts that require greater structural strength are made of metal.

Engineers and designers create the models by implementing software to create detailed simulations of the operation of the part in the vehicles or create prototypes for testing. At this stage, decisions are made on the material to be used in the part, structural integrity and performance requirements, such as: compatibility with the other parts of the vehicle, aesthetics, and other provisions of the groups or companies. [34] Some of the tests to be performed are:

A. **Stress test.** Multiple forces and pressures are applied to the parts, simulating the environment in which they will be found in normal conditions of use and in external conditions. This test allows finding irregularities and possible points of failure.
B. **Durability test.** This simulates the long-term wear of the parts by using them in repeated use cycles, to ensure that they comply with prolonged use without wear.
C. **Environmental tests.** The parts are exposed to various temperature and humidity conditions to guarantee their operation in different climates. In the case of metals and coatings, their resistance to corrosion is checked.
D. **Safety and impact tests.** Through a simulation of impacts, engineers ensure that the parts absorb or withstand forces without compromising the safety of the vehicle or its occupants. In the same way, crumple zones, simulated airbags and crash scenarios are evaluated to verify their efficiency.

Parts are assessed to ensure compliance with industry standards and regulatory requirements. [33] These include:

- **ISO/TS 16949.** Created by the International Automotive Task Force (IATF). It integrates standards from the United States and

Europe, emphasizing defect prevention, reduction of variation and waste, and continuous improvement throughout the chain.

- **IATF 16949.** It is the evolution of the earlier standard. It seeks to improve the safety and reliability of products, while promoting the continuous improvement of processes.
- **ISO 9001.** Quality management standard provides a framework for organizations to improve customer satisfaction through effective quality management systems.
- **ISO 26262.** This standard addresses functional safety in vehicles with electrical and electronic systems. It describes the processes for managing safety throughout the product life cycle, from development to decommissioning.
- **ISO 14001.** Focuses on environmental management systems and helps organizations improve their environmental performance through efficient use of resources and waste reduction.
- **ISO 45001.** This standard refers to occupational health and safety management systems and aims to provide a safe working environment for employees in the automotive sector. [34]

At this level, automotive groups have research, design and development teams, which are located in the country headquarters, or in offices in the countries or regions where their models are assembled. Some examples, with the location of the design centers are:

Source: OEM official pages

It can also be found design companies subcontracted by the groups or by companies producing auto parts, for example: EDAG, Pininfarina, Italdesign, Zagato, Bertone, Raymond Loewy, Wrightson, Johnson Controls, Faurecia, Magna, Schaeffler AG.
Similarly, materials science laboratories are also involved in this stage. These include Dow Automotive, BASF, DuPont Automotive, ArcelorMittal, Sumitomo Chemical, Toray Industries, Nippon Steel, Kobe Steel.

2. Raw Material Acquisition

The different auto parts producing companies worldwide look for their raw material as close to their operations as possible, to reduce production time and reduce operating costs. The raw material chosen to produce the part will determine the durability, performance and safety of the parts. Among the main raw material options are:

- **A. Steel.** Due to its strength and durability, it is widely used in chassis, engine components, and body panels. About 60% of vehicles are made of steel.

B. **Aluminum.** For its lightweight and corrosion-resistant properties, aluminum is used in engine blocks, wheels, and body panels. Aluminum can reduce vehicle weight by up to 30%, leading to better fuel efficiency.
C. **Plastic.** Plastics, including polypropylene, polycarbonate, and acrylonitrile butadiene styrene (ABS), are used for interior components, bumpers, and trim. It is estimated that around 20% of the total weight of the vehicle is plastic.
D. **Rubber.** Mainly used in tires, seals and gaskets. Its elasticity and wear resistance make it essential for automotive applications.
E. **Composites.** Carbon fiber and fiberglass-reinforced composites, which offer high strength and rigidity with a light weight. Mercedes-Benz has used natural fiber composites in the interior panels of its models to reduce weight and improve sustainability. [33]
F. **Leather, nylon, microfiber and other textile materials.** Mainly used for seats and interior coverings.

Raw material suppliers include:

- **Mining companies:** BHP Billiton, Rio Tinto, Vale, Glencore, Anglo American, Alcoa, ArcelorMittal, LKAB, Barrick Gold, Newmont Mining
- **Chemical and compound products manufacturers:** BASF, Dow Chemical, DuPont, ExxonMobil, Shell, Chevron Phillips Chemical, SABIC, Mitsui Chemicals, Asahi Kasei, Lanxess.
- **Steel and aluminum smelting plants:** ArcelorMittal, Nippon Steel, Tata Steel, Nucor, US Steel, Alcoa, Rio Tinto, Rusal, Norsk Hydro, Jindal Steel & Power.

3. Manufacturing

Manufacturing transforms the raw materials into final products. It is worth highlighting and remembering, that autoparts could be just a piece required for the repair or the change of one that does not work properly, or a total complete complex system, as the ones explained earlier; because of that, manufacturing could be divided in two, the **manufacturing of parts** and the **manufacturing of systems.**

3.1. Manufacturing of parts

At this level, the parts and components are created, the technique to be used depends on the material and the function of the part.

- **Forging.** Consists of shaping metals by applying compressive and heat forces.
- **Injection molding.** Commonly used for automotive plastic parts, this process involves injecting molten material into a mold to form the part.
  Automotive parts factories that specialize in plastic use this method for its ability to produce complex components in large volumes. Some of the parts manufactured using this method are: bumpers, fenders, dashboards, glove compartments, combustion chambers.
- **Casting.** Consists of mixing some materials such as silicon, alkalis and lime at high temperatures, and then shaping them by molding and cooling to create windshields and windows.
- **Stamping.** This technique is mainly used for metal parts. It consists of shaping a sheet of metal by applying a press. Automotive parts stamping is perfect for components such as body panels and structural parts.
- **Dyeing and weaving of fibers.** Corresponds to the conversion of fibers obtained from chemical compounds or processing of other materials, into yarn to then weave and create the upholstery of vehicles.
- **Additive manufacturing.** Also known as 3D printing. This technology is starting to be used in prototype manufacturing and, in some cases, for final parts. It allows the creation of complex components with high customization.
- **Vulcanized.** Used for rubber parts, such as gaskets and seals. It involves adding sulfur to raw rubber to improve elasticity and strength. This process also helps to extend the life of the components as it ensures long-lasting performance. [29]

At the end of the manufacture of the parts, finishes and treatments are given to improve appearance and performance. These can be chrome, paint and heat treatments. [29] The suppliers are:

- **Forging and casting companies.** They produce parts such as connecting rods, pistons, crankshaft, injectors and camshaft by forging, and by casting: pumps, casings, engine blocks. Examples: Shiloh Industries, Superior Industries International, Linamar Corporation, Nemak, Ryobi Limited, KYB Corporation, Showa Corporation, NTN Corporation, NTK Technical Ceramics.
- **Machining and tooling companies.** They supply the tools for cutting and drilling to shape the part to precise specifications. Examples: Kennametal, Sandvik Coromant, Iscar Tools, Walter AG, Seco Tools, Makino, Haas Automation, DMG Mori Seiki, Mazak Corporation, Okuma Corporation.
- **Textile factories.** Responsible for the manufacture of fibers, the material to produce tapestries, and other textile parts of vehicles. Examples: Jiaxing Texson Textile Co., Ltd., Quanzhou Winiw Import and Export Co., Ltd., Foshan Huayu times textiles Co., Ltd.

3.2. Manufacturing of components and systems

Small parts are joined together to form components, and some components are assembled to form vehicle systems such as: engines, brake systems, electrical systems, and suspension systems. The union and assembly are given by means of [34]:

- **Spot welding.** Commonly used to join sheet metal, particularly in body assembly. Spot welding involves applying pressure and electric current at specific points, fusing the metal parts together.
- **MIG and TIG welding.** Metal inert gas (MIG) and tungsten inert gas (TIG) welding are used to make more precise and stronger welds, often on structural components and engine parts.
- **Robotic welding.** Automation through robotic arms ensures high precision, speed, and consistency in welding operations, which is crucial for maintaining quality in mass production.
- **Surface preparation.** Clean and pretreat parts to remove any contaminants and ensure proper paint adhesion. This may involve washing, sanding, and applying a primer.
- **Electrostatic Painting.** Electrostatic spray guns are used to apply paint evenly over the entire surface. This method improves paint adhesion and reduces waste.

- **Curing.** Heating painted parts in an oven to cure the paint, ensuring that it hardens and adheres properly to the surface.
- **Quality inspection.** Checking for imperfections or defects in the paint finish, such as running, sagging, or uneven coverage.

Large companies manufacture complex components, such as engines, transmissions and panels. The following are suppliers [31][36]:

A. **BorgWarner.** It provides parts such as traction systems, engine timing systems, ignition technology, intake and exhaust gas management, sensors, transmission technology, valve and train systems. Its clients include: Audi, Dacia, Ford, GAC, Hyundai, Kia, SAIC, SEAT, Skoda, MG Motors, JAC, Foton, Ferrari, Bugatti, Bentley, Daihatsu, Hawtai, Stellantis, MAN.

B. **Tire Specialty Factories.** The Goodyear Tire & Rubber Company, Bridgestone, Continental, Hankook, Kumho, Michelin, Nexen, Pirelli, Sumitomo, Yoyo, Yokohama

C. **Eaton Corporation.** Provides exterior components such as: valves, shock absorbers, transmissions, rocker arms, clutches. Among its customers are: Nissan, SEAT, Solaris Bus.

D. **JBC.** With specialized plants, subsidiaries and affiliates in their manufacturing countries, they focus on the production of engines, suspension parts, transmissions, brake systems, batteries, internal components, bodywork, among others, for the assembly and production of its vehicles.

E. **Continental AG:** tires, brake systems, powertrain and chassis systems, safety systems and advanced driver assistance, and infotainment[!] and connectivity solutions.

F. **Aisin Corporation.** Automatic transmissions, navigation systems, hybrid systems, brake systems, door modules and sunroofs. These products are used by several of the world's leading automakers, including Toyota, GM and Ford.

G. **ACDelco.** Dedicated to the production of batteries, windshield wipers, engines, filters, chemicals and fluids, ignition parts, transmissions, steering and suspension, heating and air

[!] *It refers to the simple display of important vehicle information, as well as the incorporation of equipment that allows the transmission and/or playback of video, social networks, among others.

conditioning, electrical system, brake system and structural parts. With OEM lines for General Motor Company and aftermarket lines.

4. Distribution and sales

Auto parts distribution includes both original equipment manufacturers (OEMs) to produce new vehicles and the aftermarket for repairs, and the final sale. Distribution channels include wholesale auto parts warehouses, authorized distributors, retailers, and e-commerce platforms, both domestically and internationally. [34]

Heavy machinery auto parts have transport limitations for their distribution, due to their weight and dimensions. In most cases they can only be distributed by sea, by containers or in fractional cargo, by Ro-Ro and general cargo ships.

Some companies involved at this level are:

- **Logistics Companies.** They are responsible for the transport and storage of parts from the manufacturers to the point of assembly or sale. Some are: DHL, FedEx, UPS, TNT, DB Schenker, Kuehne+Nagel, CEVA Logistics, Nippon Express, DSV, Kerry Logistics.
- **3PL Providers.** Ryder, Penske Logistics, XPO Logistics, J.B. Hunt Transport Services, Schneider National, Werner Enterprises, C.H. Robinson, Estes Express Lines, Swift Transportation, Marten Transport.
- **Shipping Lines and Airlines.** Maersk Line, Wallenius Wilhelmsen, MSC, CMA CGM, Hapag-Lloyd, Cosco Shipping, Nippon Yusen Kaisha (NYK), Mitsui O.S.K. Lines (MOL), K Line, Air France-KLM, Lufthansa, Delta Air Lines, United Airlines.

In the countries that manufacture auto parts, the sale takes place in the stores of wholesalers and retailers of auto parts. The rest of the countries import the auto parts through representatives of the brands or authorized distributors, workshops, e-commerce, among others. At this level are:

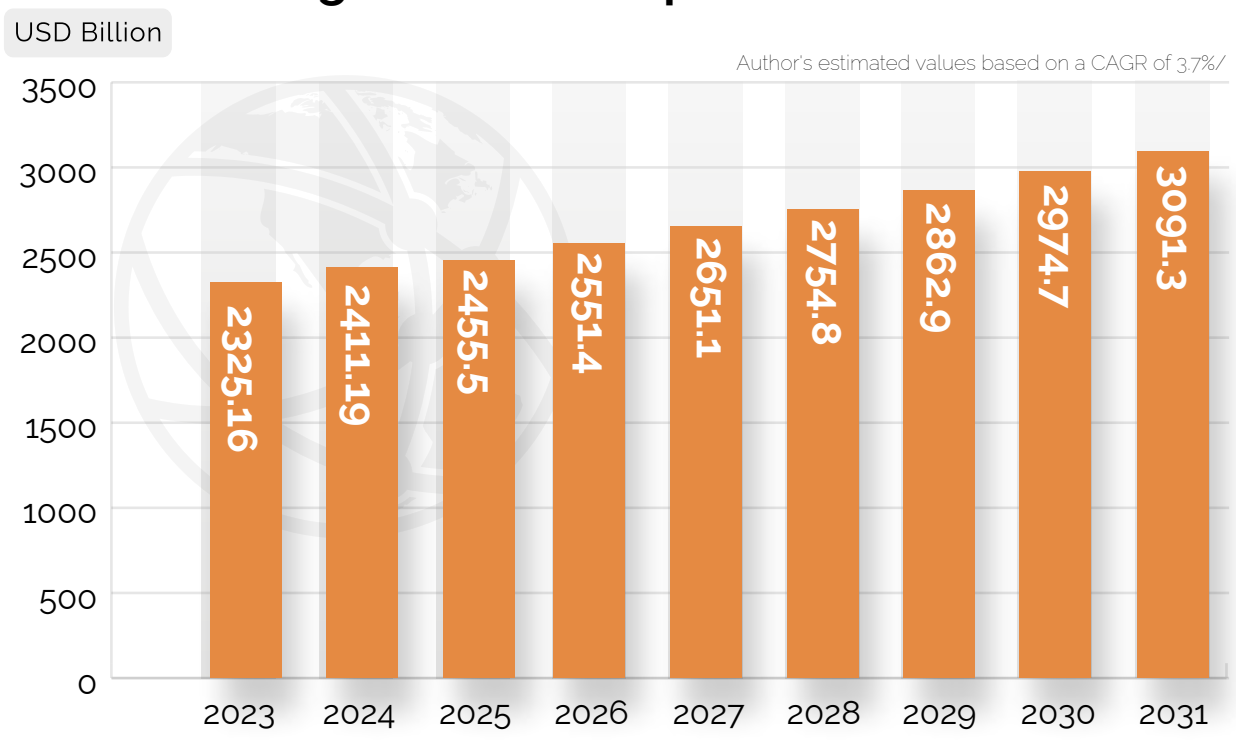
- **Car dealers or authorized representatives** of the brand in regions or countries: Toyota, Ford, General Motors, Volkswagen, Honda, Nissan, BMW, Mercedes-Benz, Hyundai, Kia, Tesla, among others.
- **Aftermarket parts distributors** and some OEMs parts: AutoZone, Advance Auto Parts, O'Reilly Auto Parts, NAPA Auto Parts, Carquest Auto Parts, Pep Boys, Monroe Auto Parts, Genuine Parts Company, LKQ Corporation, Gates Corporation.
- **Online retailers:** Amazon, eBay, RockAuto, PartsGeek, AutoZone, AdvanceAutoParts, OReillyAuto, NapaAutoParts, Carquest, PepBoys.

Global auto parts market

In 2023, the global auto parts market figure was $2,325.16 billion. Estimates suggest that about 30% correspond to OEM auto parts and 70% to aftermarket parts. The market is expected to grow to approximately $3,091.3 billion by 2031, based on a CAGR (Compound Annual Growth Rate) of 3.7% for the period between 2023 and 2032. [2]

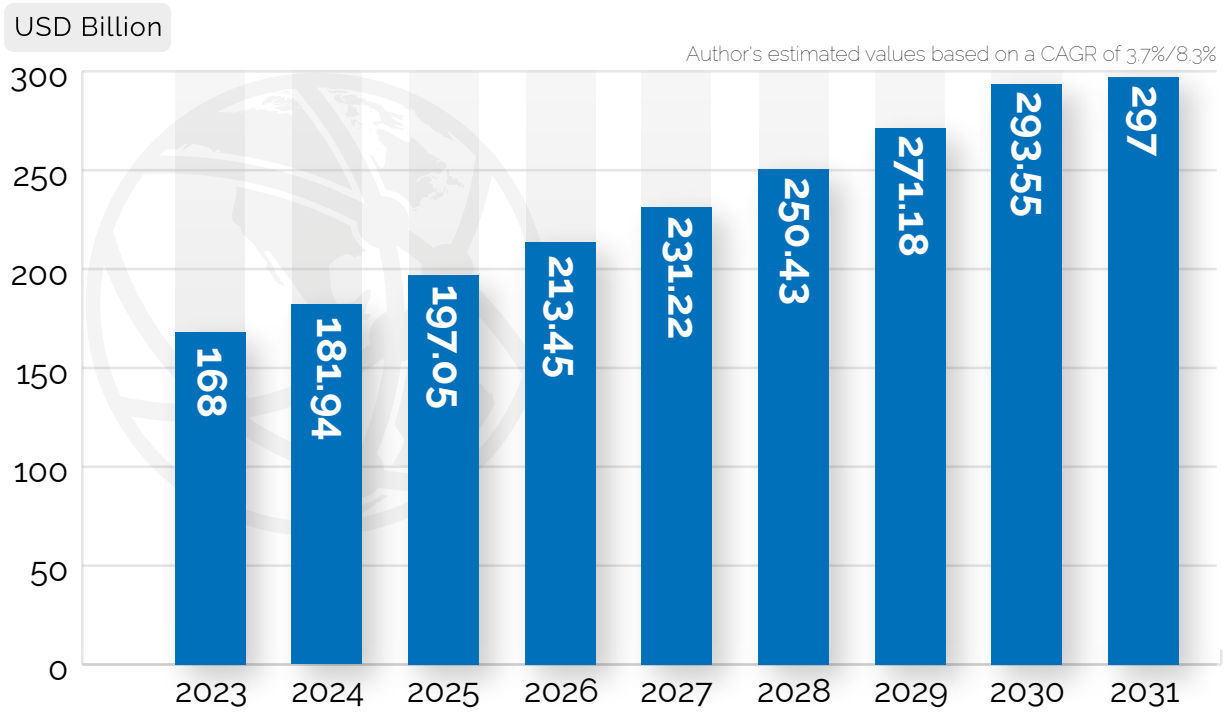
The figure for the global heavy machinery auto parts market was $168 million in 2023 and it is expected that, by 2031, it will present a growth of 8.3% with an estimated value of $297 million. [37]

Estimated growth of auto parts market worldwide



Adapted from: B. R. INSIGHTS, «AUTO PARTS MARKET REPORT OVERVIEW» [2].

Estimated Growth of the heavy duty vehicles autoparts industry worldwide



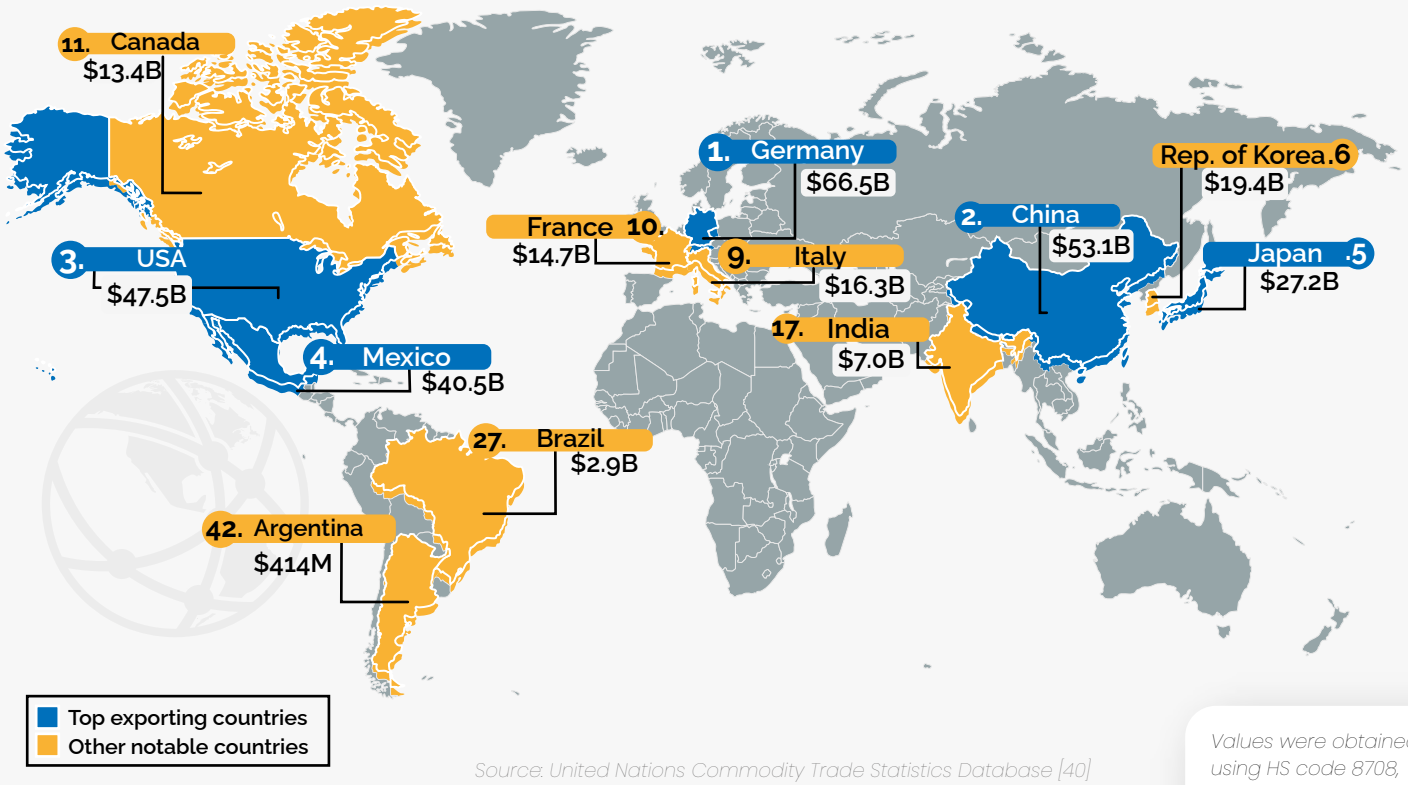
Adapted from: Verified Market Research [37].

The growth in market figures presents significant challenges and opportunities for auto parts industries worldwide. To address them, the main OEM auto parts manufacturing countries established the G7 Global Autoparts Industries Associations. This group, composed of seven major auto parts industry associations from the main vehicle production countries and regions, includes [38]:

- **ACMA** – Indian Automotive Component Manufacturers Association
- **APMA** – Canadian Automobile Parts Manufacturers Association
- **CLEPA** – European Automotive Suppliers Association
- **INA** – National Association of the Auto Parts Industry of Mexico
- **MEMA** – U.S. Engine and Equipment Manufacturers Association.
- **SINDIPEÇAS** – National Association of Auto Parts Manufacturers of Brazil
- **JAPIA** – Japan Auto Parts Industries Association

The G7 meetings facilitate the sharing of information about the challenges faced by the auto parts industries in each country due to the globalization of suppliers. They explore ways to mutually cooperate among organizations and use this shared information in the global strategies of each member company. This cooperation within the G7 is essential for ensuring that the auto parts industries of these countries remain competitive and are able to take full advantage of the expanding global auto parts market. [38]

Export value of auto parts by country (2023)



Source: United Nations Commodity Trade Statistics Database [40]

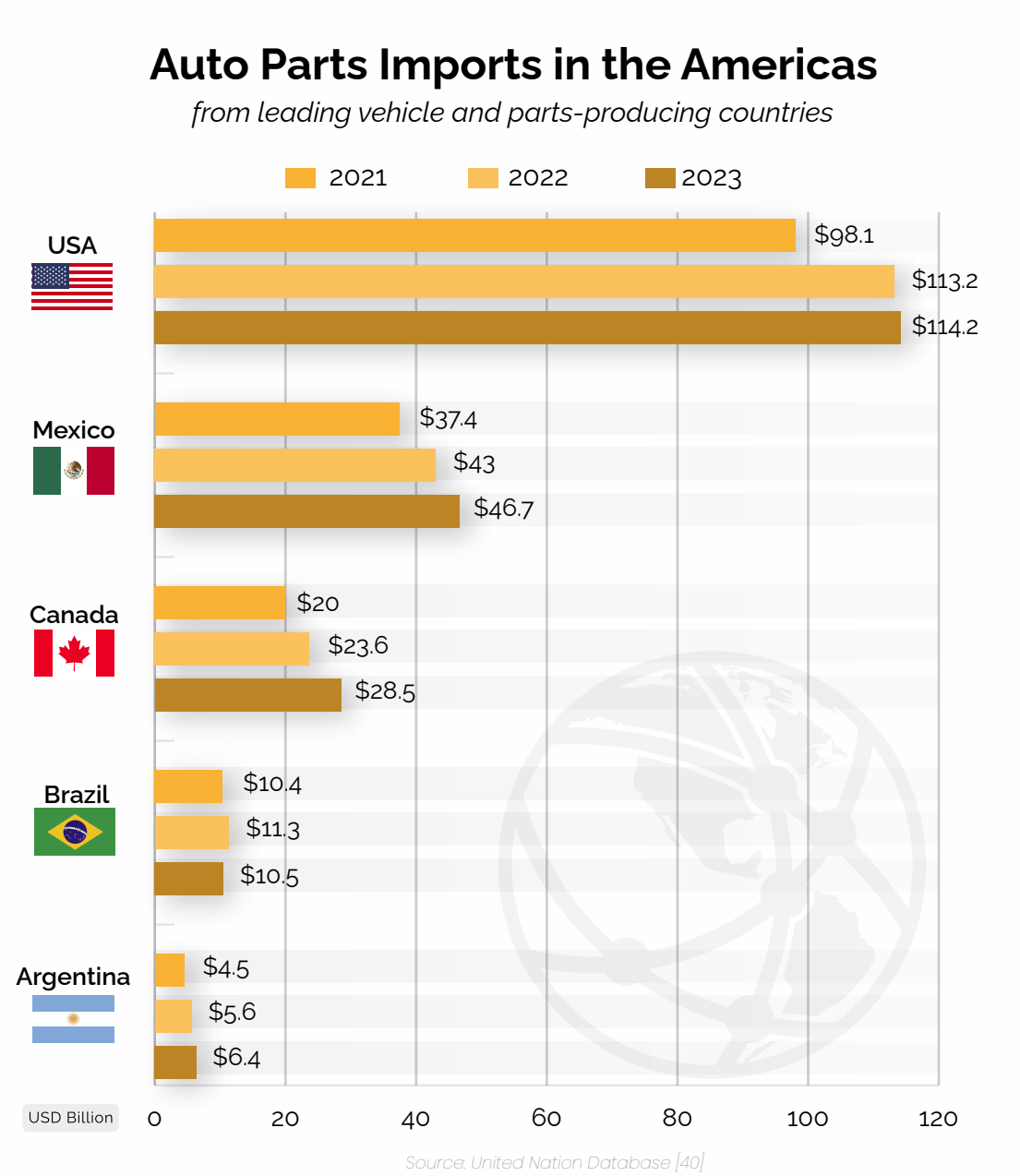
Values were obtained using HS code 8708, which includes motor vehicle parts and accessories.

In 2023, the global market for exported automotive parts and accessories reached a substantial $454 billion. This marks a 7.4% increase from the $422.6 billion recorded in 2022. Germany, mainland China, the United States, Mexico, and Japan emerged as the top five exporters, collectively contributing to 51.8% of the total export value for automotive parts and accessories. [39][40]

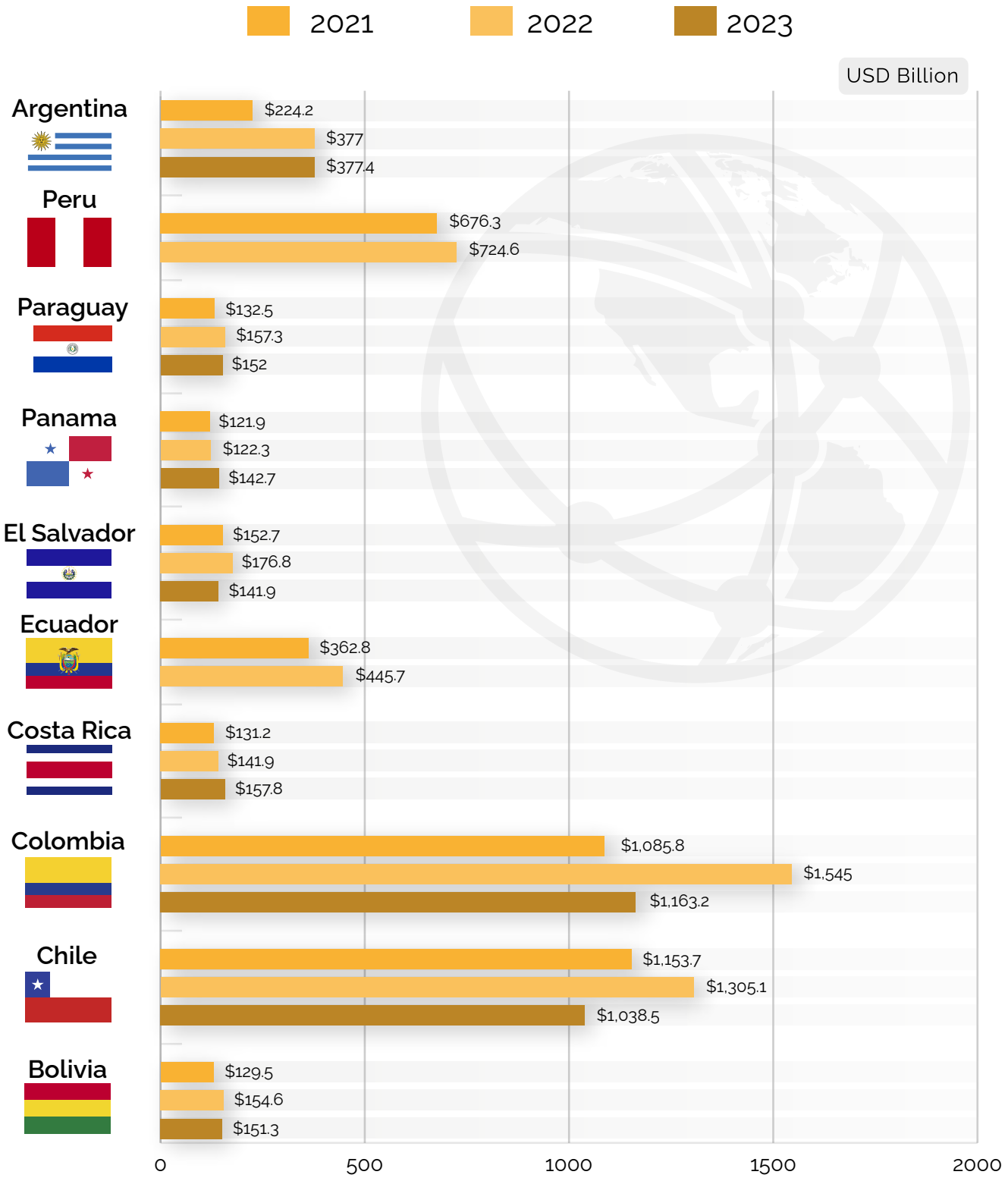
European countries led the charge in 2023, with their exports valued at $209 billion, accounting for 46% of the global total. Asian suppliers followed with a 30% contribution, while North American exporters added another 22.3% to the mix. Additionally, other Latin American countries such as Brazil and Argentina also participated in the export market. [39]

Latin America is a dynamic market. Being a region of middle-income countries, with a sizable and fast-growing middle class with purchasing power, the demographic changes expected in the region such as emerging economies, an aging population and the growing participation of the labor force, show a growing consumer population. These factors suggest an increase in the demand for auto parts. [41] And the USA and Canada stand out by having a stable economy which makes their population have purchasing power.

The import history of the last 3 years has been:



Auto Parts Imports in the selected Americas countries



Source: United Nation Database [40]

Closing

The global auto parts market, valued at $2,325.16 billion in 2023, is projected to grow steadily, reaching $3,241.4 billion by 2032. [2] This expansion is driven by increasing vehicle sales, the aging of older models, and the rising demand for replacement parts across both repair and production sectors.

In this context, countries like Germany, the United States, China and Mexico are leading exporters, while nations in the Americas, such as Canada, Brazil, and Argentina, are also emerging as key players. At the same time, the rising import activity in Colombia, Chile, Ecuador, and Peru underscores the need for a regional distribution hub to streamline intra-continental logistics.

Panama stands out as an ideal candidate, offering advanced logistics infrastructure, favorable legal regimes in free zones, and unparalleled connectivity, making it an optimal location for auto parts distribution. A clear example of this potential is GAC Motor's recent decision to establish its parts distribution center in the Colon Free Zone, reinforcing Panama's strategic advantages for manufacturers and distributors. [42]

As the demand for auto parts continues to grow, driven by increasing vehicle sales and the aging of existing models, the need for an efficient supply chain becomes even more critical. This not only ensures the timely distribution of auto parts for repairs but also supports the production and delivery of new vehicles.

The following paper, **Driving Efficiency: The Supply Chain for Vehicles**, will delve deeper into the dynamics of this sector.

Discover more...

Notes

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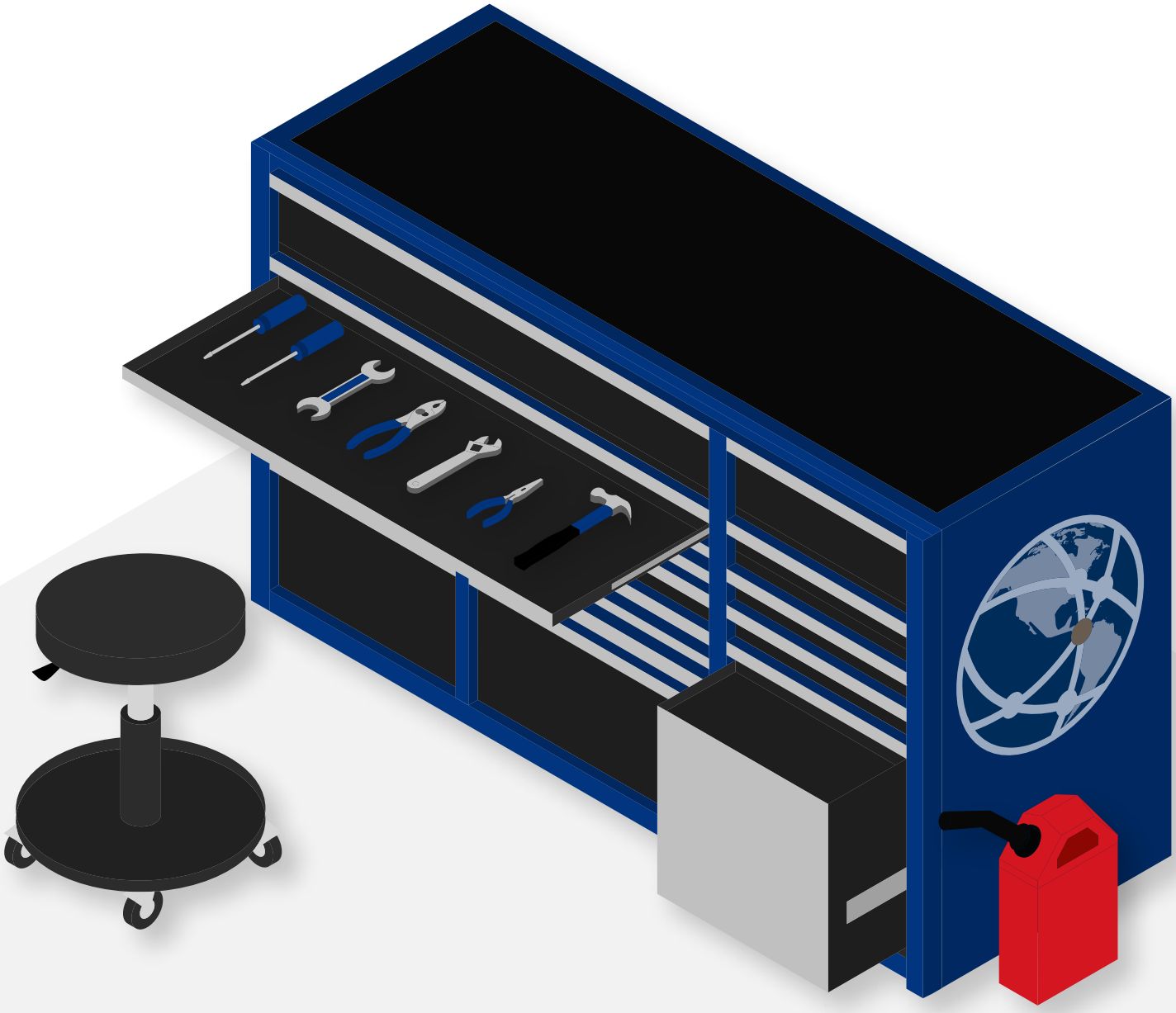

About the **Why Panama** Program

In the current dynamic global landscape, it is clear that having access to high-quality insights is crucial when determining the optimal location for regional distribution in order to take advantage on the present structure of global value chains.

Georgia Tech Panama Logistics Innovation & Research Center recognizes the importance of key insights in the decision-making process, and works closely with companies seeking to assess their supply chains and how Panama can become a key part of their global logistics network.

The "Why Panama" program utilizes quantitative data and analytics to assess key variables and compare the costs, investments, and service benefits of setting up a distribution center in Panama. By conducting a thorough analysis, the program aims to provide businesses with valuable insights into the advantages of establishing a hub in Panama.

To know more you can contact Jeancarlos Chen at **jeancarlos.chen@gatech.pa** or Jorge Barnett at **jorge.barnett@gatech.pa**

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The Georgia Tech Panama Logistics Innovation and Research Center is located in Panama City, Panama. It was launched in 2010 by an agreement between the Georgia Institute of Technology and the Goverment of Panama through the National Secretariat of Science, Technology and Innovation (SENACYT).

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