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The evolution of the offering strategies of car manufacturers

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ABSTRACT

This thesis describes the evolution over time of the characteristics of the cars offered by the world's most important carmakers.

First, an introduction about the automotive industry which focuses on its historical background, its structure, its value chain, and its current major transitional factors is given.

The core of this thesis is then the analysis of the evolution that the industry experienced and is experiencing. The analysis is carried out through the consultation of historical data series, concerning the characteristics of the products offered, such as vehicles efficiency, CO_2 emissions, size, weight, power, and footprint.

In addition, the main current evolutionary trends regarding the automotive industry such as the diffusion of electric vehicles, the autonomous driving and the interconnectivity, the new business models, and the users' behavior regarding the role of the car are explained and analyzed.

In conclusion, through the analysis of a survey, some possible scenarios about the future of the automotive industry are discussed.

The purpose of the thesis is, through these analyses, to try to understand how the automotive industry is responding to the ongoing challenges that the world is facing.

INTRODUCTION

The automotive industry is one of the most impactful sectors worldwide in economic terms (revenues, production volumes, etc.) but also regarding environmental issues. Indeed, nowadays environmental issues related to vehicles and other transports is an always more discussed topic.

Vehicles have been existing for many years, but the evolution in terms of features that they experienced is significant. Starting from the Model-T car, during the years, vehicles have developed to be always smarter and more sophisticated, because of the increasing requirements and desires of users regarding price, design, quality, safety, and fuel economy. Moreover, the raising awareness of environmental issues challenged the traditional fueled car, next to whom, nowadays, electric cars coexist.

Road transport is one of the major causes of CO_2 emissions, and therefore the whole automotive sector is trying to respond and adapt its offer to the current global challenges. In addition, this sector needs to adequate to the targets that governments and other institutions set. These targets could concern vehicle CO_2 emissions, vehicle type of fuels and other car features, but also restrictions in car circulation and other limitations. Consequently, car manufacturers should adjust their offering strategies and business models considering all these factors, and this could result, for example, in starting to offer other services such as the car sharing.

The thesis is divided into 3 chapters. The first chapter describes the automotive industry in general terms, starting from its background and then explaining its structure, its value chain, its segmentation, and finally its current major transitional factors.

The second chapter analyses how the cars evolved over time. More precisely, it illustrates the evolution of the main features of cars, how they changed and the motivations which brought to these changes. Moreover, some of the major current trends are explained.

The final chapter is guided by an analysis of a survey which scope is to understand the users' attitudes related to car use and the opinions they have regarding some current topics related to the automotive industry. After the analysis of the answers, some possible future scenarios are discussed.

The final goal of this thesis is to understand how the automotive sector is tackling to the current global challenges and discussing some possible solutions for a better future.

CHAPTER 1

Introduction to the automotive sector

This chapter has the purpose of introducing the automotive industry and its characteristics from the origin of the sector to the current situation. To understand the ongoing challenges and transformations that this industry has to face today, it is indeed important to explain how the automotive industry was born and how it evolved and developed over time.

To get an overview, in 2022 the industry was ranked the 1st global manufacturing industry with regard to market size, valued approximately $2.9 trillion (Moore, 2022).

1.1 Automotive industry background

The automotive manufacturing industry has always been one of the most significantly impactful sectors of the global economy.
Its impact is extreme in relation to several factors: revenues, production volumes, number of employees, but also global oil consumption and environmental issues (Moore, 2022).

Despite the high economic importance of this sector, as it will be explained in the subsequent paragraphs, the automotive system, as it is, is not sustainable for the future and there are environmental pressures on the industry (Nieuwenhuis & Wells, 2003). But before analyzing this phenomenon, the history of this industry will be described.

The birth of automotive is attributed to the development of the gasoline engine in the 1860s and '70s, in France and Germany (Binder & Rae, 2022).
At the beginning, a car was a craft-made product, that is a unique product, hand-made, each one different from the others. But subsequently new significant suppliers took over the scene, preceding the mass production that would have taken place later in the United States. These suppliers were mostly located in France, and they brought to the automotive industry the concept of *standardization* (already existing in other sectors), offering the supply of engines,

gearboxes, axles, and other core components of the final product. Thanks to this standardization that enabled the access to the key components to all the potential players of the market, between 1895 and 1905 a certain number of brands, even if low vertically integrated, could increase their volume of vehicles manufactured; the modular construction of cars was spread. They were made with a component, the chassis, that included all the parts that allowed the movement of the vehicle: engine, wheels, transmission, and axles (Nieuwenhuis & Wells, 2015).

Hence, the industry was born in Europe, but thanks to the development of mass production techniques, put in place initially by Henry Ford with the Model-T car, America has been in a dominant position for the first half of the 20th century (Binder & Rae, 2022). In Michigan at Highland Park, Ford developed the Model-T car as a sort of early modular approach, since the car was made of an independent chassis and separate body assembled in line (Nieuwenhuis & Wells, 2015).

At the beginning, cars were introduced as a product for adventures. But later, its diffusion made a car an opportunity for being transported. The first users of cars as a means of transport were taxi companies, followed by professional figures such as doctors and veterinarians.

By 1907, the most motorized countries in the world were the UK, the US and France. Indeed, there was 1 car every 640 in the UK, 1 every 981 in France, and 1 every 608 in the US (Nieuwenhuis & Wells, 2003).

Since standardization allowed costs reduction and mass production simplified processes, the next step was to think about improving process assembling performances.

Therefore, the modular approach proposed by Henry Ford was different from the new mass production. Indeed, many modern cars utilize all-steel 'unibody', 'unit' or 'monocoque' construction that instead provides a unique structure that incorporates both the body and the chassis.

It was Edward Budd in the years from 1910 to 1914, together with his chief engineer Joe Ledwinka, who contributed to the development of this technology based on the all-steel welded body. Consequently, the modern mass production of cars derives both from Henry Ford and Budd and Ledwinka's innovations (Nieuwenhuis & Wells, 2015).

It is important to highlight that the Budd-type steel body technology requires an extreme amount of capital to invest initially (because of the need of press, press tooling, and welding and

painting activities), but then it enables to produce high volumes at a lesser cost per unit, allowing the industry to exploit the economies of scale that characterize the mass manufacturing. This new technology comprehended all the main steps of the manufacture of a car: press, weld, and paint, increasing the efficiency and the quality of production and reducing consequently the number of employees involved in the process.
Budd and Ledwinka were among the pioneers of this technology, which involved the transition of the industry from the modular production of Model-T cars from in-house components to the steel bodies manufacture as a core activity. This so-called 'Buddism' system successfully worked for many years because the market was experiencing a continuous increasing demand (Nieuwenhuis & Wells, 2015).

Starting from the introduction of cars mass production, the profitability derived from them suffered a constant decline due to different reasons. The need of shorter product cycles and more product differentiation led to an inevitable loss in economies of scale, because to respond to the external market pressures, firms needed to reduce the volume of production of the vehicles and increase their typologies, obviously producing minor quantity (Nieuwenhuis & Wells, 2015).
At the same time the industry had to face environmental pressures and a more differentiated market demand, which led to higher product development costs and lower profitability.
These problems raised the necessity to find solutions to regain the profitability of the sector, such as the globalization and consolidation of the industry (larger manufacturers linked to more potent suppliers), the reduction of types of platforms and consequent reduction in costs and complexity (in order to regain the exploitation of economies of scale), the need to reduce every typology of waste by 'leaning' the industry (Nieuwenhuis & Wells, 2003). Indeed, Toyota developed some principles that gave rise to the Lean Production, which will be explained later in this chapter.

However, the life duration of the Ford-Budd mass production system has been extended because of the profitability of manufacture and sale of almost standardized cars of some emerging markets like Brazil, China, and India. Companies such as General Motors and Volkswagen partly owe their profitability to these new markets, protagonists of the 2008 recession recovery (Nieuwenhuis & Wells, 2015).

Thanks to the contribution of Ford and Budd’s technologies, the mass production was accomplished.
By 1925, 50% of the US body manufacturing was based on Budd all-steel technology. The final challenge, however, was to create the mass demand that could cover all the car offer that was spreading. In this perspective, General Motors was a protagonist in solving this problem. Under Alfred Sloan and the General Motors Acceptance Corporation, they introduced some innovation that revolutionized the hitherto valid concepts. For example, they started conceding the trade-in as a down payment, which became then a new source of business (the market of used cars). Another important novelty was the focus that General Motors had on the styling and the external presentation of the vehicles. It was diffusing the concept that a product could present different characteristics and that, from a basic car, an end user could arrive to get a more complex and sophisticated one. In this time, the idea of planned obsolescence was born, approaching more the modern consumer expectations (Nieuwenhuis & Wells, 2015).

As every system in history, the automotive distribution system has changed and evolved throughout the years. A mixed distribution structure composed of distributors (wholesalers), branches (owned by manufacturers) and agents with the task of gathering orders characterized the structure in the late 19th and early 20th century.
After the World War One, producers wanted to gain more control over the dealers that were increasing in number because of the market expansion. With the phenomenon of the mass market after World War Two, subsequently, dealers had to afford sort of sunk costs related to significant increasing investments regarding vehicles and components belonging to brands. This made dealers to be autonomous but at the same time influenced by manufacturers’ guidelines, creating a vertical quasi-integration. In this period, this type of seller’s market (highly asymmetric) contributed to create possibilities for car producers to obtain substantial profit margins.
When the demand stopped being homogeneous and started becoming more sophisticated, the simple distribution system that existed could no longer satisfy the market. New competencies and skills were required to face the increasing need for trade-ins next to the sales of new vehicles.
Briefly, the features of the distribution systems required to be changed to respond adequately to the market growth and speedy motorization that took place in the second half of the 20th century (Stocchetti et al., 2013).

The necessity to adjust the structure rose starting from the 1970s, when due to some dynamics, the market became progressively more buyer oriented. Some reasons that caused this variation are the oil crises, the decreasing of first-time buyers and the related increase of replacement demand, and the new competitor Japan in the international market.
Although these events were already important, the real pressure for change took place starting from the new century, with the advancement of the technology, the globalization and the consequent growth of competition, and finally the economic crisis (Stocchetti et al., 2013).

With the transformation of the system caused by external pressures, the market shifted from a seller to a buyer’s market, and this created a sort of «mismatch» between the different level of stages of the industry system. Consumers, thanks to the higher availability of information, were more aware and consequently their demand (that were mainly replacement demand) was more oriented to ask for quality, reliability, tailor-made details, and residual values. Competition grew also because of the spread of electronic media, that allowed people to compare products, reducing information asymmetries that could be traduced in a decrease in profits for manufacturers. At this point, franchised dealers became fundamental as customer touchpoints, where attention to customers, brand image, personalized relationships and supply of complementary services made the difference (Stocchetti et al., 2013).

If it is argued that in the first half of the 20th century America dominated the industry, in the second half of the 20th century, the American production dropped from 80 percent of the total to 20. Japan and other western European countries, facilitated by the European Economic Community (EEC), became the major producers and exporters (Binder & Rae, 2022). As anticipated earlier, one problem was the energy crisis of 1973-74 and 1979 that particularly hit the US. American auto makers found a solution in downsizing their programs to produce cars that were less bulky and less heavy. Despite this car improvement, users started buying light trucks, canceling the gains derived from more efficient cars. At this point, two typologies of motorist existed: the real auto lovers and the mass of drivers that saw the car just to go from one place to another (Nieuwenhuis & Wells, 2003).

As the next table shows, the United States again became the leader in 1994, but starting from the beginning of the 21st century, as it will be explained later in the chapter, China became the absolute market leader in terms of production volume (Binder & Rae, 2022).

Table 1.1: Car use in selected countries (1995)

Country	Cars in use	No. persons/car	Total vehicles	No. persons/ vehicle
US	139000000	1.9	208000000	1.2
Italy	30000000	1.9	32806500	1.7
Canada	13800000	2.1	17545000	1.7
Australia	8391500	2.1	10638200	1.7
Germany	40499443	2.0	43561316	1.9
New Zealand	1652556	2.1	2005191	1.8
France	25100000	2.3	30295000	1.9
EU	161348724	2.3	182951643	2.0
UK	24962263	2.3	28170924	2.1
Belgium	4239051	2.4	4276388	2.1
Japan	44680037	2.8	66853500	1.9
The Netherlands	5632891	2.7	6290863	2.4
Ireland	990384	3.6	1145537	3.1
S. Korea	6006290	7.3	8468901	5.2
Brazil	12500000	12.5	15020000	10.4
CIS	18000000	16.3	27500000	10.7
India	3446330	245.6	5846382	144.8
China	2400000	500.0	7120000	168.5
Bangladesh	48000	2250.0	108500	995.4
World	492731463	11.0	665844845	12.2

Source: Nieuwenhuis & Wells, 2003.

In total, in 1995 vehicles (cars and trucks) reached over 665 million units, that is 12.2 units every 100 people (Nieuwenhuis & Wells, 2003).

The automotive market has always been dominated by industrial aspects. Nowadays because of the proliferation of brands, the ability to convey impactful messages and other factors, automakers must at least rethink their positioning, aware that competitive dynamics are increasingly variable.

After having discussed the historical part, let us now analyze the structure of the industry.

1.2 Automotive industry structure

Nowadays the core activity of the automotive industry consists of the development and production of internal combustion engines and in the manufacturing and painting of body shells, thus investing most of the resources in them. These represent the key elements to achieve the economies of scale but also the opportunities to gain the promptness to respond to the market preferences. In terms of investments, the assembly of the engine into the final product is considered a secondary activity (Nieuwenhuis & Wells, 2015).

Today between 60 and 80% of the ex-warehouse value of the final product is outsourced by the major car makers.
There are three fundamental activities in an assembly that require significant investments: *press shop*, *body-in-white*, and *paint*. The latter is the most oriented to satisfy the requirements of the final consumers. Indeed, it is the most external part of the car, and while other components such as engine and transmission are not visible, bodies are required to change and be adapted more frequently as to respond to the market preferences. Thus, investments in bodies are to be made regularly and must be observable in a significant way by externals (Nieuwenhuis & Wells, 2015).

The automotive industry is composed of all those firms that produce motor vehicles and their components, for example engines and bodies. It includes both passenger vehicles, its core products, and commercial vehicles, such as large transport trucks (Binder & Rae, 2022).

The automotive industry is highly concentrated, that is, few large firms especially from Japan, USA, and Germany retain a big amount of power over all other smaller companies. Since the end of the 20th century, the concentration of the industry grew, because of a wave of mergers and acquisitions and equity-based alliances. The strong concentration of the industry leads to the creation of high barriers to entry and allow the largest firms to set their own standards, binding suppliers with transaction costs and investing more resources in innovations and products related to specific segments of customers (Sturgeon, Memedovic, Biesebroeck, Gereffi, 2009).

Starting from the late 1980s, the automotive industry has followed a similar growing path as some other important industries such as the electronics and consumer goods. Several factors pushed towards the growth of the industry globalization: the increasing global production, the wave of mergers and acquisitions, the cross-border trade and consequently the Foreign Direct Investment (FDI). Countries like Brazil, China and India could offer cheap but skilled labor and consequently they attracted FDI with the aim to supply local markets and export back to developed countries. Nonetheless, a strong regional structure characterizes the industry (Sturgeon et al., 2009).

The first signals of globalization in terms of investments have occurred from the 1980s, when Japan invested in North America and Europe, and in the 1990s with the establishment of machinery by Mercedes and BMW in North America (Nieuwenhuis & Wells, 2003).

As it will be described in the next paragraphs, the value chain of the automotive industry is composed of different players. The most important are the vehicle manufacturers, which were traditionally divided into three categories:

1. *High volume, full range producers*. For example, GM, Ford, VW, and Fiat. They are the protagonists of the market because of the enormous production volume and low price, offering a range of various vehicles for the mass consumption, competing on cost reduction (which means exploitation of economies of scale with the consequent reduction of unit cost).

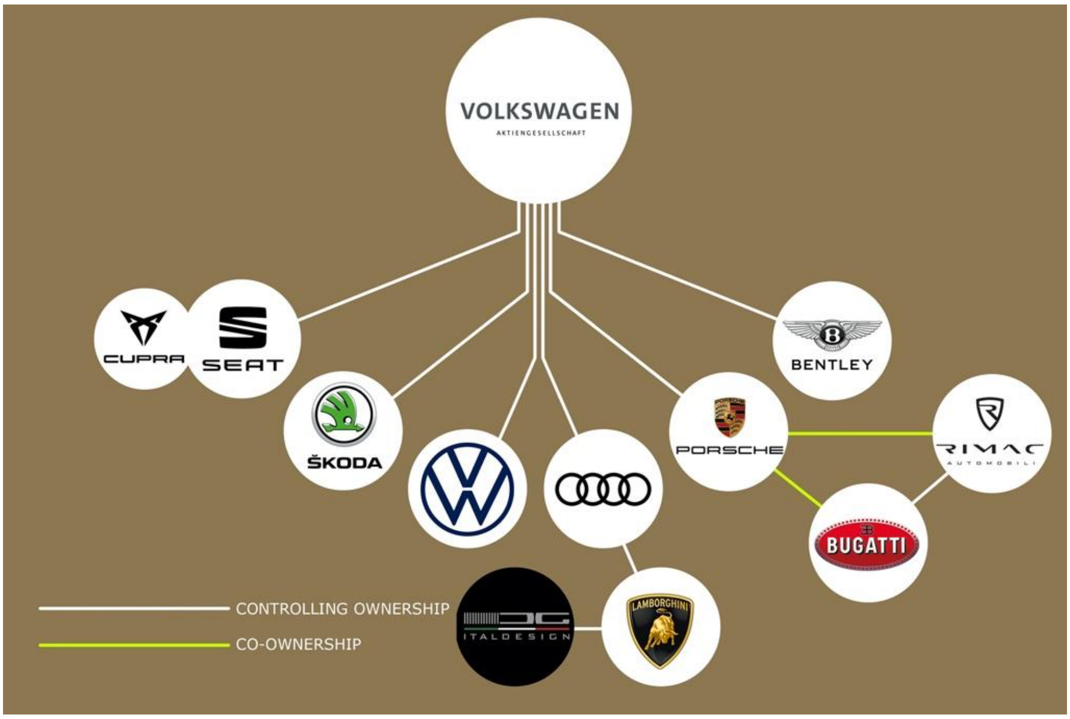
2. *Specialist producers*. For instance, Audi, Mercedes, Volvo, and BMW. They offer cars with higher standards and consequently prices are required to be increased. The competition here is based on differentiation and cost recovery, where firms are able to cover the costs because consumers are willing to pay more money for a car in exchange of a higher quality guaranteed by the company's reputation.

3. *Niche producers*. Companies like Ferrari or TVR offer exclusive cars with extremely high-performance levels, requiring the customers to pay a very high price.

Despite this traditional structure, what emerges after the process of globalization of the industry is a disintegration of this structure. Multi-brand constellations took place and independents ran out (Nieuwenhuis & Wells, 2003). So many productive models and so many productive forms coexist today: it is a dynamic coexistence and not a static equilibrium.

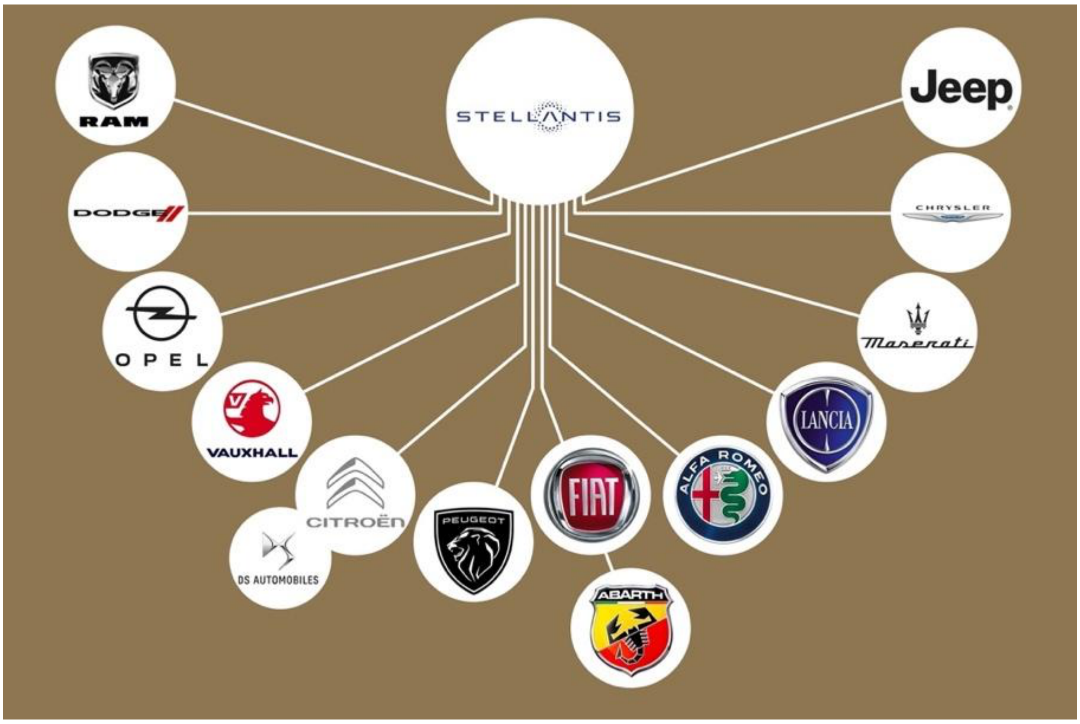
Today there exist few parent companies that incorporate almost all the world's top car brands. The images below are some examples of the current structures of relationship among brands in the automotive sector: Volkswagen, founded in 1937; Stellantis, founded in 2021 because of the merger between Fiat Chrysler Automobiles (FCA) and Groupe PSA; and Renault-Nissan-Mitsubishi Alliance, founded in 1999 and strengthened in 2020 (WhichCar, 2022).

Figure 1.1: Relationship structure - Volkswagen



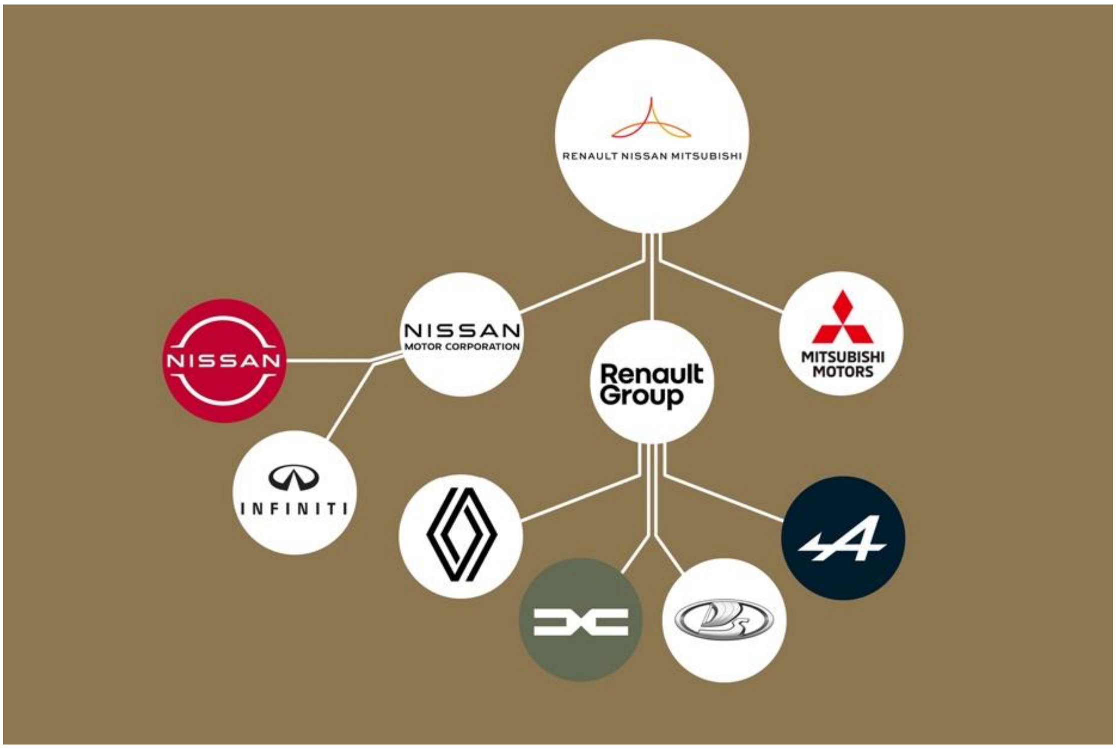
Source: WhichCar, 2022

Figure 1.2: Relationship structure - Stellantis



Source: WhichCar, 2022

Figure 1.3: Relationship structure - Renault-Nissan-Mitsubishi Alliance



Source: WhichCar, 2022

To face the always more challenges (for example Covid pandemic, materials shortages, extreme weather events, etc.) that hinder the continuous and prompt production of vehicles and goods in general, many firms such as Tesla and Volkswagen are opting for a more vertical integrated approach. The goal is to guarantee the supply of fundamental components in the face of constant interruptions. Therefore, through vertical integrations, OEMs and their suppliers work to secure supply of those materials and parts that are usually difficult to source or scarce in availability, with the scope to always have all components for manufacturing available.

For example, in May 2022, Tesla signed a long-term supply agreement with one of the largest nickel producers worldwide, the firm Vale, with mines in Brazil, Canada, and Indonesia. It is one of many agreements Tesla has, because it would like to avoid relying only to a company (the key point is to create a multiple sourcing strategy).

Moreover, in 2022 Volkswagen signed a memorandum for cobalt and nickel supplies. It is about a three-way partnership which involves VW, Huayou Cobalt, and Tsingshan Group for the extraction of nickel and cobalt from Indonesia. The aim of the project is to guarantee a sustainable supply chain of battery raw materials and improve cost efficiency. VW is also involved in a second partnership for refining nickel and cobalt sulfates, which are much needed for battery cathode production. These two partnerships aim at contributing to the company's target to reduce in the long-term by 30-50% the cost of each battery (Chow, 2022).

Lead automotive firms can be ranked according to different criteria: market capitalization, earnings, revenue, employees and so on.
Let us see how firms are ranked with regard to their market cap, which is the total value of a firm's shares of stock (it is calculated by multiplying the price of the share by the total number of outstanding shares; thus, it is a variable value).
Data reported below refers to 19th February 2023. Values could change, but basically this is the current trend of the automotive industry.

Figure 1.4: Largest automakers by market capitalization

Rank	Name	Market Cap	Price	Today	Price (30 days)	Country
1	Tesla TSLA	$659.11 B	$208.31	▲ 3.10%		USA
2	Toyota TM	$194.50 B	$142.85	▲ 0.11%		Japan
3	Porsche P911.DE	$110.86 B	$121.70	▼ 0.70%		Germany
4	BYD 002594.SZ	$103.84 B	$39.57	▼ 1.93%		China
5	Mercedes-Benz MBG.DE	$85.16 B	$79.61	▲ 2.84%		Germany
6	Volkswagen VOW3.DE	$81.43 B	$139.96	▲ 0.18%		Germany
7	BMW BMW.DE	$69.79 B	$106.39	▲ 0.51%		Germany
8	General Motors GM	$60.20 B	$43.17	▲ 0.16%		USA
9	Stellantis STLA	$55.55 B	$17.29	▲ 2.07%		Netherlands
10	Ford F	$51.38 B	$12.89	▼ 0.15%		USA

Source: CompaniesMarketcap, 2023.

1.3 Automotive value chain

Through the system of development and production of a car, each activity requires different times. The table below reports the various time that each phase of the process requires. The main goal of a car manufacturer is to reduce the time needed to sell a vehicle after the final assembly. (Nieuwenhuis & Wells, 2003).

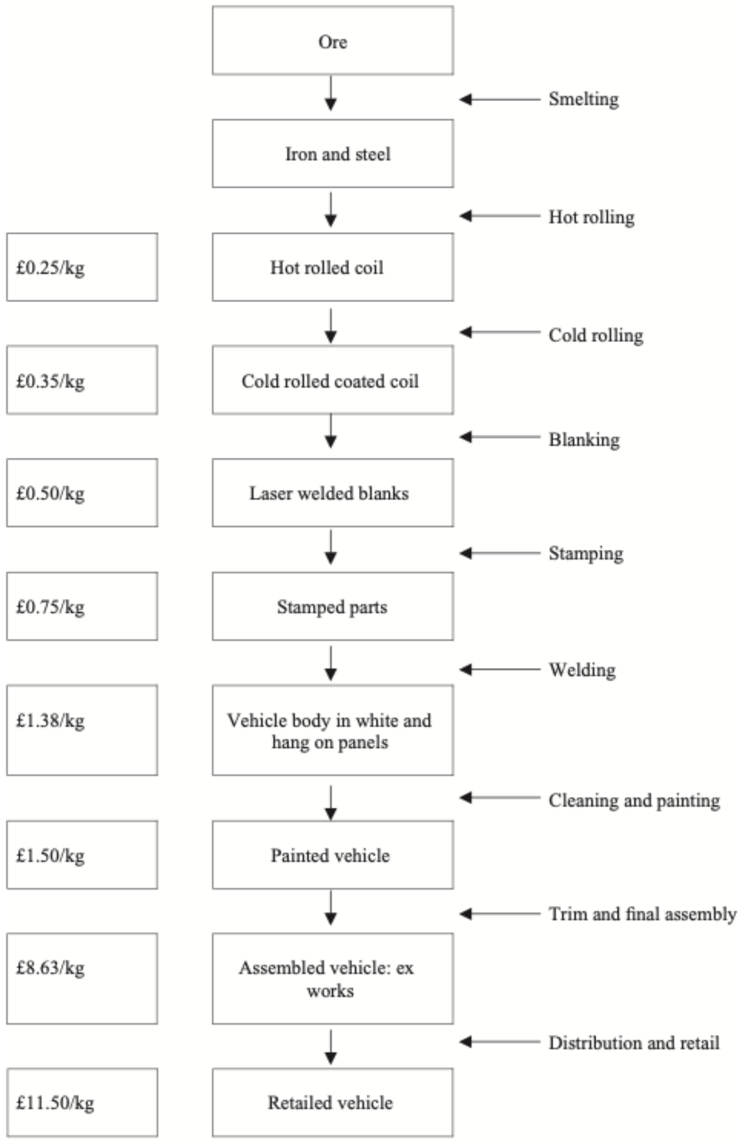
Table 1.2: The value funnel

Phase	Time taken at each phase, order to delivery
Iron ore extraction Crude petroleum production Silica mining, etc.	90–300 days
Alumina production Iron/steel production Aluminium production Polymers	11–26 days
Semi-manufactured materials Sheet, bar, ingots, granules, etc.	3–26 days
Components	1–21 days
Modules	30–180 minutes
CAR ASSEMBLY	12–18 hours
Franchised dealers / sales	40–70 days

Source: Nieuwenhuis & Wells, 2003.

Another interesting aspect to analyze is the value added to the product at each stage of the production process. For example, in 2002 in the UK, the price the market gave to a Ford Focus was about £11.50/kg. This price is the result of different added values along the chain. Figure 1.5 delineates the steps of the value-added chain and reports the price of each activity.

Figure 1.5: The value-added chain

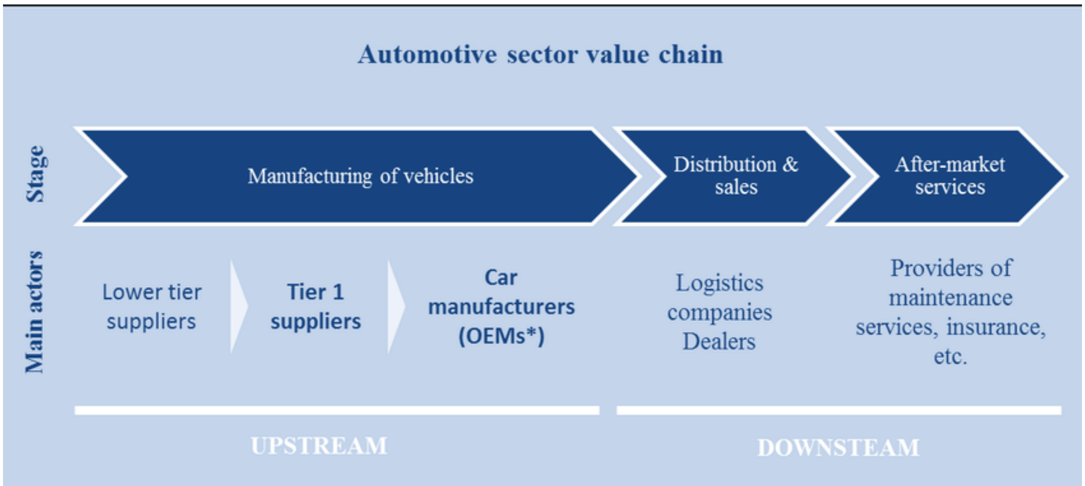


Source: Nieuwenhuis & Wells, 2003.

It can be noticed that the chain begins with a low value activity, and then every further step increments the value of the material. The starting value is multiplied several times and grow significantly until it reaches the end of the chain. Making numbers simpler, in this case, if the initial price was £1.00/kg, the final market price would become £45/kg. That is why manufacturers press suppliers to reduce costs, a reduction in price would give them the possibility to increase their profits by incrementing the units sold (Nieuwenhuis & Wells, 2003).

Every value chain is composed of lead firms, the ones that have the control over strategies and finance, and suppliers. As it can be seen from the Figure 1.6, there are different suppliers: Original Equipment Manufacturers (OEMs) are the most important for the realization of the final product, as they are the lead firms (usually giant employers) of the industry, and they care about the design of the product and the manufacture of engines and transmissions. It was argued that the automotive value chain was producer-driven because these companies retained a large amount of power within the chain until the 1990s with the advent of large global suppliers caused by the outsourcing phenomenon (Sturgeon et al. 2009).

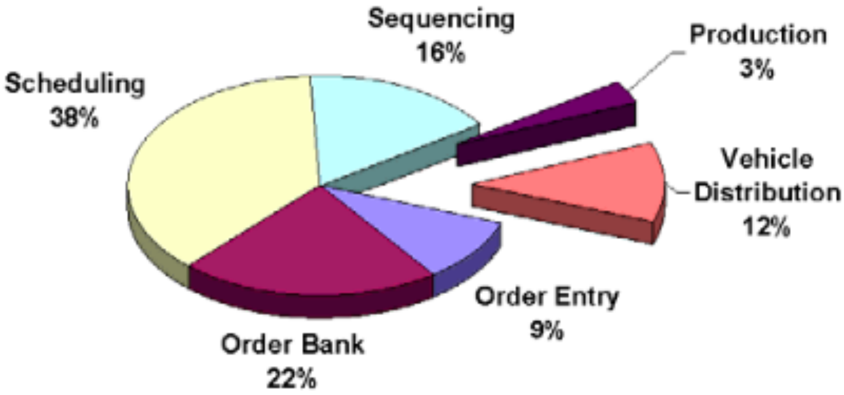
Figure 1.6: Automotive value chain: stages and main actors



Source: Paunov, 2019.

Increasing competition due to globalization caused the decline of the *build-to-forecast* approach, according to which orders were based on analysis of past sales. To face this continuously growing competition, car makers tried the *build-to-order* approach, which permits end users to choose the features of the product before producing it. However, this approach limits car makers for different reasons: consumers are not experts and consequently their choices could be silly; it causes long lead times; demand information is distorted. It is a vicious cycle that encourages manufacturing based on forecast, and firms are allowed to achieve more economies of scale by using assembly lines with appropriated components and by making use of integrated pressed steel monocoque bodies. These factors affect the time of production: on average it takes 40 days from the order to the distribution (Sturgeon et al. 2009).

Figure 1.7: Time Delays in the Order Fulfilment Process



Source: Sturgeon et al., 2009.

As the graph above shows, time for physical production is extremely reduced compared to time needed for other activities. Taking into consideration the various times, the result is that consumers are not involved in the process of the car production, and that traders and car makers rely on large inventories and discounts to satisfy the market demand (Sturgeon et al., 2009).

The advent of globalization inevitably changed the supply base, which is currently divided between global and local suppliers. It is an opportunity for global suppliers because they can serve all the giants of the industry, while in the past, producers were used to be served by local suppliers that varied depending on the location. Nowadays a supplier, to be competitive and be considered by its potential buyers, must have a global supply system. Each component must be served with equal price and quality everywhere. It is therefore important to have a strong logistics network that permits them to arrive in each place the client requests (Sturgeon et al., 2009).

There are three main possibilities for suppliers to be linked with the lead firms: *relational* approach, *market* linkage and *captive* linkage. The relational approach binds suppliers to the firm because they work together to study and develop components that will form the complete design of the vehicle. In presence of a market linkage, instead, there are more opportunities to switch to other suppliers, since in this case the lead firms develop all the parts of the vehicle internally and consequently, they are open for bids. Finally, we talk about captive linkage when suppliers are requested to do investments for some specific firms, thus even in this situation switching to others would be difficult.

The approach that players choose has significant importance, since in the automotive industry only few parts are standardized, and specifications for other components of each product are needed. The introduction of vehicle *platforms* is an attempt of lead companies to reduce the efforts related to the vehicle design, as they comprise rolling chassis, suspension parts, engines, and transmissions. But their benefit is limited for different reasons, for instance they are shared only among brands belonging to the same lead firm. Another reason that limits the use of platforms is the willingness and need of firms to avoid the homogenization of the car and reach performance goals, therefore most of the parts should keep being specific to each model (Sturgeon et al., 2009).

In conclusion, to make a vehicle performant and differentiated, it is important not to standardize the whole components of the product, but instead try to understand which type of linkage with suppliers fits better with each firm, depending on its needs and opportunities.
In the past, the big 2, General Motors and Ford, and more generally European and US lead companies always played with market approaches, but with the growth of the outsourcing phenomenon they understood the need of working together and closely with the suppliers. Sometimes suppliers are not completely compensated for their services, and the result is the swinging from one approach to another.
Japanese firms, differently, usually recurred to captive relationships with their suppliers, eased by the fact that Japanese lead firms kept most of the processes in-house. With this approach they create financial ties and suppliers devote their work to their most important clients.
Regarding the different approaches that firms from diverse countries adopted, some managers of an American suppliers in 2000 stated as follows:

> "There is some truth to the idea of that some assemblers are more loyal to their suppliers than others—Japanese assemblers are the most loyal, followed by Europeans. Americans are the least loyal. The Japanese transplants set high hurdles, but the expectation is for long-term business and that problems will be fixed" (Sturgeon et al., 2009).

An important part of the automotive industry is the *distribution*. It accounts for about 25% and 30% of the car list price and people involved in this phase are more than the ones involved in the production process. Moreover, the value that customers perceive is not only the intrinsic

one, but includes all the services related to the sales point, attributing to the distribution chain a responsibility for the effectiveness of the entire automotive system.
Because cars are durable, highly economic-impactful goods for users, it is important for firms to develop an appropriate distribution system that permits them to satisfy the market demand, which is complex and highly segmented. The success of the whole automotive system depends on the level of coordination of different players of the chain such as market-level importers, franchised dealerships, and logistics firms (Stocchetti, Trombini, Zirpoli, 2013).

There are no homogeneous models of retailing around the world, but they vary across different countries. A list with the description of the main models follows:

- *US model*: retailing is based on price and incentive and players are large independent sites that sell a high number of new vehicles annually (more than 500).

- *UK model*: players are large dealer groups, multi-franchise and multi-location. In this model second-hand cars are fundamental for profits. Some sites are owned by manufacturers, many solo sites sell less than 300 new vehicles annually.

- *Japanese model*: retailing is based on specification and players are small sites controlled by car manufacturers. Small market for second-hand cars.

- *Mediterranean model*: there is a strong presence of sites owned by producers, which represent the main players of the model. There are also many single franchise, single site and small independents together with second tiers for sales only or services only. This model is characterized by an important loyalty to domestic brands.

- *German model*: it is characterized by regional dealer groups, multi-site single franchise, many small independents and some sites owned by manufacturers. Every outlet sells few vehicles and there is high demand for specification with high delivery times (Nieuwenhuis & Wells, 2003).

1.4 Automotive lean manufacturing and business models

The previous paragraph described how players of downward activities of the system reacted to the transformation that was going on in the industry. Upstream activities, instead, had the necessity to become more efficient and flexible to cope with the evolution of the system through solutions such as lean component supply and lean manufacturing (to minimize wastes both in terms of material and in time). Indeed, having a valid and efficient production process is a fundamental aspect of the value chain.

Lean manufacturing is based on a set of principles that permitted Toyota to outperform regarding factors such as efficiency, quality, and flexibility (Stocchetti et al., 2013).

It is commonly recognized that Toyota was the pioneer of Lean Production (indeed it is also known as Toyota Production System), but it is important to highlight that already Henry Ford started using some basic principles, as he stated:

> "One of the most noteworthy accomplishments in keeping the price of Ford products low is the gradual shortening of the production cycle. The longer an article is in the process of manufacture and the more it is moved about, the greater is its ultimate cost" (Kilpatrick, 2003).

Lean manufacturing was born in Japan in the 1950s, with Toyota that founded a new production process that opposed the US model that dominated the automotive industry, based on the principle "doing more with less". This necessity was born as a consequence of some problems that the mass production generated, for example the elevated costs of maintenance and repair of products incurred because of malfunctions and defects caused by mass production. The aim was therefore to eliminate every type of waste and to stop making errors during the production process (Americi, 2020).

Kilpatrick (2003) reported the definition of Lean as follows: *"a systematic approach to identifying and eliminating waste through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection."* It is important to note that this approach only

works when applied to the entire system of an organization, both in core and secondary activities, otherwise a certain amount of waste would still be present.
The co-developer of Toyota Production System Taiichi Ohno identified Eight Wastes that he stated to account for almost all the costs of non-Lean organizations:

- *Overproduction*. To avoid producing more that consumers demand, the solution here is to produce following a pull system or produce only when consumers order to do it.

- *Waiting*. To cancel waiting times for material, information and so on, a JIT (just-in-time) approach is applied.

- *Transportation*. In order to avoid several movements among different players of different stages, material should be transferred directly to the location of the assembly line where it will be used (known as the POUS technique, *Point-Of-Usage-Storage*).

- *Non-Value-Added-Processing*. Reworking, deburring, and inspecting are some examples of non-added-value activities of the process.

- *Excess Inventory*. Overproduction leads to over inventory, and it represents a cost both in terms of space and cash flow.

- *Defects*. Defects and errors related to manufacture and services represent a waste of resources in terms of material and labor and require remanufacturing goods and responding to complaints (employing additional labor force).

- *Excess Motion*. It is linked to the *Value Stream Mapping* to identify wastes in the production process. Poor workflow and inconsistent work methods can lead to unneeded motion.

- *Underutilized People*. Factors such as organizational culture, scarce hiring practices and lack of training lead to underutilization of people in terms of their physical, mental, and creative abilities (Kilpatrick, 2003).

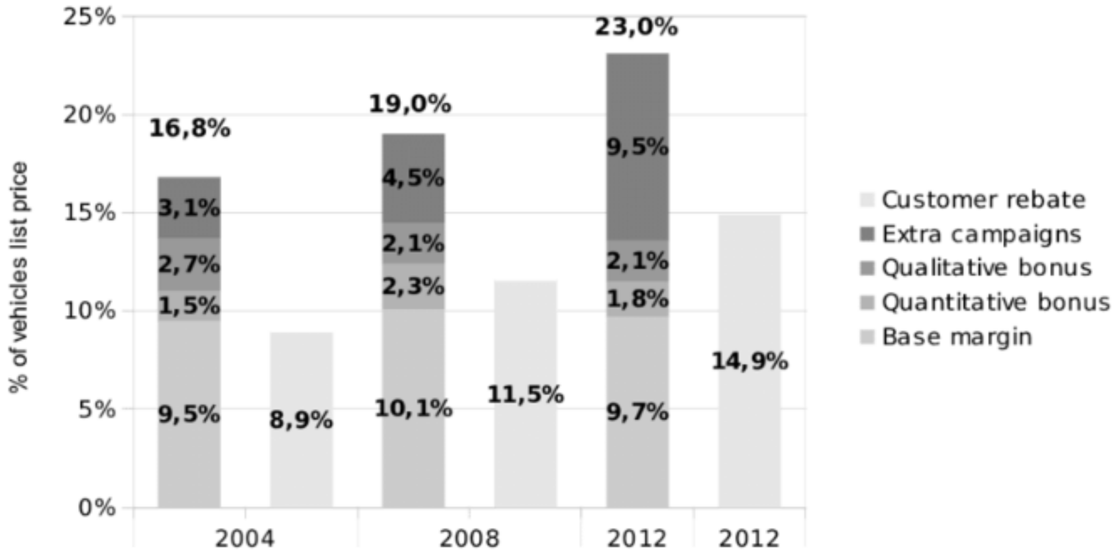
To respond to the necessity of eliminating these wastes, there are some tools which manufacturers can draw on. These tools should be utilized together to improve the overall production process, since utilizing only few could negatively impact the organization.
These tools are called Lean Building Blocks and some of them are: *Pull System* which is opposite of Push System used historically when sales were based on forecast; *Kanban* (to organize the orders of material); *Works Cells* instead of straight assembly line to better communicate; *Point-Of-Use-Storage,* as seen in the previous paragraph; *Quick Changeover,* a method used to waste less time in switching the process from one product to another (Kilpatrick, 2003).

Advantages deriving from the application of Lean techniques concern different aspects of a company. Indeed, some research found out the following: Lead Time was decreased by 90%, quality increased by 80%, productivity grew by 50% and utilization of space was reduced by 75%.
In addition, the administrative departments improved in relation to different functions. Reduction of paper employed in the offices, reduction of errors in processing orders, reduction in demand for employees which became more efficient and could afford to do more orders are some examples (Kilpatrick, 2003).

However, it is complicated for an organization to implement in a proper way all the Lean Building Blocks. For example, companies might fail in trying to apply Lean techniques because they implement the blocks in an inappropriate sequence, they spend several times in training instead of "doing", people in the organization feel uncomfortable with radical changes, managers are more interested in short-term results instead of long-term and so on (Kilpatrick, 2003).

Shifting to changes in economic aspects that accompanied the transformation of the system described in the above paragraphs, it can be argued that dealers have seen a decrease in their profit margin. Increasing intra-brand competition has created the necessity for dealers to boost their efficiency and draw profits from other activities such as used cars and services to clients. Despite some re-organization of the manufacturing process aimed at reducing costs, dealer margin for a new car dropped from a typical 15% in the mid- 1990s to 10% in recent years.
The graph below shows how the composition of dealer margins changed over the years, with regard to the Italian market (Stocchetti et al., 2013).

Figure 1.8: The structure of dealer margins



Source: Stocchetti et al., 2013.

As Figure 1.8 demonstrates, the significant change is regarding two elements: the customer rebate, which increased significantly, and the size of extra campaigns needed to remain in the market and activate dealers. As a result of extra sales campaigns effect, gross margin has stayed more or less equal, but volume losses caused the unsustainability of the business. Indeed, for example in Italy, dealers' sales dropped from about 1.7 million units in 2004 to 0.9 million vehicles in 2012, with other countries following the same trend (Stocchetti et al., 2013).

This situation has made it difficult for many dealerships to survive, favoring the retailer concentration, where larger financially stable actors were experiencing acquisitions in order to achieve economies of scale. The concentration process grew quickly as a consequence of the large drops in volume of sales: in Italy sales outlets dropped from 6,130 units to 5,215 units over a decade (15% decrease).
Asian brands instead have entered the market or enlarged their network of distribution, enhancing the downward trend in more mature markets. Considering Italy, for instance, one dealer out of three exited the distribution industry in the last decade (Stocchetti et al., 2013).

Although in the past retailer concentration was seen as a threat by manufacturers, they later started considering its advantages. Few dealerships in Europe (3%) are factory-owned, and this allows manufacturers to exert more power and control over the dealers and their activities. But this solution is also useful to serve metropolitan areas where costs are too high to be sustained

by independent dealers, and to take advantage of the closeness to the end market in the form of marketing and retail laboratories. But since this solution represents only a minimal part of dealers, manufacturers started to see the Internet as a complement resource to better communicate with customers.
Nevertheless, at the moment, both factory-owned stores and digital technologies are not substituting the franchised distribution channel (Stocchetti et al., 2013).

A positive aspect, however, lies in the dealer's satisfaction with the manufacturer. Since the transformation of the industry has attributed to dealers a role of creating value (instead of only adding value), their increasing satisfaction drives them to enhance their commitment towards both producers and consumers, bringing positive implications for all three parties. Anyhow, the evolution of the system calls for a sustainable alternative to the franchised distribution system (Stocchetti et el., 2013).

Let us now analyze how the business model of franchised dealerships evolved and adapted according to the needs of the environment.
A business model responds to three basic questions:

- «who are the customers »,
- «how is the company intending to provide value to them», and
- «how is the company extracting value out of it».

By answering the above questions, a business model allows the firm to identify the necessary elements to develop its strategies. In particular, it identifies four components: the *target*, the *offering* for the target, the *chain of processes involved* to ideate the offering, and the *profit model* needed to the company in order to extrapolate value as profitably as possible (Stocchetti et al., 2013).

The business model that generally characterized the automotive industry is no more suitable for the current situation, consequently firms had to shift to a more innovative business model that allowed them to give an appropriate response to market needs.
The figure below summarizes the features of the traditional compared to the innovative business model in automotive dealerships (Stocchetti et al., 2013).

Table 1.4: Features of business model innovation in automotive dealerships

Element	*Traditional*	*Innovative*
Target	New car customers within the sales territory	More proactive attitude (also outside the territory), finer segmentation (aiming at willingness to pay) and broader target (i.e. used cars, services, etc.)
Offering	Sale of new vehicles of the represented brand (with provision of some after-sales support)	Broad mix of businesses to stabilize business, increase strategic autonomy and increase share of customer wallet
Chain of activities	Order management, finance management, delivery management	Prospecting and lead management, database management, customization capabilities, follow-up procedures
Profit model (value capture)	Margin on new vehicle sales (considerably influenced by manufacturer)	Margins on all business segments (less influenced by manufacturer and more dependent on autonomous choices)

Source: Stocchetti et al., 2013.

In terms of target customers, the dealers traditionally enjoyed a sort of protection in a given territory with its inhabitants which represented almost a “natural” market. The elements that contributed to the offering were the sale of new cars together with some related after-sales services. The difference between the selling price and the cost paid to the producers constituted the profit margin (Stocchetti et al., 2013).

Over time it was necessary to progressively change the business model. In the innovative model the target requires to be larger, and dealers should become more proactive in searching customers, going beyond their territory. This fact raises the necessity to utilize more professional and technical marketing tools, such as geo-marketing and the correct use of social media, to exploit the potential of targeted initiatives at the expense of the ordinary mass-marketing. Another task of dealers is now to examine and have knowledge of customers’ needs and willingness to pay, so that they can segment the market in a proper way and more precisely. With a broader target that is no more limited to new car customers, offering needs to be widened by adding to sales of new vehicles also sales of used cars, the provision of finance and insurance, accessories and other components supplying, rental services, repair and maintenance work and other related activities. This "upgrade" partially eliminates the dependency that dealers have on manufacturers. Indeed, elements such as the buying price, the selling price, operating costs, and volumes are decided by producers.

Regarding activities, dealers in the traditional model just concentrate on the management of orders, while in the innovative model they are requested to become more proactive, thus managing different processes (for example, they need to develop the ability to manage customer data from prospect to sale). In short, dealers shift from being passive players under the guidance of manufacturers to being active agents with the responsibility to establish their own policies and strategies.

Consequently, the profit model changes. Dealers are no more totally addicted to manufacturers and are able to generate profits based on their own choices and strategies to exploit market opportunities, since apart from new car sales, other activities are controlled by themselves (Stocchetti et al., 2013).

Despite all, every region experiences different dynamics and market life cycles, thus there will exist several paths of transformation in the industry. Moreover, the automotive industry presents some features such as the low frequency of purchase, the high price per unit, and the need for after-sales services that differentiates it from other industries. Finally, it remains to be seen how much the represented brand influences the business model, which strongly depends also on the power of the brand (Stocchetti et al., 2013).

1.5 Industry segmentation and current major transitional factors

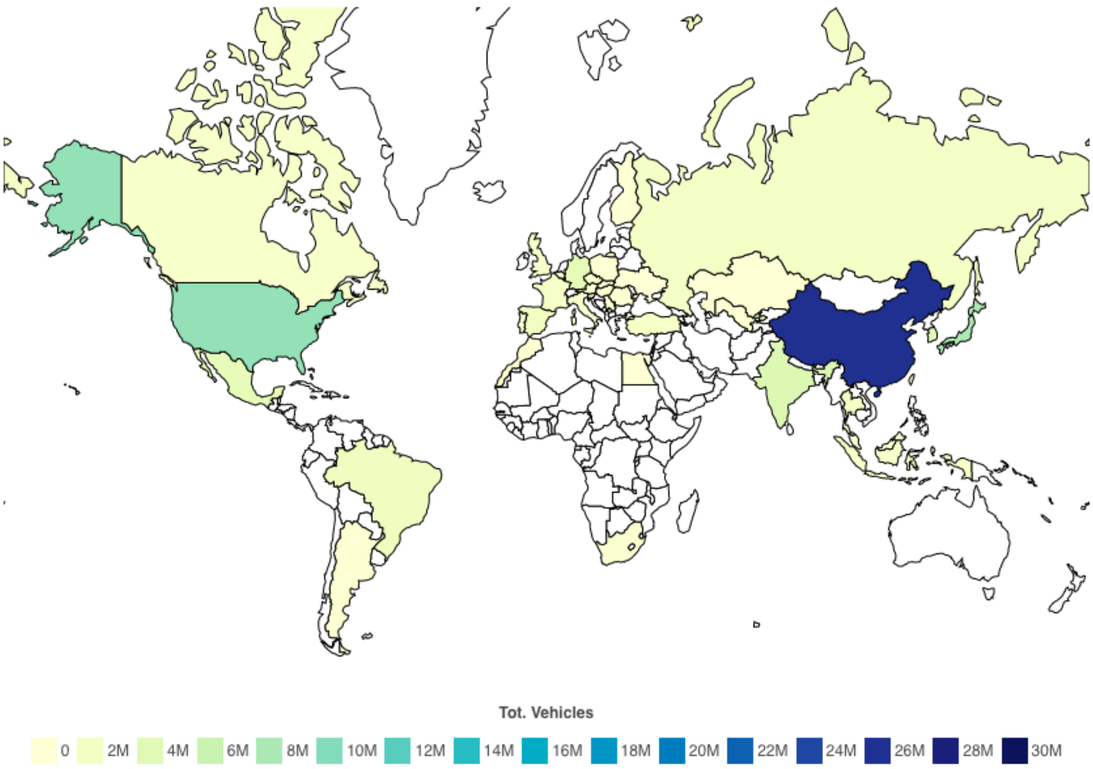
The global production is divided into two sets: one composed of the US, Germany, and Japan, and the other of the BRIC countries (Brazil, Russia, India, and China). But the current trend is towards the growing consumption of the emerging middle class in developing countries such as China (Stocchetti et al., 2013).

The figure below represents the distribution of car production around the world. As it can immediately be noticed, China and the United States are the two largest vehicle producers, even though China's production is far greater. China is the world's largest producer, with more than 27 million units produced (cars and commercial vehicles). We refer to China's biggest manufacturers as the "Big Four": SAIC Motor, Dongfeng, FAW, and Chang'an.

In second place, the United States produces in total more than 10 million cars and commercial vehicles. General Motors, Ford Motor Company, and Fiat Chrysler are the "Big Three" manufacturers in the United States (World Population Review, 2023).

A more detailed analysis regarding worldwide car production will be presented in the next chapter.

Figure 1.9: Car Production by Country



Source: World Population Review, 2023.

Here follows the list of the first 10 countries by number of vehicles (cars and commercial vehicles) produced in 2022 (Oica, 2023):

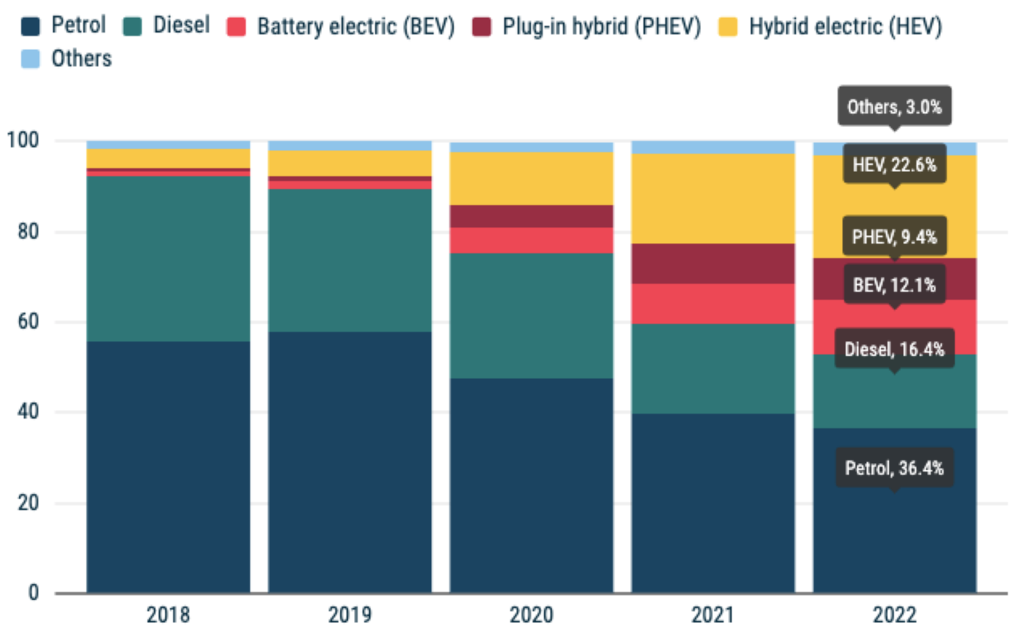
China	27.02 million
United States	10.06 million

Japan	7.83 million
India	5.45 million
South Korea	3.75 million
Germany	3.67 million
Mexico	3.50 million
Brazil	2.36 million
Spain	2.21 million
Thailand	1.88 million

In terms of differentiation of products, diverse categories of vehicles characterize the complex automotive industry.

The chart below shows the market segmentation concerning the types of vehicles that currently compose the industry. One of the most emerging priorities of people today is to shift to cleaner energy and automobiles that limit their negative impact on the environment. However, in the near future, petrol and diesel vehicles are likely to continue to remain the most spread (Moore, 2022).

Figure 1.10: % of new passenger cars by fuel type in the EU – from 2018 to 2022



Source: Acea, 2023.

Nowadays there are different typologies of cars that are considered eco-friendly.
According to Philips (2022), «*an "eco-friendly" or "green" car is a vehicle that pollutes the environment less than others and works more efficiently reducing the negative impact on the environment. Thus, the concept of eco-friendly cars includes cars running on alternative fuels and those running on gasoline*».

Let us synthesize the main types of eco-friendly vehicles available in the car market.

- *Electric Vehicles (EVs)*: a vehicle that is not powered by an internal combustion engine but is run by an independent source of electricity (such as a battery) and produces no exhaust emissions. Its diffusion is increasing but still represents a low percentage.

- *Plug-in Hybrid Electric Vehicles (PHEVs):* this vehicle has a rechargeable battery and an internal combustion engine (petroleum or alternatives). It relies on the electric motor until charged and then switches to the internal combustion engine.

- *Fuel Cell Vehicles (FCVs):* it is an electric vehicle that substitutes the battery with fuel cell to power its engine. This car is usually considered a zero-emission vehicle, as by combining hydrogen and air in the presence of a catalyst, a fuel cell generates the electricity needed to drive an electric motor, with water vapor as the only waste product.

- *Natural Gas Vehicles (NGVs):* the fuel utilized for the engine is only methane. This vehicle is environmentally friendly and attracts the users thanks to its reduced cost compared to other environment-friendly alternatives.

- *Flexible Fuel Vehicles (FFVs):* it is a car that can be run by both gasoline and by a flexible proportion of gasoline and ethanol. There are specific norms that regulate the mixture percentage, depending on the weather of a particular area (for instance, in Sweden E75 is sold from November to March).

- *Gasoline Hybrid:* it is a combination of an internal combustion engine (which powers the vehicle) with one or more electric motors that utilize the energy from the batteries. This type of vehicle allows it to save fuel and release low emissions, without compromising its performance (Philips, 2022).

There are several advantages in choosing an electric vehicle. First, the maintenance costs of BEVs (battery-powered electric vehicles) are lower, because they are made with a minor number of components with respect to traditional vehicles. Second, they are almost silent and light. In addition, they can be charged both at home and at gas stations. PHEVs allow people to drive over short distances (for example, from home to work) with electricity only, thus reserving the use of petrol engines for longer trips. Finally, these vehicles reduce the commitment of the internal combustion engine even during the coasting or deceleration, thanks to the regenerative braking system, which consents to recover the otherwise wasted energy (Philips, 2022).

It is widely recognized that nowadays there is a strong need to pay more attention to the environment, and certainly the automotive industry has a strong impact on it (Philips, 2022). To confirm that, it is sufficient to know that up to 29% of the EU's CO_2 emissions are due to the transport sector, with a rise of nine points since 1990. Of this percentage, 14% of emissions are caused by automobiles, almost half of the total sector CO_2 emissions. The urgent purpose of institutions is therefore reducing emissions, but there are some difficulties in driving the required innovation for the industry. For example, even if the total cost of ownership (TCO) is lower, consumers are reluctant to purchase more environmentally friendly vehicles because of their higher price and lower autonomy (Stocchetti et al., 2013).

The main current goal is generally to reduce waste and environmental concerns such as pollution. To respond to such emerging needs, automakers have to adapt their production and products (Philips, 2022). Today one of the main challenges is not only to create a more environment-friendly vehicle, but also to make the production itself less impactful for the environment. Indeed, from the end of the 20th century, it rose the awareness that the environmental issues were not only related to car emissions and air pollution. With the introduction of the life cycle analysis, it is therefore recognized that potential environmental concerns derive also from the materials and the production process (Nieuwenhuis & Wells, 2003).

The current global factors and revolutions that are changing all the markets are also hitting the automotive sector: digitization, new business models and innovative technology are some examples. Therefore, there are four main trends that will characterize the industry in the future as a response to these external pressures: diverse mobility, autonomous driving, electrification, and connectivity (Moore, 2022).

These four factors threaten to disrupt the whole industry. First, people's awareness and their sensitivity towards the environment are increasingly spreading the need for *diverse mobility*. This means that people pay more attention when using their own cars, opting for e-hailing or car sharing. The inclusion of apps and other technologies in the industry is expected to generate $1.5 trillion more in revenue, and it is expected to also increase the number of cars sold, even if at a slower rate, thanks to the development of cars destined to the sharing (EmpireCLS, 2016).

A second fact that will revolutionize the automotive industry is the probable future advent of *autonomous driving*. It is argued that about 15% of the cars sold in 2030 will be completely autonomous, and this seems now real thanks to the improvements in advanced technologies that tech giants like Google are experiencing. However, some doubts regarding the driver’s acceptance to stop keeping the wheel and the limitations imposed by the regulations could hamper its effective use (EmpireCLS, 2016).

Electrification is one of the biggest changes of the industry. Regulations are becoming more and more severe, and some consumers are willing to shift to electric vehicles, due also to the lower battery costs and the expanding infrastructure for vehicle chargers. The demand for these cars will vary depending on the location, for example it will be higher in trafficked urban centers where norms are stricter, but generally everywhere it is expected to sell from 10 to 50% of electric vehicles (EmpireCLS, 2016).

All the above-mentioned factors will lead to the need of *connectivity* among vehicles, always more autonomous and technologically advanced. There will be the necessity of collaboration between the lead automotive firms and the tech giants, to offer a complete and complex vehicle with software and other features, similarly to a computer (EmpireCLS, 2016).

CHAPTER 2

Evolutionary trends

This chapter has the purpose of describing and analyzing the main evolutionary trends that are currently characterizing the automotive industry. Looking at how specific data regarding cars features changed over time will be helpful to understand which direction is taking this sector and how it is affording the ongoing challenges.

2.1 Cars' features evolution analysis

In this paragraph, it will be analyzed how the characteristics of the cars evolved over time. In particular, the reported data cover the period from 1975 to 2022 (2022 values are preliminary), and they regard all light-duty vehicles delivered for sale each year in the United States (US Environmental Protection Agency, 2023).
Data tracking started following the Energy Policy Conservation Act of 1975, which established the first CAFE (Corporate Average Fuel Economy) standards for light-duty vehicles in the United States (DieselNet, n.d.).
The statistics distinguishes the vehicles in two regulatory categories, cars and trucks, which are moreover divided as follows: *All Car* is made of *Car SUV* and *Sedan/Wagon*, while *All Truck* is divided into *Minivan/Van, Pickup,* and *Truck SUV*.
The complete database can be found in the Appendix of this elaborate.

For each year and each category, it is reported the production share it represents and some other variables that characterize the vehicles:

- *MPG (Miles per Gallon)*
- *MPG City*
- *MPG Highway*
- *CO_2 (g/mi)*
- *CO_2 City (g/mi)*
- *CO_2 Highway (g/mi)*

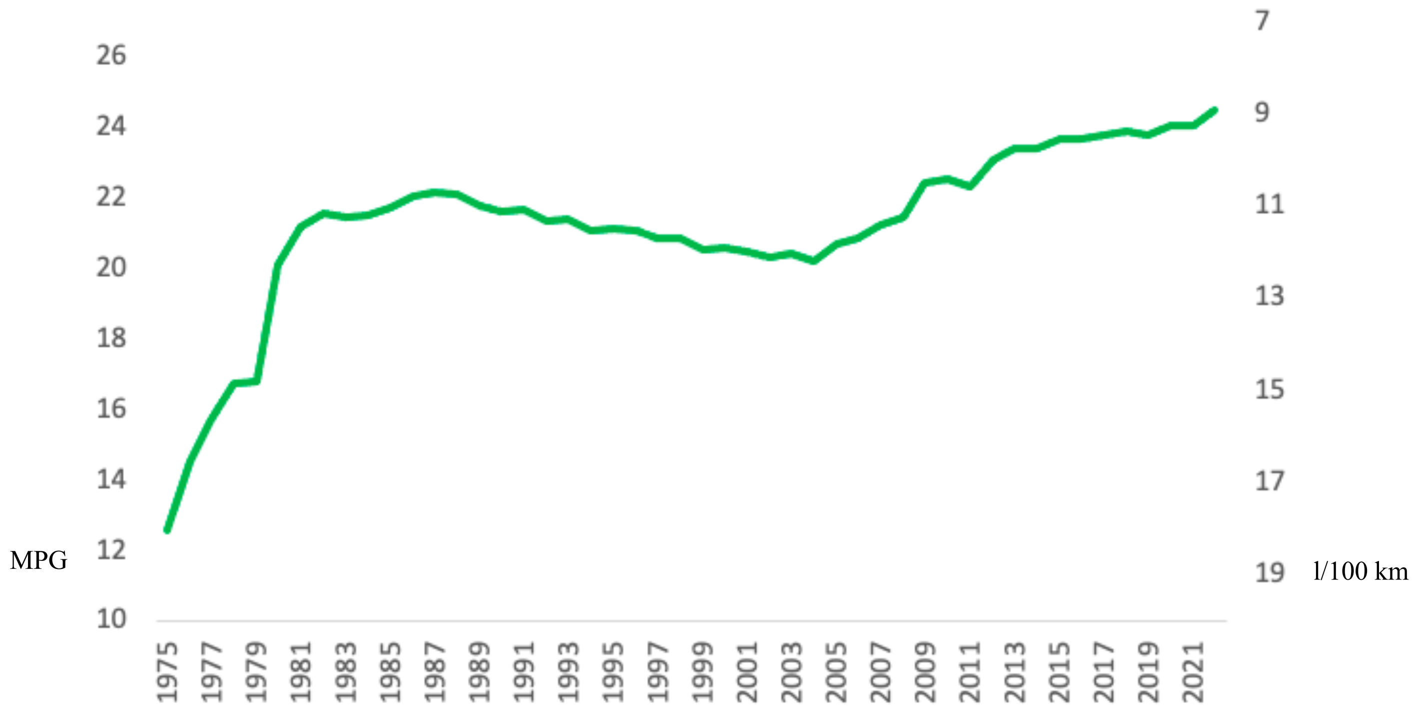
- *Weight (lbs)*
- *Horsepower (HP)*
- *Footprint (sq. ft.)*

Let us now take into consideration the changes that the above-mentioned variables made over time.

First, initially and for most years, cars represented almost all the production of the vehicles. While at the end of the analysis, cars were no more the majority, indeed the database clearly reports that the percentage of trucks production increased. For example, in 1980 car production share was 0.84 while in 2021 only 0.37, in favor of trucks that represented 63% of the total production (US Environmental Protection Agency, 2023).
A first reason could be that utilizers became more aware and careful about the functions of a vehicle. While at the beginning people considered the car only as a means of transport, over time this concept enlarged and buyers now also consider additional aspects, such as the extent of versatility, the power, the capacity of the vehicle and so on (OSVehicle, 2023). However, the behavior of buyers about purchasing cars will be analyzed later in this chapter.

Moving to analyzing car features, it can be stated that, on average, MPG (Mile per Gallon), which indicates the distance that a vehicle can travel with one gallon of diesel or gasoline fuel, improved over time, meaning that vehicles became more efficient. Starting from a value of 13.06, in 2021 it almost doubled to 25.42, with some oscillations during the period. Of course, if we consider the different types of roads where we can travel on, the result is that MPG value is higher when in highways (14.61 in 1975 and 28.59 in 2021) with respect to cities (12.02 in 1975 and 22.17 in 2021), and that trucks consume more than cars (on average 11.63 vs 13.45 in 1975 and 22.72 vs 31.85 in 2021) (US Environmental Protection Agency, 2023).
To better understand, it is useful to convert MPG values into l/100 km values. One MPG is equal to 235.214583 l/100km (Mgptolitres.com, n.d.).
The chart below shows the path of MPG values and l/100 km values for all vehicles from 1975 to 2022, according to US Environmental Protection Agency research. MPG values are indicated on the left axis, while on the right axis they are shown the corresponding l/100 km values.

Figure 2.1: Real-World MPG & l/100 km for all vehicles, model year 1975-2022



Source: elaboration on data from US Environmental Protection Agency, 2023.

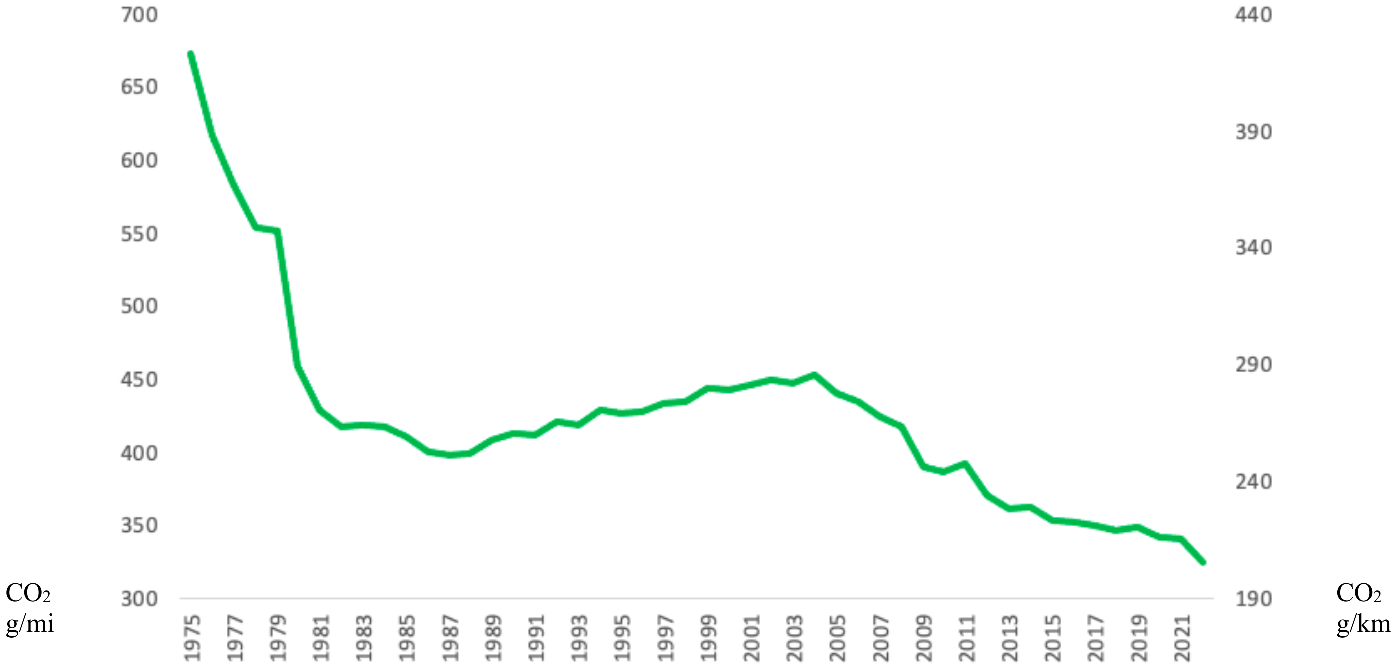
Another variable to analyze is the value of CO_2 emissions deriving from a vehicle. In the data collected by the US Environmental Protection Agency, this value is expressed in grams per mile.

As it can be imagined, during the reference period this value has decreased: from 680.60 in 1975 to 346.85 in 2021, where the value is higher when driving in the cities (739.74 in 1975 and 398.13 in 2021) and lower for highways (608.31 in 1975 and 308.16 in 2021), and it is also higher for trucks compared to cars (763.86 vs 660.64 in 1975 and 390.66 vs 272.48 in 2021) (US Environmental Protection Agency, 2023).

The graph below shows how CO_2 emissions for all vehicles changed during the period 1975-2022. It reports the values of CO_2 emissions in grams per miles (g/mi) on the left axis, and the values of CO_2 emissions in grams per kilometer (g/km) on the right axis. One g/mi corresponds to about 0.62 g/km.

It can be argued that although the situation improved over time, we are still not close to the objective of some institutions such as ACEA, which would like to reset the CO_2 emissions by 2035 (Sicurauto.it, 2022). However, aspects related to the environmental issues will be deepened in the next paragraphs.

Figure 2.2: Real-World CO_2 g/mi & g/km for all vehicles, model year 1975-2022



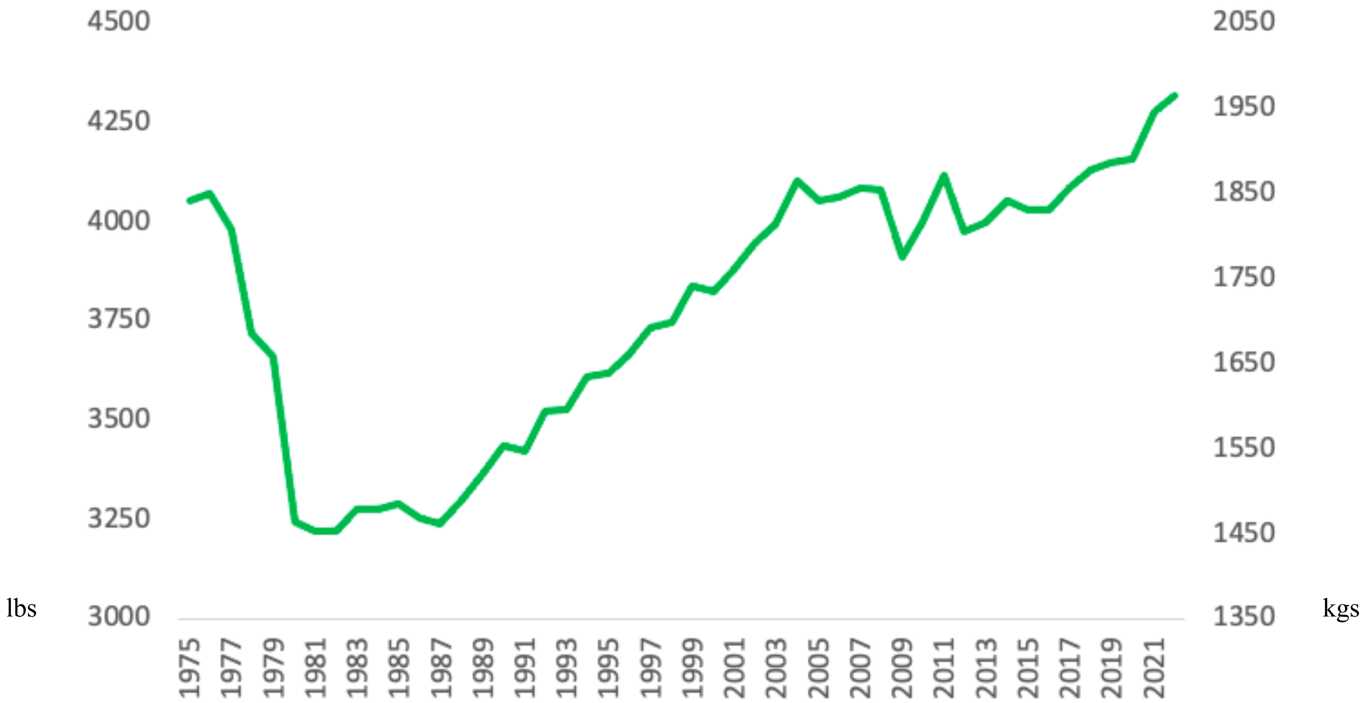
Source: elaboration on data from US Environmental Protection Agency, 2023.

Other two variables to be considered are the weight and the horsepower (the power that an engine produces) of a vehicle.

Regarding weight, the trend was that vehicle weight oscillated over time, but it grew in the last years. In the US Environmental Protection Agency database, weight is measured in lbs (1 lb is about 0.45 kg), and on average it was equal to 4060.40 in 1975, 3201.76 in 1981 and finally 4282.42 in 2021 (US Environmental Protection Agency, 2023).

The chart below reports the average weight of vehicles during the period 1975-2022, according to the US Environmental Protection Agency. Values in lbs are shown in the left axis, while values in kgs are reported on the right axis.

Figure 2.3: Weight (lbs & kgs) for all vehicles, model year 1975-2022



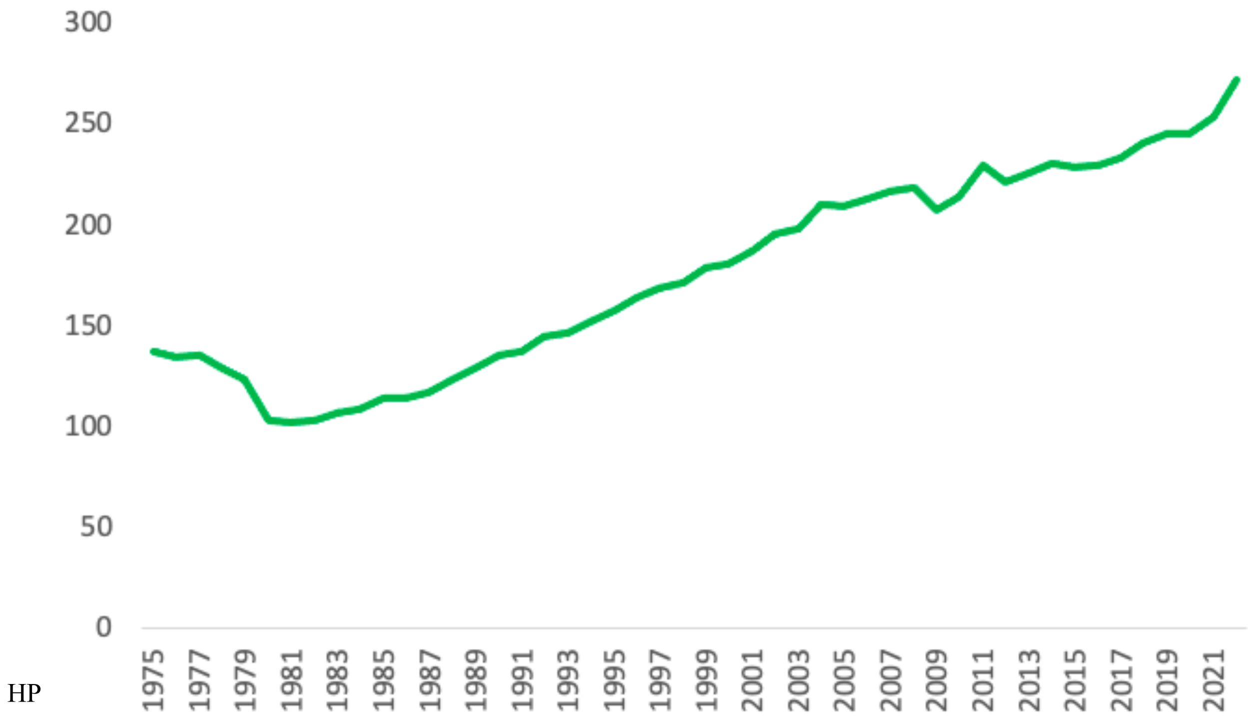
Source: elaboration on data from US Environmental Protection Agency, 2023.

Nowadays cars are heavier for different reasons, for the dimensions (vehicles are bigger, and people feel safer when driving a big car like a SUV) and the numerous accessories that characterize them (because of the customers' requirements). Further reasons will be analyzed later in this chapter.

Moving to horsepower, vehicles became more powerful in terms of engine. The most powerful category is the one of pickups, but as it can be seen from the analyzed database, the trend grew for all vehicles. On average, HP was 137.33 in 1975 and 253.43 in 2021 (with a preliminary value for 2022 of 272.35). Pickups reached 337.21 in 2021, while sedan/wagon, the less powerful, 214.43 (US Environmental Protection Agency, 2023).

The following figure shows the average path of horsepower for vehicles during the period 1975-2022, according to the US Environmental Protection Agency.

Figure 2.4: Horsepower (HP) for all vehicles, model year 1975-2022



Source: elaboration on data from US Environmental Protection Agency, 2023.

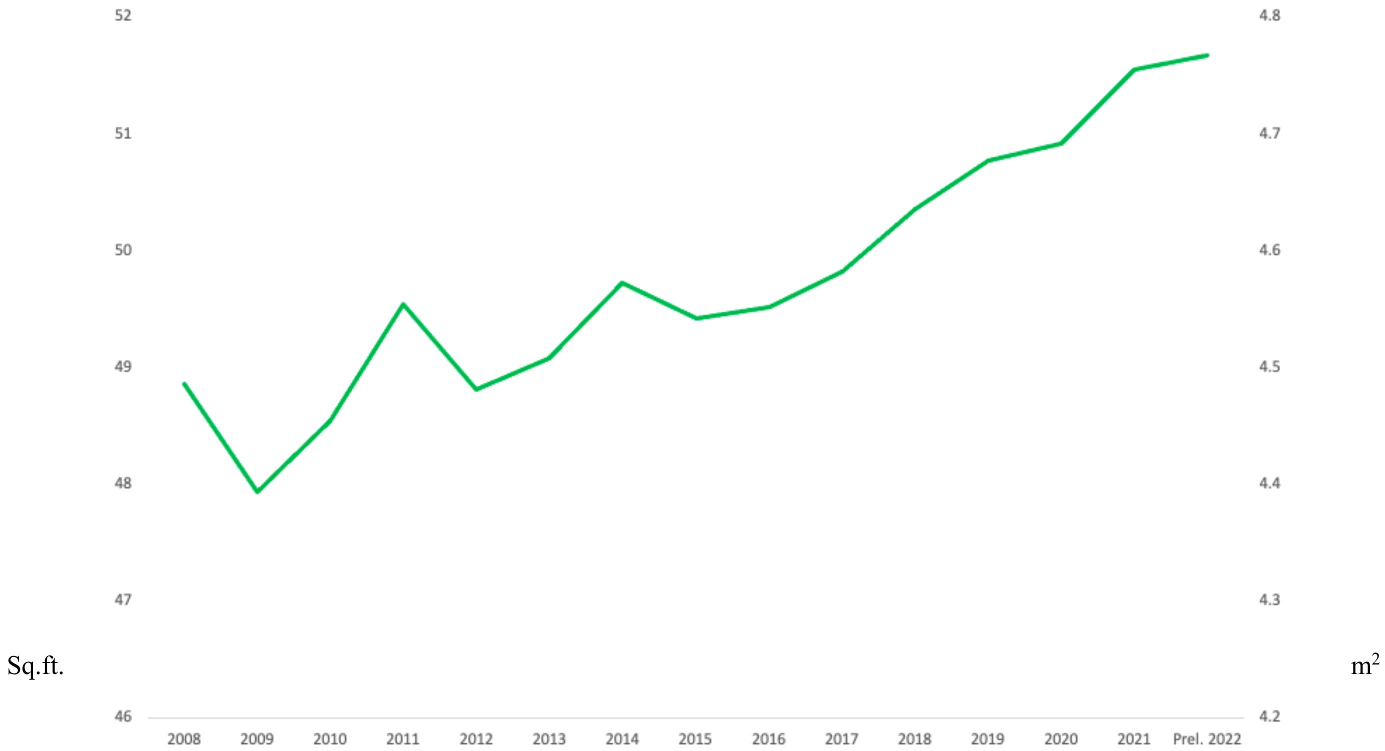
Starting from 2008, a new parameter was introduced: the footprint, measured in square feet (sq. ft), which indicates the area delimited by the four tires of a vehicle.

As we can expect, this area grew slightly over time (from 48.9 in 2008 to 51.5 in 2021), because of the increase in vehicle size (US Environmental Protection Agency, 2023).

One square foot is equivalent to about 0.093 square meters (m^2).

The figure below shows the evolution of the footprint values expressed in sq. ft. and in m^2 for all vehicles. On the left axis, values expressed in sq. ft. are shown, while values expressed in m^2 are reported on the right axis.

Figure 2.5: Footprint for all vehicle (sq. ft. & m^2), years 2008-2022

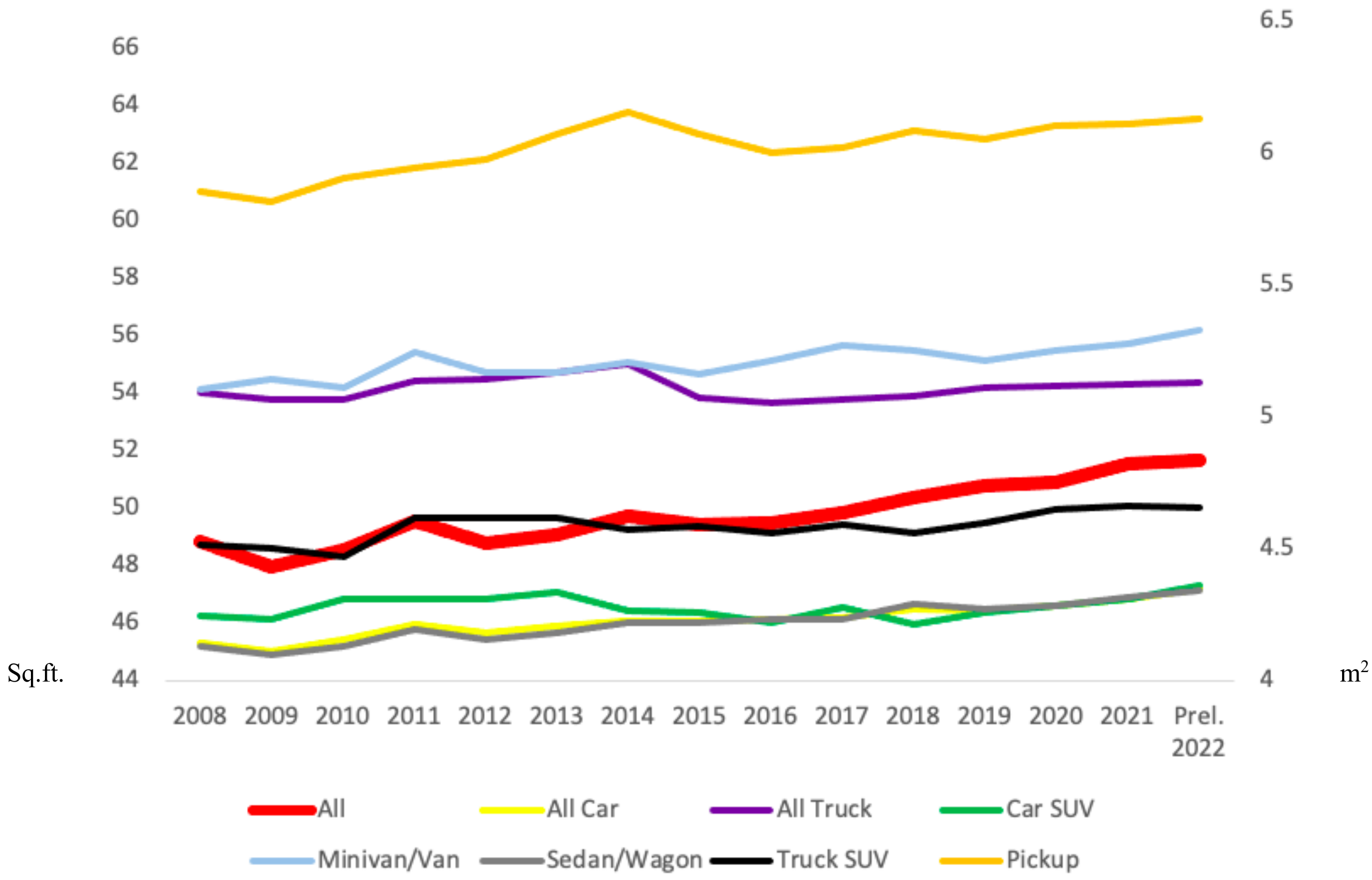


Source: elaboration on data from US Environmental Protection Agency, 2023.

The next graph shows the evolution of footprint values expressed in sq.ft and in m^2 divided by vehicle category. The values expressed in sq.ft. are reported on the left axis, while the values expressed in m^2 are indicated on the right axis.

The red line highlights the value of all vehicles, which is a pondered average.

Figure 2.6: Footprint divided by vehicle category (sq.ft & m²), years 2008-2022



Source: elaboration on data from US Environmental Protection Agency, 2023.

Summarizing the results of this first analysis, it can be stated that, tendentially, most of the vehicle production switched from cars to pickup "trucks". Considering the features instead, vehicles became more efficient in terms of MPG, improved regarding CO_2 emissions, became heavier (with wider footprint) and more powerful (US Environmental Protection Agency, 2023).

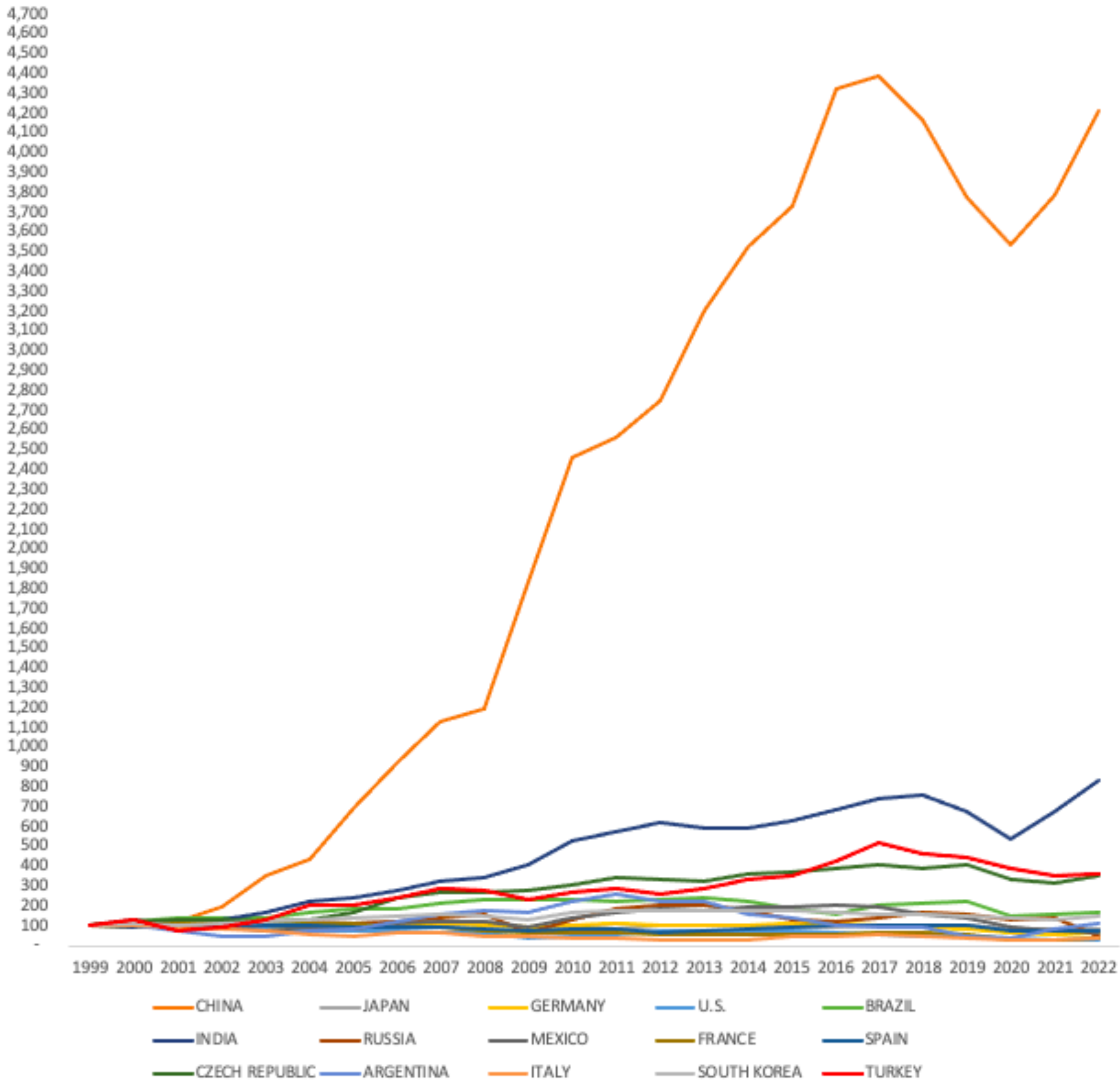
2.2 Vehicles production and vehicles efficiency

In the previous paragraph we have seen the main trends of evolution about some significant characteristics that cars experienced in a specific period. However, it is important to understand why and how this evolution took place.

Before concentrating on the evolution of vehicle features, it is interesting to understand how the production of vehicles has been spreading worldwide, and how much some nations such as China grew in production.

The following figure shows the growth in cars production of the major producers worldwide, for the period 1999-2022, where 100 represents the production during the base year 1999.
As it can be seen from the chart, China's growth has been rampant: in 1999 it produced about 5 hundred units, while in 2022 the production shifted to more than 23 million units (Oica, 2023).

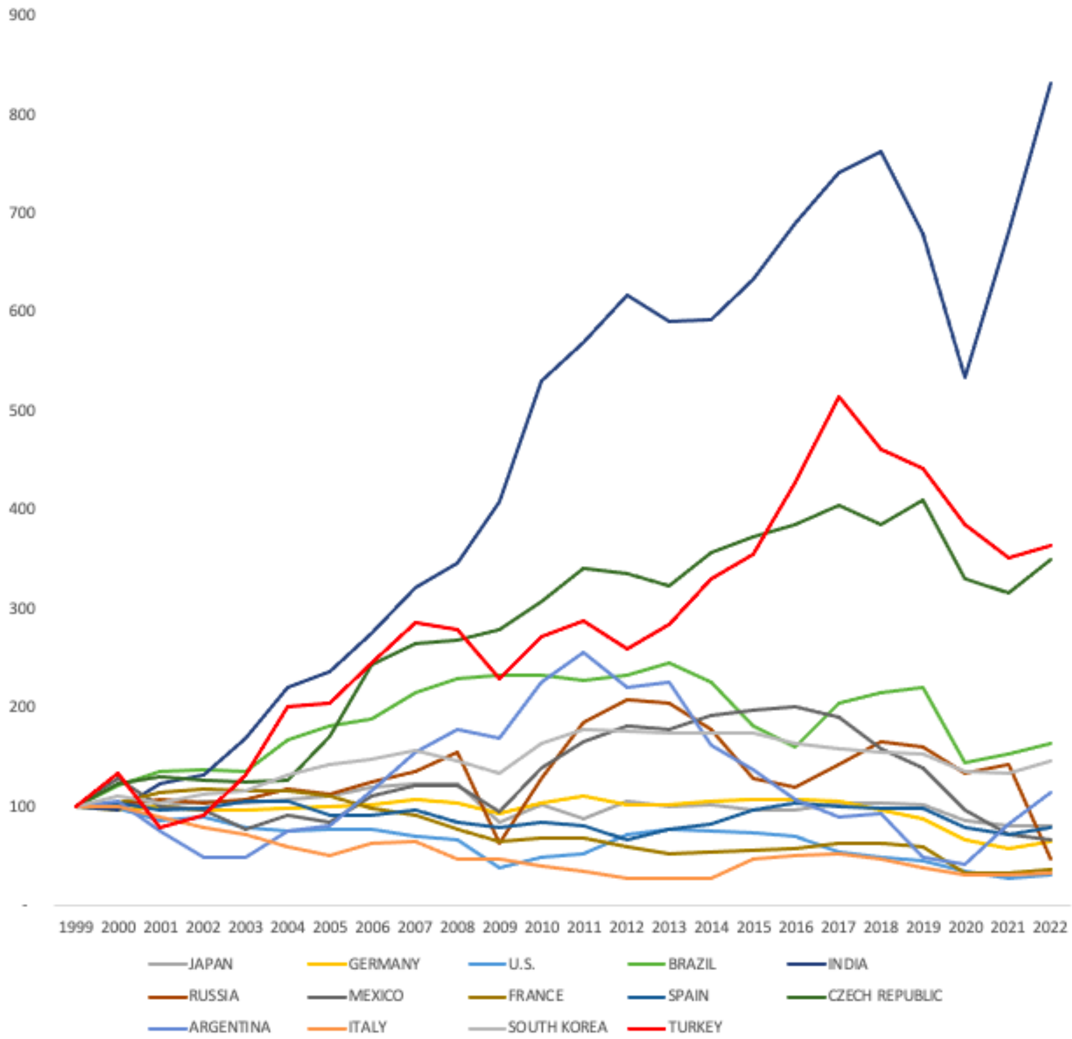
Figure 2.7: Worldwide car production of major countries, years 1999-2022.



Source: elaboration on data from Oica, 2023.

Since China's growth was so extreme that other nations' path is difficult to understand from the above graph, let us consider the same chart, but excluding China.

Figure 2.8: Worldwide cars production of major countries (excluding China), years 1999-2022.



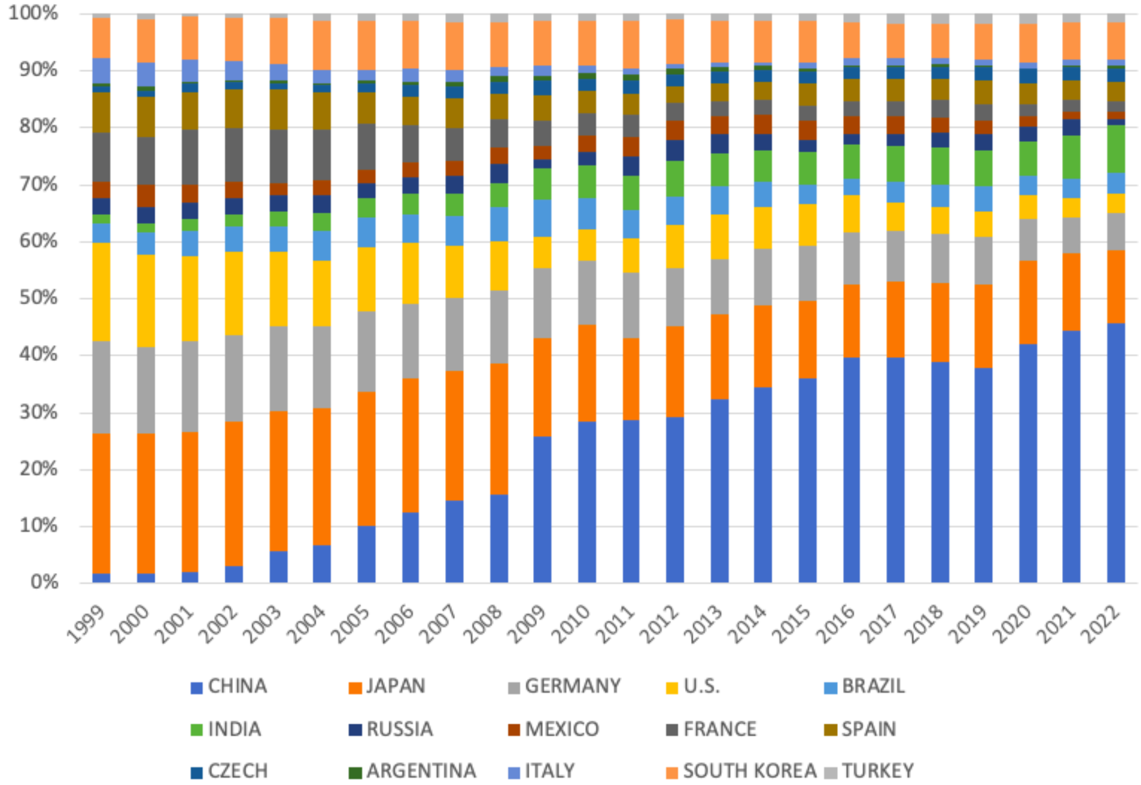
Source: elaboration on data from Oica, 2023.

As we can better understand from the figure above, there are some nations, such as Italy, France, and the U.S. that show a decreasing trend in production over the year. On the other hand, countries such as India and Turkey show a positive trend.

All the details regarding production of vehicles can be found in the Appendix.

Another interesting way to look at how the worldwide production evolved over time is to look at how the overall production has been shared among countries, as the following figure reports.

Figure 2.9: Car production shared among major countries, years 1999-2022



Source: elaboration on data from Oica, 2023.

By looking at these graphs, the leader in production is China, which is also the country that grew the most. On the other hand, even if Turkey grew a lot with respect to 1999, it still represents a minor share of the overall production. Finally, Japan is still one of the major producers, despite its decrease in units manufactured (Oica, 2023).

Moving on the features analyzed in the first paragraph of this chapter, MPG value increased over time. Vehicles efficiency is something firstly required by users, that nowadays have the need to “waste” least time possible to fuel the car and a greater necessity to travel longer distances without interruptions, and that, of course, would like to spend less money.

At the early beginning of the car era, the Model-T by Henry Ford was powered by gasoline and could support 21 miles per gallon. However, other vehicles could not satisfy such a standard. Indeed, the MPG in 1935 was about 14, and in the ‘70s it decreased to only 12.

The necessity to produce more efficient vehicles resulted because of the Arab oil embargo that caused a worldwide shortage, making the fuel prices extremely high and creating the

opportunity for new car models to become more competitive if presenting the characteristic of fuel economy (Roberts, 2020).
As explained earlier in the chapter, modern vehicles are always bigger and heavier, requiring more power to be moved. Moreover, vehicles weight is influenced by new safety features and technological progresses, but there are some characteristics that can be helpful to improve MPG values. (Roberts, 2020).
Technology is the main character that plays a significant role in improving fuel efficiency. Indeed, investing more capital for buying a more technologically advanced vehicle can allow users to save more money in the long run, because there are some technological characteristics that help to make the car more efficient in terms of fuel consumption (DeLorenzo, 2020).

There are some specific features that a potential buyer should consider. First, the start/stop technology permits the auto to stop and restart automatically when resting at the traffic light or in similar situations, and this is useful both for fuel economy and for reducing emissions. Another common feature in modern vehicles is the intelligent cruise control, which is helpful for fuel efficiency by controlling the stop-and-go scenarios. Continuously variable transmissions (CVTs) are another method that auto manufacturers are offering as a solution to improve fuel economy, where the scope is to keep the engine turning at a constant rpm (revolutions per minute). Finally, the combination of traditional internal combustion technology with electric power seems to be another option. Conventional hybrids are usually cheaper than plug-in hybrids, but the latter could allow you to commute by only applying EV mode (depending on each person’s route), since its autonomy is from 20 to 50 miles (DeLorenzo, 2020).

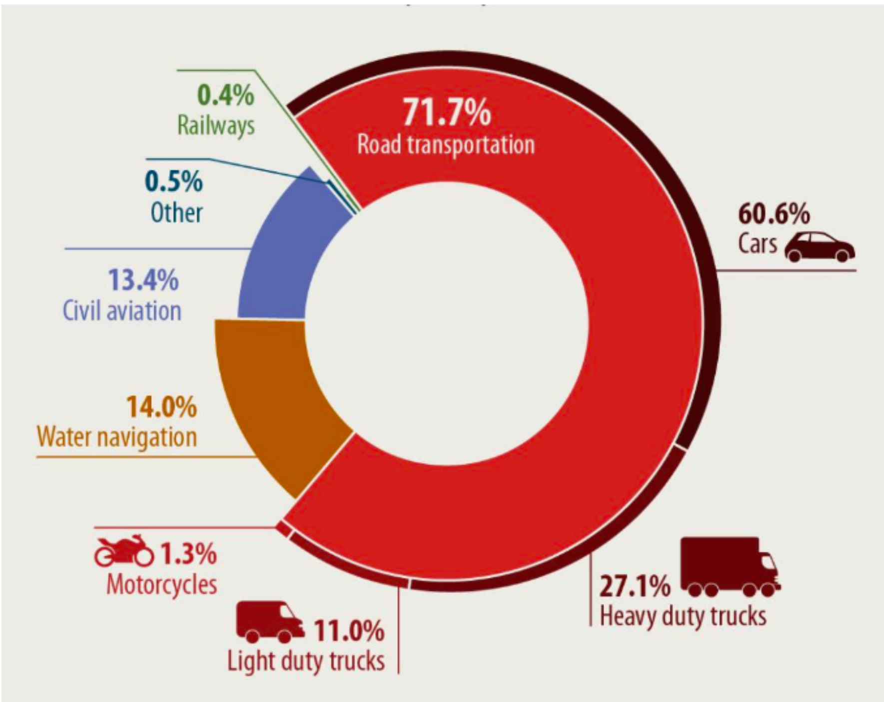
Fuel efficiency is one of the most important features that characterizes the evolution of cars. But there is also an evolution that concerns the fuel types. Indeed, as it will be discussed later in this chapter, nowadays some governments are pressing to stop the production of some types of cars. UK’s government is willing to discontinue the production of diesel and petrol cars by 2030. Therefore, the market for electric vehicles is increasing, but even if they are eco-friendly, they are not always efficient in terms of fuel consumption.
At the beginning an electric car was not the best option because of the absence of charging ports (indeed a diffusion of electric vehicles is only possible when an adequate charging infrastructure to support them is available), but now there exist some vehicles that can afford to perform over 100 MPGe (miles per gallon equivalent, a unit utilized for comparing energy

consumed by alternative fueled vehicles with respect to traditional fueled ones), hence now one of the focal points when considering a fully electric vehicle is the MPGe ratio (Roberts, 2020).

2.3 CO_2 emissions, electric vehicles, and government's policies

Nowadays one of the global priorities is to hinder CO_2 emissions and the related environmental issues such as climate change. Consequently, the EU has a central role in setting some standards for the automotive industry, considering that this sector has a great impact on the whole economy and on the environment. Indeed, the transportation sector is one of the main sources of global emissions, and as it can be seen from the figure below, about 70% of them are due to road traffic. Hence, the EU's goal is to reduce greenhouse gas emissions, and to do that it has recently approved a plan that states that, starting from 2035, all new cars sold in the EU must be zero emission vehicles (Hernandez, 2023).

Figure 2.10: Greenhouse gas emissions breakdown by transport mode – 2019

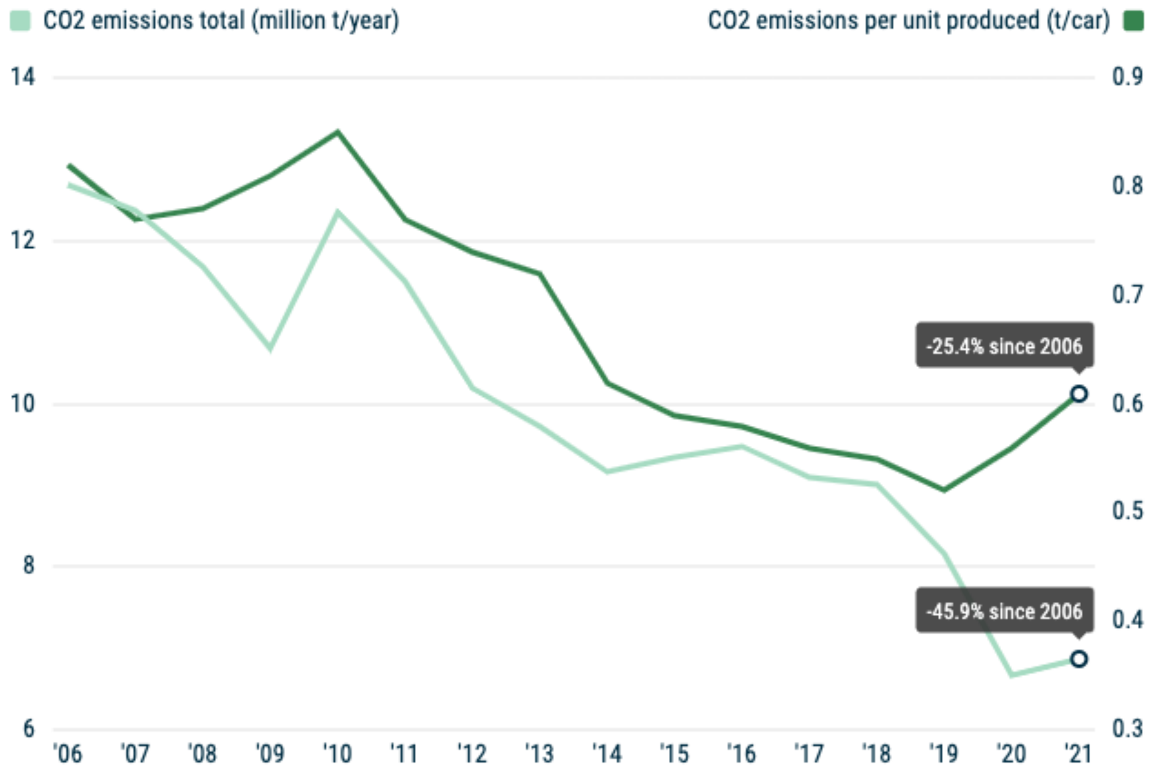


Source: European Parliament, 2023.

The above graph indicates that passenger cars are the major polluters. Consequently, it is needed to make vehicles more efficient or change fuel type to decrease pollution deriving from them.

As it has been stated in the first paragraph of this chapter, CO_2 emissions deriving from vehicles and from its production decreased over time, responding to the needs of the environment.
The following chart shows CO_2 emissions from car production in the EU for the period 2006-2021.

Figure 2.11: CO_2 emissions from car production

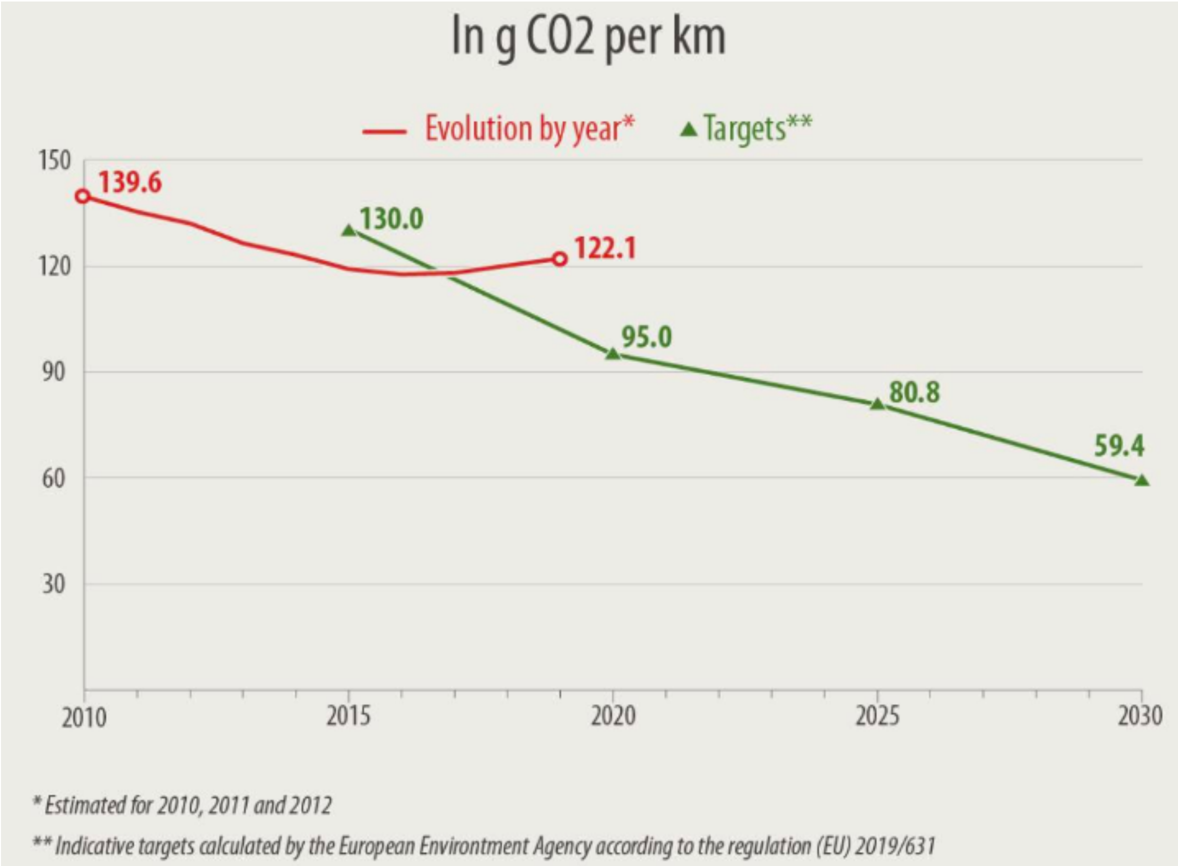


Source: Acea, 2022.

In 2021 EU car manufacturers reduced by almost 46% the overall production emissions, and by more than 25% the emissions per car produced compared to 2006. This reduction was possible thanks to the increased resort to the utilization of renewable and low-carbon energy sourcing (Acea, 2022).

The graph below shows the evolution and the targets of emissions from new passenger cars measured in CO_2 g/km (European Parliament, 2023).

Figure 2.12: Evolution of CO_2 emissions in g/km from new passenger cars

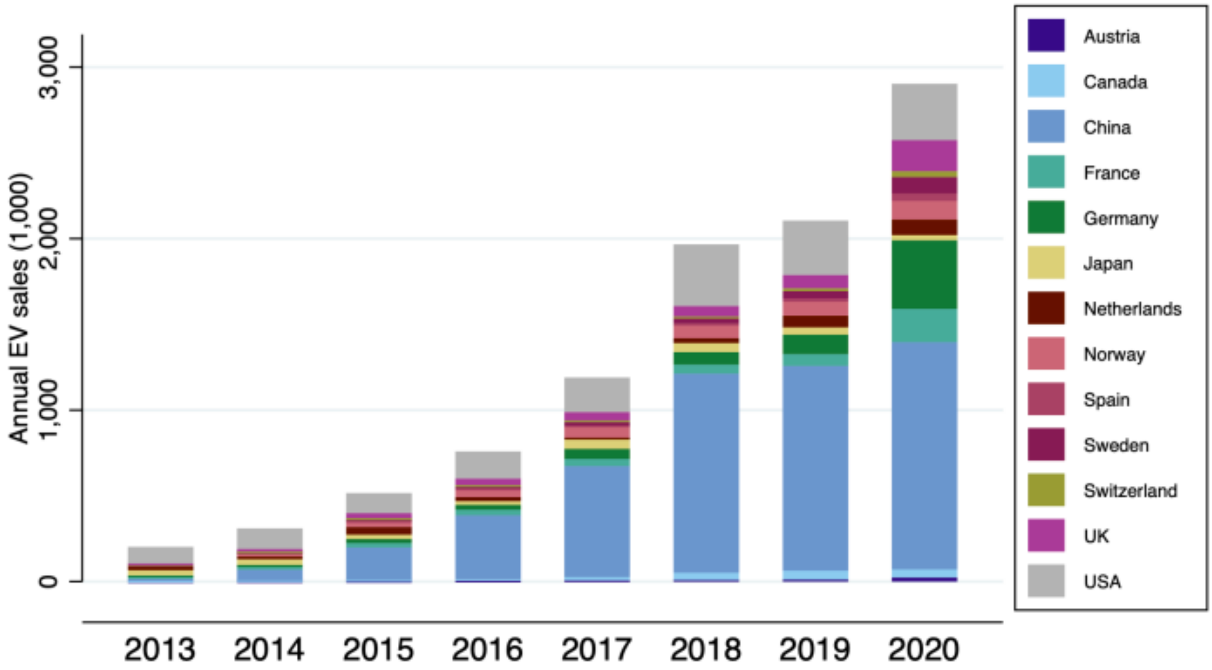


Source: European Parliament, 2023.

As it can be seen from the graph, we have an evolution that is not completely following the target. Nowadays, the question is whether the diffusion of electric vehicles could be a solution.

The figure below reports the annual EV (electric vehicle) sales by country for the period 2013-2020, including both plug-in Hybrid EVs and Battery EVs (Li, Wang, Yang, and Zhang, 2021).

Figure 2.13: Annual EV sales by country



Source: Li et al., 2021

As it can be seen from the chart, in the years from 2016 to 2019 China was the largest EV market, considering that it accounted for 40-60% of sales worldwide. However, in 2020 Europe had the primacy with 43% of market share, with Germany, United Kingdom, France, Norway, Netherlands, and Sweden as main countries. On the other hand, the market share of the US dropped from 47% in 2013 to 10% in 2020 (Li et al., 2021).

The strong growth of the EV market is not aligned with the decline that the market of the overall passenger vehicle experienced lately. However, this growth is strongly heterogeneous across the different countries. For example, the first place is occupied by Norway, where the EV share increased from 18% in 2015 to 67% in 2020. Other countries such as Spain and Canada still present a growth, but with smaller EV share.

Reasons related to large different growths among similar nations are still not clear, but in general richer areas such as Northern Europe have a higher percentage of EV compared to African and Asian countries.

Moreover, since each market has its own preferences and requirements, the number of EV models grew from 90 to 370 worldwide (from 2015 to 2020), and it has been noted that people prefer to buy from local brands, expect for Tesla which is the only one appearing in the most favored brands of all the markets (Li et al., 2021).

Regarding the EU, to get an idea of electric vehicles diffusion in terms of number, Acea reported that, in 2022: "*36.4% of all new cars registered in the European Union run on petrol, while diesel accounts for 16.4% of registrations. 21.6% of new passenger cars in the EU are electrically chargeable vehicles (12.1% battery electric + 9.4% plug-in hybrids), while hybrids account for 22.6% of total car sales*" (Acea, 2023).

Moving on the purpose of reducing CO_2 emissions, the European Commission Executive Vice President Frans Timmermans declared that "*the direction of travel is clear: in 2035, new cars and vans must have zero emissions*" and that "*the new rules on CO_2 emissions from cars and vans are a key part of the European Green Deal and will be a big contribution to our target of being climate neutral by 2050*". Moreover, the plan also expects that, by 2030, new vans' average emissions decrease by 50%, and the ones of new cars by 55% compared to 2021.
However, there are some European countries that do not agree with this plan. For example, Germany asked for a permission to sell vehicles run on e-fuels (that utilize the captured CO_2 emissions). Italy, Romania, and Bulgaria abstained from the vote and Poland vote against the new law (Hernandez, 2023).

Additionally, the US is moving in this direction. In 2021, President Biden signed an executive order stating that the target for 2030 is that half of all new cars and light trucks sold in the US must be zero emissions vehicles. In addition, some states such as California, Massachusetts, New Jersey, New York, Oregon, and Washington have announced that the sale of new gas-powered vehicles will no longer be allowed starting from 2035.
However, the transition to zero emissions vehicles will be significantly difficult, due to different reasons: the elevated cost of electric cars, the lack of an adequate charging infrastructure, and China's dominance of the battery supply chain (Hernandez, 2023).

EU intends to complement the target of CO_2 emissions set for cars and vans by 2035 with other measures, among which: a new emissions trading system (ETS) for road transport and buildings, an increasing share of renewable transport fuels, the removal of tax advantages for fossil fuels, and a revision of the alternative fuels infrastructure legislation to expand capacity.

Moreover, European Parliament is working for renewing measures regarding planes and ships, because both maritime transport and aviation need to be more eco-friendly, considering that even if their emissions are a low percentage, they are constantly increasing (European Parliament, 2023).

More impactful decisions have been taken from different cities around the world with the common goal of becoming car-free cities as soon as possible. Some examples:

- *Madrid, Spain:* starting from November 2018, gas and diesel vehicles that were not registered to residentials were prohibited. Moreover, Madrid is taking part in an initiative that aims at eliminating completely diesel vehicles by 2025.

- *Paris, France:* urban traffic is still not fully eliminated, but there are some specific days where it is not allowed to circulate by car, to limit the negative impact on the environment.

- *Oslo, Norway:* starting from 2019, there are no more parking spots in the city (except for some special needs), to encourage people to move by bicycle or walking. The target is to become a zero emissions city by 2030.

- *Hamburg, Germany:* this city is restructuring some streets to make them more suitable for bikers and walkers. The purpose is to offer green routes for 40% of the territory by 2035 (Scambieuropei, 2019).

2.4 Vehicles size, vehicles power, and the role of technology

It has been stated that, over time, pickup truck production increased worldwide (especially in America), but why would people choose a pickup truck rather than a car?
Nowadays there are plenty of typologies of available vehicles, and before deciding to buy one, a potential buyer usually considers different variables, such as: price, size, fuel economy and level of emissions, seat number, handling sensations, place where you live, family needs, reputation of the brands, and so on (Car Brand Names, 2022).

Even if trucks are expensive and there are not so many offers from producers (because there is a smaller number of manufacturers and consequently less competition), taxes are high, and their size is not suitable for driving in congested city traffic, there are many reasons why some people prefer them to cars.

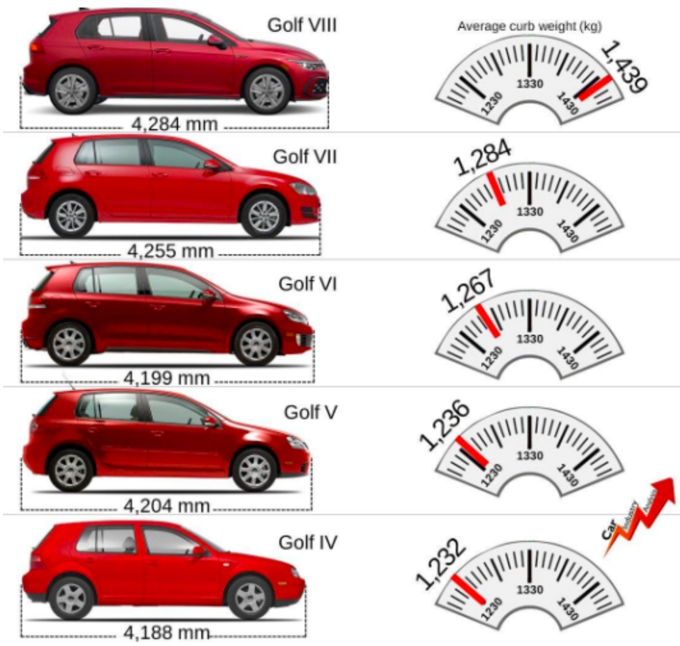
One reason is that they have powerful powertrains, useful for those who need a torque for towing, but also for those who love the sound of such an engine. Moreover, a truck differs for its off-road abilities, indeed it is suitable for users that have the necessity to experience off-road driving, thanks to some characteristics such as all-wheel drive system, high ground clearance, and durable suspensions (difficult to find in common cars). Another important distinctive aspect is the cargo bed, which, depending on the model, can transport up to 7,000 lbs of load. Finally, people that are not interested in load capacity, powertrains or off-road driving could choose a truck as well, only for its "brutal image" (Car Brand Names, 2022).

As in the first paragraphs data demonstrated, vehicles are getting bigger (size, weight, footprint). This trend is currently holding, and this is due to different reasons such as regulations, customers' requirements, and tech features that guarantee safety of passengers. To keep being competitive, auto makers must adapt to the customer demand, and all the requested features always need more space. Some safety standards are required by the government, others are required by users: the result is the augmented size of the vehicle. Every new car model is therefore bigger than its previous one (Okula, 2020). Consequently, increased size means increased weight and footprint, whose completed data are gathered in the Appendix.

Carmakers need to update the vehicles they offer or substitute them because of safety and environmental reasons (they must comply with some specific normative), but also for reasons that are not related to normative, such as: sales performance, market surveys and potential customers' preferences, scale economies, competitors, and highly influential entities (Munoz, 2023).

To clarify ideas, let us consider two popular cars as examples of vehicle evolution over time. Volkswagen Golf, for instance, has not extremely augmented its length in 5 generations (+96 mm, Golf IV was 4,188 mm, and Golf VIII 4,284 mm) but its weight went from 1,232 kg (2,716 lsb) in Golf IV to 1,439 kg (3,172 lbs) in Golf VIII, an increase of 207 kg (about 456 lbs) (Munoz, 2023).

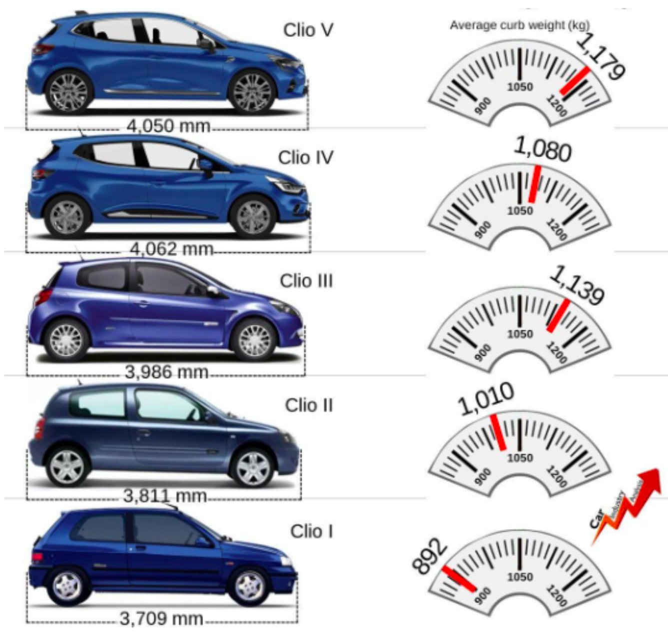
Figure 2.14: Evolution of Volkswagen Golf



Source: Munoz, 2023.

On the other hand, the Renault Clio had a more significant increase in length. Clio I was 3,709 mm, while after 5 generations, Clio V became 4,050 mm (+ 341 mm). Regarding its weight, it went from 892 kg (1,966 lbs) to 1,179 kg (2,599 lbs), an increase of 287 kg (almost 633 lbs) (Munoz, 2023).

Figure 2.15: Evolution of Renault Clio



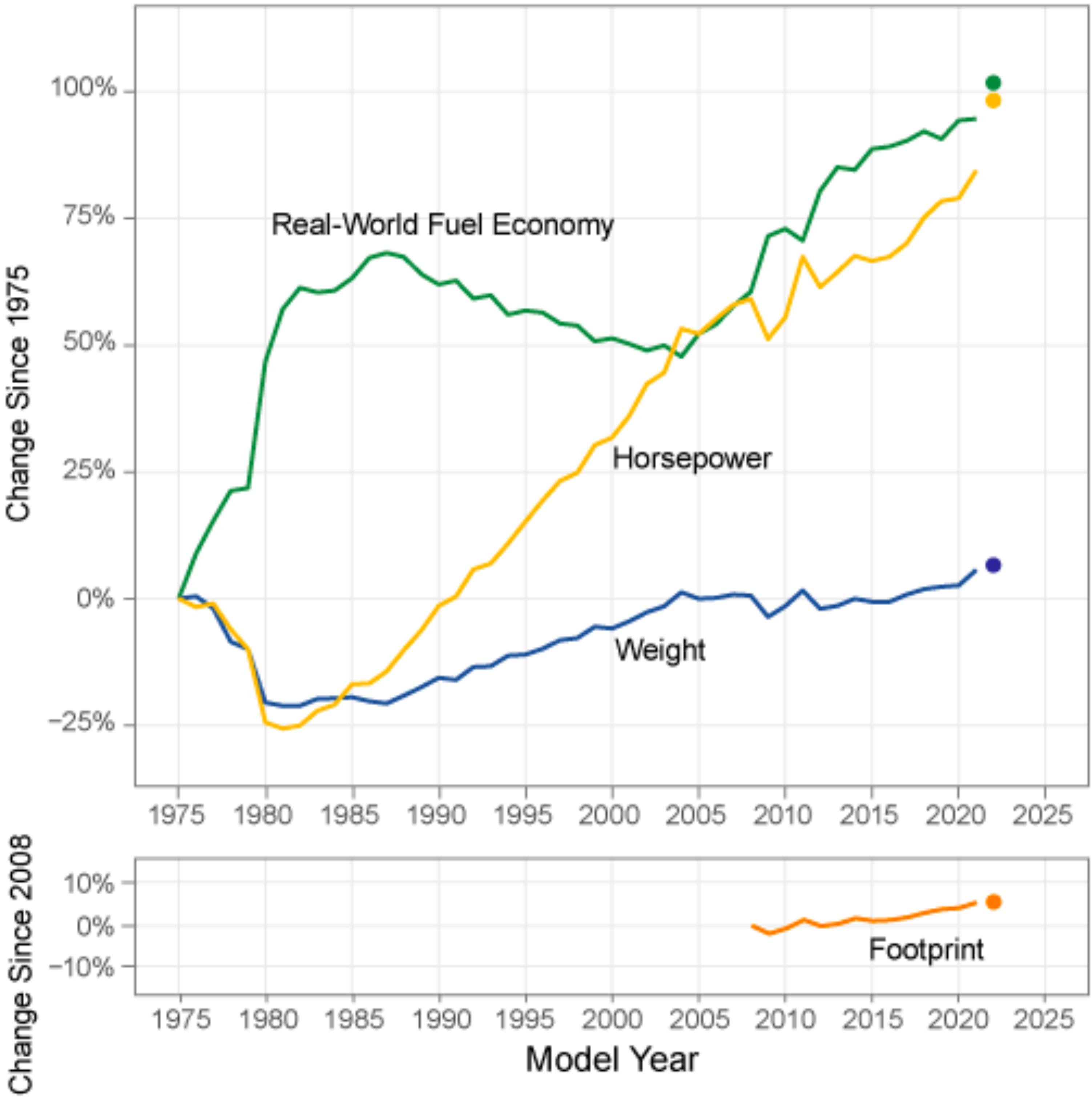
Source: Munoz, 2023.

Moving on vehicle power, it has been already stated that it is increased over time. Indeed, at the beginning people used to see a car as a mere means of transport, whereas nowadays there are users that are passionate about cars and have the desire to own a more performant vehicle.

However, the power of a vehicle should be related with its weight to be assessed. For example, the HP of a vehicle could be seen high for a small car, but the same number could be the minimum to make a SUV move.
All else being equal, a major weight and horsepower result in lower fuel economy and in higher CO_2 emissions (US Environmental Protection Agency, 2022).

The following figure shows the change in percentage of fuel economy, horsepower, weight, and footprint from 1975 to today.

Figure 2.16: Percent Change based on 1975 values in Real-World Fuel Economy, Horsepower, Weight, and Footprint based on 2008 values.



Source: US Environmental Protection Agency, 2022

As the figure 2.16 shows, 2004 has been a turning point. Indeed, during the two prior decades, because of vehicle size and content increase due to the technology innovation and market trends, vehicle power and weight increased, and therefore, there has been a constant fuel economy decrease together with an increase of CO_2 emissions. But after 2004 (which is recognized as the model year), the connection of market trends with technology innovation has allowed to reverse course: average new vehicle horsepower increased by 20%, weight by 4%, fuel economy by 32%, and, since 2008 (when EPA started recording data), footprint by 5%.
It is interesting to highlight that fuel economy improved in every type of vehicle, but because of the users' shift towards less efficient vehicles, some benefits deriving from the new technologies have been offset (US Environmental Protection Agency, 2022).

So far it has been stated that in general vehicles increased their size and weight over time for various reasons. Technology is for sure the main player that allowed cars to become safer and more attractive for clients.

Safety is without doubt the main reason for vehicle size increase. Indeed, nowadays new vehicles must pass various safety tests to be allowed to circulate, and consequently they need sensors, wiring, and airbags, and with a particular well-studied deformation, they need to resist frontal, lateral, passive, and active impacts (for drivers but also for cyclists and pedestrians). All these elements that automakers have to integrate contribute to the continuously increasing structure of vehicles (Rocchi, 2023).

Another important aspect that plays a significant role is design. In the last years, to satisfy the need to appear more aggressive and sportier, wheels of mostly all vehicle models have been increasing in size. The majority presents large alloy wheels (larger than in the past) with tall and indispensable wide tires (width and height of wheels must increase proportionately). If tires and wheel arches increase, car trucks become consequently larger.
The choice of an automaker of widening vehicles models is almost always a response to a competitor. A challenge of a courageous carmaker would be to disrupt this trend and try to launch a new model without widening it, or even trying to reduce the width (Rocchi, 2023).

Soundproofing is another key element to be considered. The common desire is to produce quieter vehicles, and to satisfy it and result in less noise polluting, vehicles must offer more "stuffed" passenger compartments. Increase in size, especially in width, requires a specific study for many aspects (dashboard, crash structure, wheels, tires, suspension arms, etc.), and has an impact on the prices that buyers will pay (Rocchi, 2023).

We are in front of a paradox, if considering that, to reduce CO_2 emissions, vehicles should be lighter, more compact, and more agile. Moreover, electric vehicles could perform worse if they have a huge mass to move.
Another problem is related to vehicle weight. According to EuroNCAP (European New Car Assessment Programme), the fact that vehicles are always getting heavier could be dangerous, because a heavier car requires more power to be stopped. Therefore, in case of an accident, the bigger the weight, the major the risks for people of potential other vehicles involved. Consequently, EuroNCAP recommends adopting appropriate crash-absorption facilities together with effective driver assistance systems, with the aim to prevent possible adverse situations (Rocchi, 2023).

2.5 Autonomous driving and interconnections

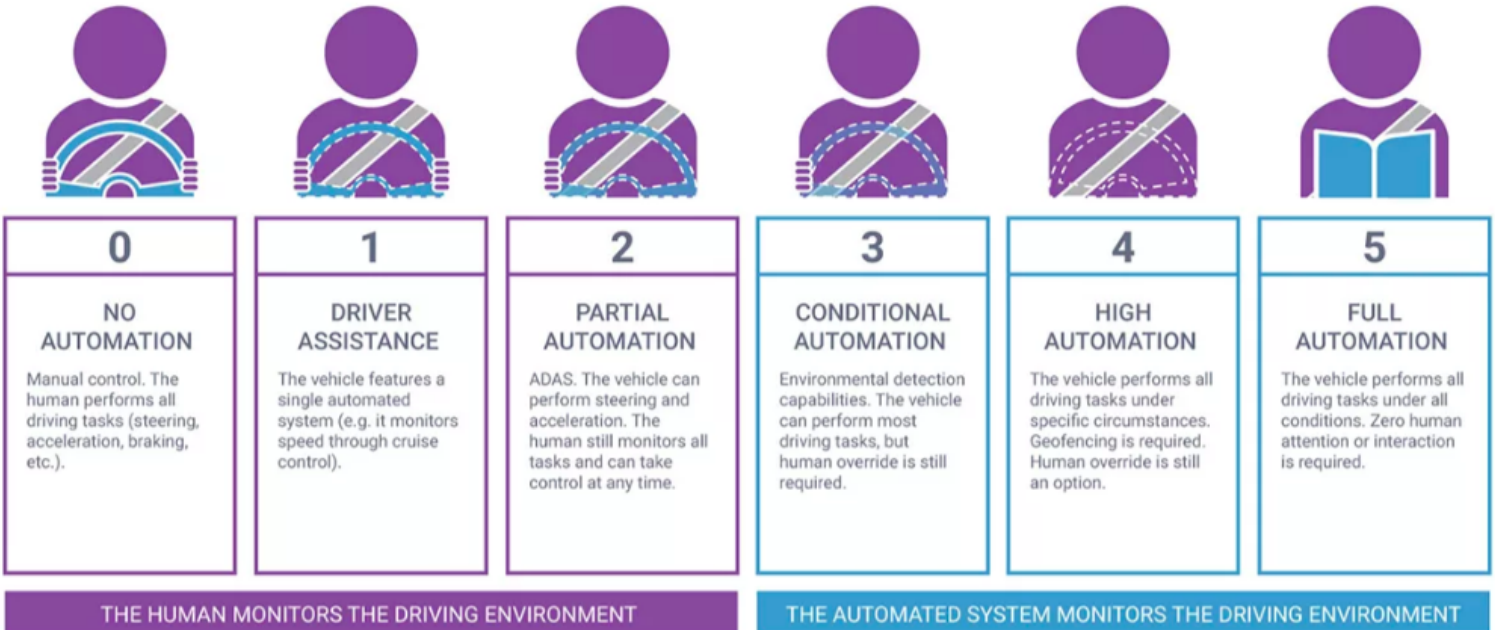
Technology and Artificial Intelligence have for sure the biggest impact on vehicle evolution: a car is no more only an object to own, but also a service to use. Indeed, nowadays if you buy a new car, you do not receive a pure means of transport, but also a computer and a telephone integrated on it. The software installed in vehicles permits them to be always more connected, smarter, and safer. For example, it is common to have a monitor that shows information such as speed, maps, traffic signs, and that works as navigator, a video camera as assistant for parking, 3G and 4G connection. Briefly, technology helps drivers to keep concentrating while driving by offering some services that improve everybody's safety. The final goal for the future is the completed autonomous driving (Abstract, 2019).

According to Synopsys, "*an autonomous car is a vehicle capable of sensing its environment and operating without human involvement. A human passenger is not required to take control of the vehicle at any time, nor is a human passenger required to be present in the vehicle at all. An autonomous car can go anywhere a traditional car goes and do everything that an experienced human driver does.*"

The U.S. Department of Transportation adopts 6 levels of driving automation designed by the Society of Automotive Engineers (SAE), where the Level 0 is fully manual and the Level 5 is fully autonomous (Synopsys, n.d.).

The levels are described in the figure below.

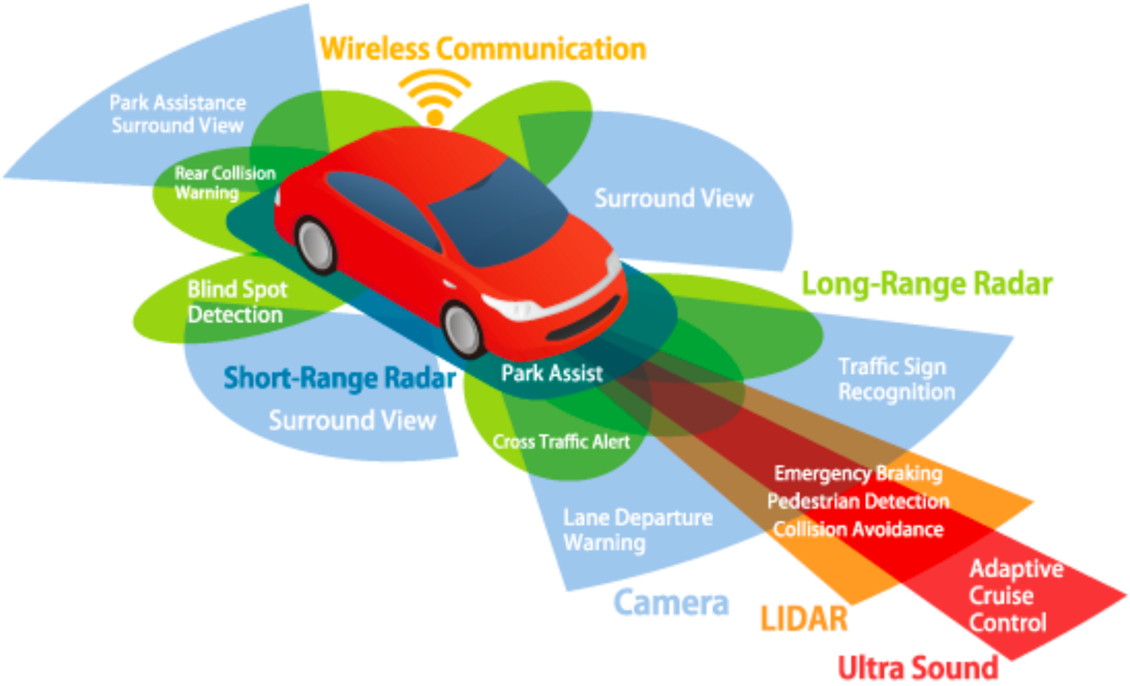
Figure 2.17: Levels of driving automation



Source: Synopsys, n.d..

Autonomous cars work thanks to different highly technological elements: sensors, actuators, complex algorithms, machine learning systems, and powerful processors to execute software. Sensors situated in various parts of the vehicle allow it to create a map of the surrounding, and cameras recognize traffic lights, read road signs, look at pedestrians and other vehicles that circulate (Synopsys, n.d.).

Figure 2.18: Self-driving car technology



Source: Landmark Dividend, n.d..

The figure above shows how a driverless vehicle works. In addition to all the technologies it employs, it is important to highlight that 5G networks present on the vehicles will allow autonomous cars to connect and communicate with each other (V2V). If a car detects a danger on the road, the information will be passed to the vehicle behind that will adjust its route.
Moreover, a vehicle will be able to communicate with infrastructure (V2I). For example, after having set in the car software the route a person is willing to take, information regarding parking spaces available would be constantly transmitted to vehicles, enabling them to know exactly where to park and avoiding them to waste time fighting for parking spaces. Finally, an autonomous vehicle will communicate with pedestrians (V2P). Communication with other vehicles and infrastructure is important, but with pedestrians it is extremely important. The 5G network will allow users to locate each pedestrian by recognizing their smartphones or other devices (Landmark Dividend, n.d.).

It is clearly a complex vehicle which needs several studies and tests before becoming available to the public. Fully autonomous vehicles are still not available to the market, because of the existence of some challenges, for example:

- Lidar and radar: it is still not clear whether lidar (light detection and ranging) signals of multiple cars would interfere with one another.
- Weather conditions: in case of heavy precipitation or other phenomena such as snow that covers the road signs, how will the system work?
- Traffic conditions and laws: how autonomous cars will behave in bumper-to-bumper traffic remains a question and a specific regulation needs to be created.
- State vs. Federal regulation: if different states have different norms, it is to be clarified if borders can be crossed with an autonomous car.
- Accident liability: it is to be defined who will be liable for accidents, whether the human passenger or the manufacturer.
- Artificial vs emotional intelligence: a still open question is whether the autonomous cars will have the same life-saving instincts as human drivers to establish connections with other vehicles drivers and pedestrians (Synopsys, n.d.).

On the other hand, autonomous cars could also bring positive consequences. First, elderly and physically disabled people could become independent in terms of driving. Secondly, they could extremely cut CO_2 emissions.
If the 3 revolutionary trends of automotive (vehicle automation, vehicle electrification, and ridesharing) were adopted, by 2050 the benefits could be the following: traffic congestion reduction; decrease in transportation costs (vehicles, fuel, infrastructure); improvement in walkability and livability of cities; release of parking lots for school, parks, etc.; urban CO_2 emissions reduction by 80% worldwide (Synopsys, n.d.).

So far it has been stated that one of the main current global priorities is improving road safety. Safety on the roads has improved compared to the past, but one important ongoing challenge is still to make the whole transportation safer.

Surely, autonomous driving and interconnection between vehicles are a potential solution to improve road safety. However, although today many vehicles already own some technological advanced supports for driving, there are no harmonized regulations, at European level, that assess the safety of automated driving functions during vehicle operation. Having such a regulation and assessment could be helpful for users to make them more confident and less reluctant in relying on modern technologies (Technische Universität Dresden, 2023).

With this purpose, some experts are working on projects to develop some foundations for testing automated driving functions. One attempt comes from the SivaS Research Project (*Sicherheit des Vernetzen und Automatisierten Straßenverkehrs*, that is Safety of Networked and Automated Road Traffic), which is a new German project launched on 1 April 2023 by the Technische Universität Dresden, in Saxony (Technische Universität Dresden, 2023).

Prof. Günther Prokop, Head of the Chair of Automobile Engineering at TU Dresden, states that the criteria to assess the quality and safety of automated driving systems are necessary and highly demanded by stakeholders in industry, politics, and society. To develop them, it is important to have a complete knowledge of driving behaviors, interactions between road users and the creation of critical traffic situations regarding today's road traffic.
The aim of the project is "*to create technical and methodological foundations for the safe operation of automated and connected vehicles and to develop methods for evaluating and validating the quality of the driving function during operation with regard to road safety and environmental compatibility*" (Technische Universität Dresden, 2023).

This innovative project involves a total volume of 1.8 million euros (80 percent funded by the Federal Ministry for Digital and Transport as part of the mFUND innovation initiative) and four participants. TU Dresden is represented by Prof. Günther Prokop together with Prof. Regine Gerike (Head of the Chair of Integrated Transport Planning and Traffic Engineering), while the other partners are FSD Fahrzeugsystemdaten GmbH Dresden/Radeberg, and the city of Hoyerswerda (Germany) (Technische Universität Dresden, 2023).

The project is supposed to last until December 2024, and it is part of the federal government's plans to increase the use of automated vehicles in road traffic.
The outcomes of this project will be the "*basis for the evaluation of the Autonomous Driving Act and the Ordinance on the Approval and Operation of Motor Vehicles with Autonomous Driving Functions in the Specified Operating Range (AFGBV), as well as for the revision of the Framework Regulation 2018/858/EU for the approval of automated vehicles in large-scale production",* affirmed the Chairman of the Technical Advisory Board at FSD, Jürgen Bönninger (Technische Universität Dresden, 2023).

This project is fundamental because it creates the basis to respond to the current problems, that have been mentioned above in the paragraph, that still hinder the advent of fully autonomous vehicle circulation.

2.6 New business models in automotive industry: the case of Toyota

If in the past the common praxis was to buy a car (better if new), today buying a car is no more accessible for many people. Indeed, its costs are exponentially increased for many reasons, such as electrification, and the issues related to raw materials derived from the Covid-19 pandemics and the more recent war in Ukraine.
Automakers must therefore respond to the need of continuing to make accessible cars, by modifying their offerings, in particular the way users can obtain a vehicle, and make their business models more adequate to the current situation.
We are living in an era where everything is by subscription: smartphones, TVs, energy, and now with KINTO by Toyota and Lexus, vehicles have officially become part of the "subscription economy". KINTO was born to respond to the current market demand, where many people cannot afford to buy a car, and therefore the rental service seems to be a solution (Lago, 2022).

KINTO is a mobility platform created by Toyota Group, whose name derives from the Japanese word *Kintoun* ("flying cloud"). With this idea, Toyota Group tries to remain competitive in its industry, even if the business model and in particular the way people use cars, and the role of vehicles are changing.
This platform provides 5 services: *One, Flex, Share, Join and Go*, with differences based on the type of auto utilization.

- *KINTO One*: it is a long-term rental service (12-72 months), with a down payment and an all-inclusive monthly fee. Here, users can choose among 100% hybrid cars (full hybrid or plug in).

- *KINTO Flex*: it represents the long-term rental evolution, that is the medium-term rental service. A user can take a car from 1 to 12 months with a flexible subscription, no advance payments, and an all-inclusive monthly fee, with the possibility to terminate the subscription every moment without fines.

- *KINTO Share*: it is the carsharing services via app, but with some differences with respect to some popular car sharing services such as Eni Enjoy. With KINTO Share, cars cannot be parked or collected everywhere, but only in dedicated spaces, such as airports or train stations, or at Toyota dealers. Therefore, this formula could be less flexible than other car sharing services, but it allows to keep a higher quality of vehicles and to exploit the platform to make use of vehicles for various reasons (from the "rent a car" to the courtesy car service to clients).

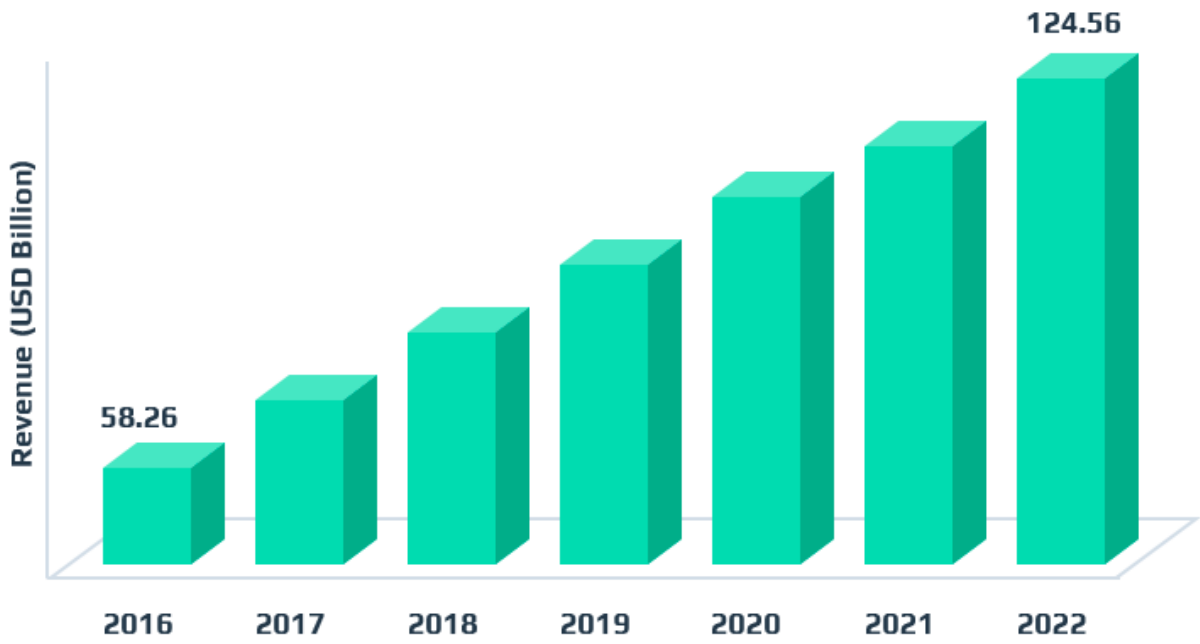
- *KINTO Join*: it is a carpooling software designed for companies that want to incentivize car sharing among colleagues in their commute. Companies that adopt it in their welfare opportunities can obtain a certification for being positively impactful for the environment, because contributing to promote CO_2 emissions reduction.

- *KINTO Go*: it promotes multimodal mobility, and it allows planning a journey by booking and buying tickets for public transport means, trains, taxis, and paid parking (Lago, 2022).

It is clearly an important evolution of the automotive industry, where companies transform themselves from constructors to mobility suppliers.
KINTO is one of the most structured realities in Italy, and the aims are in line with the current challenges of the world. Regarding this, Mauro Caruccio, CEO of Toyota Financial Services Italy, Chairman and CEO of KINTO Italy stated: "*KINTO was born with a distinctive value system and aims to be a Mobility Provider capable of meeting all mobility needs and generating benefits at all levels for the individual, who will be able to benefit from greater flexibility, available time, and incur lower costs for their travels; for the environment, thanks to the use of electrified motorizations; for communities, which will be able to enjoy more livable cities; and for the economic system, which will be able to use resources more efficiently*" (Lago, 2022).

From the chart below, it can be seen how revenue deriving from the car rental market increased over time.

Figure 2.19: Global car rental market, 2016-2022 (USD Billion)



Source: Intellias, 2023.

New business models offering various types of services in addition to the traditional car sale is necessary to capture the younger public. Indeed, young people with the desire to buy a personal car are decreasing for different reasons.

Buying a car is extremely expensive (especially for a young person), and obtaining a loan is difficult: a potential user could choose to rent a car. Moreover, if someone needs to frequent the city center, a scooter is a valid alternative because it eliminates traffic and parking issues.

In addition, young people generally prefer to invest money for example in travels, and low-cost flights and trains permit them to travel a lot without owning a car.

Finally, autos were always desired because of their highly emotional content. Nowadays, because of traffic, issues related to road safety, and cars transformation, the concept of emotion is giving space to the concept of experience, that is safety. The common aim is for vehicles to circulate in regulated, low-risky, and automatically controlled speed limits infrastructures (Prosino, 2021).

In conclusion, over the last decades vehicles have improved in many features: efficiency, CO_2 emissions, design, and so on. But the pure sale of cars is no longer the main trend that is interesting in the automotive industry.

Environmental issues, together with the high costs of buying and owning a car, the willingness to come back to more livable cities, and the necessity to use resources more efficiently are challenging the traditional business model of automakers in favor of eco friendly vehicles (electric vehicles that need less assistance, which represents a current significant cost for drivers) with different options of accessing them (car rental, car sharing, etc.) (Abstract, 2019).

CHAPTER 3

Future scenarios

This final chapter has the purpose of discussing which scenarios could characterize the automotive sector in the future, considering the ongoing worldwide challenges and the current trends. The discussion is carried out through the analysis of a survey, whose aim is to understand if the choices of car manufacturers and other institutions to respond to environmental issues and other global challenges are supported by people.

3.1 Objectives and structure of the survey

This chapter is based on a survey developed with the goal to understand whether the evolutions experienced by the automotive sector during the years, described and analyzed in the previous chapters, are in line with the "sentiment" of people.
Although open to anyone, the survey is focused particularly in the age category 18-30, the generation that should be, in theory, more likely to be sensitive to the currently sustainability challenges, such as the air pollution, the climate change, and so on, and that have an impact on the future of the planet.
For example, the most important questions of this survey are the ones related to discovering if people worry about the CO_2 emissions and the pollution caused by vehicles, their sensitivity regarding the alternative fuel types, their idea about the limitation of cars circulation, and their thoughts about autonomous driving as a potential solution to increase road safety.

After having individuated the objectives, it has been defined the target to administer the questionnaire to, that is the general public. About that, some questions regarding the age, the place of living, and the availability of a personal car are the most important to consider when analyzing the survey.

The survey has been created with the application Google Forms, it has been spread online through its link during the period from 30th August 2023 to 6th September 2023, and it has been completed anonymously.
Answers to the survey have been 109. One answer will be excluded from the analysis, since the user declared to be included in the age range "17 or less", while the questionnaire was designed for people having a driving license.

The survey was composed of 33 questions in total, and it was divided in two parts.
The first section aims at investigating the opinions of users with respect to the central topics of the survey and their attitudes to car use, the second part has been created with mainly socio-demographic questions to frame the user's personal situation.

Briefly, the first section asks for the opinions of the person responding to the survey.
In particular, the first 8 questions were related to the level of importance that a user gives to specific features of a vehicle (values are on a scale from 1 to 9, where 1 is the lowest level of importance and 9 is the highest one). In this context, questions were:

- When buying a car, how much importance do you give to the vehicle CO_2 emissions?
- When buying a car, how much importance do you give to the vehicle efficiency?
- When buying a car, how much importance do you give to the vehicle type of fuel?
- When buying a car, how much importance do you give to the vehicle power?
- When buying a car, how much importance do you give to the vehicle size and weight?
- When buying a car, how much importance do you give to the technological features of the vehicle?
- When buying a car, how much importance do you give to the vehicle quality-price ratio?
- When buying a car, how much importance do you give to the possible status symbol that gives you that vehicle?

The vehicle features included in the above questions reflect the features analyzed in the Chapter 2 of this elaborate. Moreover, three further attributes have been added, the car technological aspects, the quality-price ratio, and the status symbol, because even if not contemplated in the analysis of data in the Chapter 2, they have been reputed important to understand in a more complete manner which aspects a person give importance to when choosing to buy a car.

Further 14 questions asked to express the level of agreement to specific statements, with the purpose of understanding how much users worry about the sustainability and how much they are sensitive to the consequences caused by car use.
The level of agreement has been set with a likert scale composed of the following possibilities: Strongly disagree, Disagree, Neutral, Agree, Strongly agree.
The statements in this context were the following:

- Currently, owning a car is a priority in my life.
- If I think about my future 20 years from now, owning a car would be a priority in my life.
- In my opinion, the place where I live would be better if cars were banned from the city center.
- In my future 20 years from now, I would like to live in a place where cars were not needed in order to live my life normally.
- I prefer a city center without cars circulation.
- If I could, I'd never use the car.
- Vehicles are the main source of air pollution, therefore I try to use my car the least possible.
- I try to take the train, the bus/tram, or the metro whenever I am able to.
- I feel safer when I travel by train rather than by car.
- I feel safer when I travel with a big car rather than a small car.
- Nowadays I would choose an electric or hybrid vehicle rather than a traditional fueled car.
- I think that prohibiting cars from city centers is a right choice.
- I think that autonomous vehicles would be an important solution to improve road safety.
- I would feel safe when traveling inside of a driverless car.

Finally, 4 other questions completed the first part. These questions asked for a choice among possible answers, in particular:

- In your opinion, should the use of cars be limited?
    - Yes
    - No
- If yes, in your opinion, which is the main reason why the use of cars should be limited?
    - Pollution
    - Road accidents

    - Better quality of life in car-free centers
    - Traffic congestion
    - Other
- If you could choose between travelling by train or by car for long distances, what would you choose?
    - Train
    - Car
    - Other
- If you chose car, why?
    - Time flexibility
    - Comfort
    - Cost
    - Other

The second part of the survey regarded more personal questions about the person. In particular, 7 final questions were asked to have a better image of who was responding, giving importance especially to the age and the number of inhabitants of the living town, and knowing their habits concerning the use of the car.

The questions were the following:

- Which of the following categories includes your age?
    - 17 or less
    - 18-30
    - 31-40
    - 41 or more
- Where do you live?
    - A very big town (>1,000,000 inh.)
    - A big town (500,000 – 1,000,000 inh.)
    - A medium town (200,000 – 500,000 inh.)
    - A small town (50,000 – 200,000 inh.)
    - A very small town (<50,000 inh.)
- Do you own (or do you have the availability) of a personal car?
    - Yes
    - No
- Is the car indispensable to move in the place where you live?

    - Yes
    - No
- How do you usually reach the place where you work/study?
    - Car
    - Bike
    - Train
    - Bus/tram/metro
    - Walking
    - Other
- Usually, how often do you drive a car?
    - Everyday
    - A few days a week
    - A few days a month
    - A few days a year
    - Never
- Do you utilize mostly your own car or other cars?
    - My own car
    - A family car
    - Car sharing
    - None of the above.

All the questions of the survey were mandatory, except for two questions that were asked to be completed only if, in the previous question, was given a specific answer.

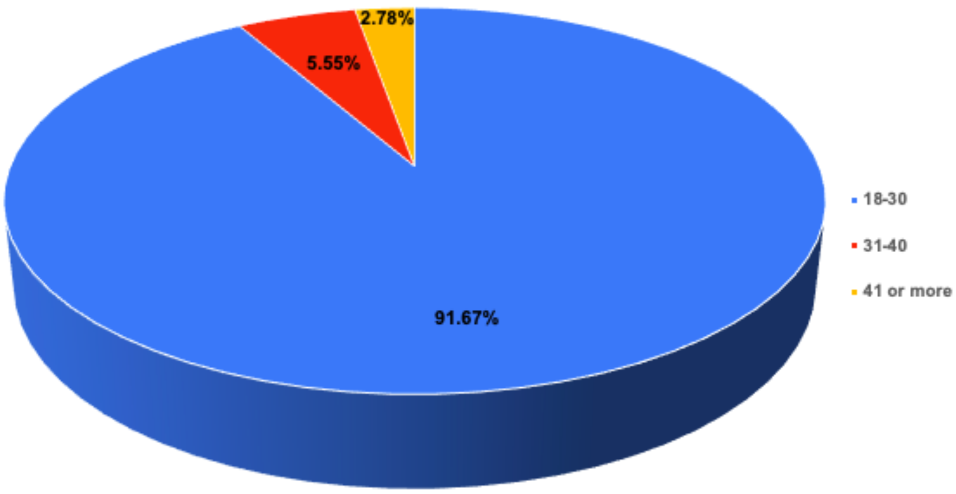
The construction of the survey has been inspired by the themes that have been discussed in the previous chapters of this elaborate. Hence, the questions and the statements have been chosen considering the trends of the automotive sector already described. The evolution of vehicle features, the electric vehicle, autonomous driving, the possibility to ban cars from city centers are the main topics on which the survey develops.
Moreover, understanding how much interest people have on environmental issues and how much effort they do for reducing impacts on the planet is a key point of this survey.

3.2 Sample description

As anticipated in the previous paragraphs, 109 users responded to the survey. However, from now only 108 surveys will be considered for the analysis, since one user's age does not guarantee to have the license to drive a car.

Let us see the age of the interviewees. In this case, age is important because it is fundamental to understand if the new generations have developed or are trying to develop a new way of living, more sustainable, and in line with the trends of the automotive sector.

Figure 3.1: Age categories of interviewees

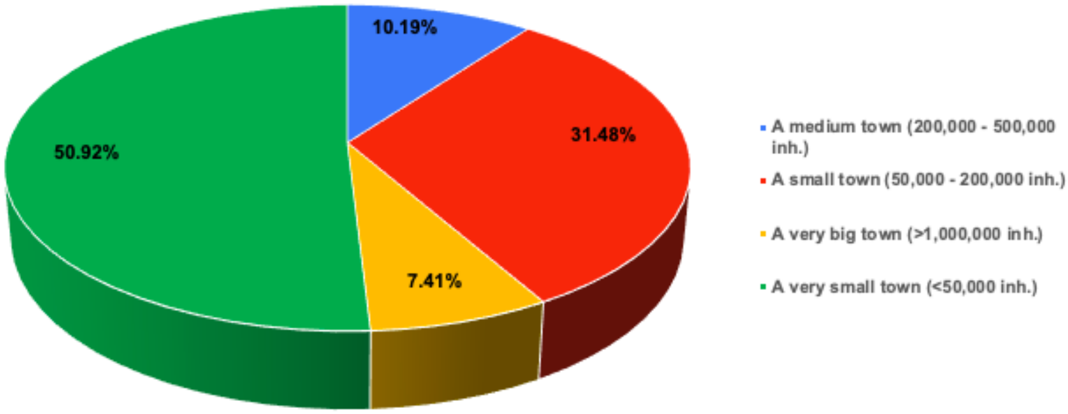


Source: own elaboration from survey data

As the above figure shows, the sample age was the following: 91.67% of people are included in the age category 18-30, 5.55% in the age category 31-40, and 2.78% of interviewees are older than 41.

The second important question to define the sample was the one regarding the living place. As the following figure shows, the majority of people interviewed (50.92%) live in very small cities with less than 50,000 inhabitants. 31.48% of interviewees live in a small town (50,000 – 200,000 inhabitants), 10.19% live in a medium town (200,000 – 500,000 inhabitants), and finally 7.41% live in a very big city with more than 1,000,000 inhabitants.

Figure 3.2: Size of the interviewees' cities, divided according to the number of inhabitants.



Source: own elaboration from survey data

In this survey, the place where a person lives most of the time is an important variable, because big and very big towns usually offer much more public transport solutions with respect to smaller towns or rural areas. Moreover, smaller towns usually lack some services, forcing their inhabitants to travel longer distances with respect to people living in bigger cities.

Other questions regarding the interviewees have produced the following outcomes:

- 86.11% owns a personal car (or has the availability of a personal car, for example a company car);
- 68.52% declared that a car is indispensable to move in their living place;
- 67.60% usually utilizes the car to reach the working/studying place, 9.26% utilizes the bus/tram/metro, 8.33% walks, 6.48% goes by bike, 3.70% takes the train, and the remaining 4.63% selected the option "Other";
- 66.67% drives a car every day, 16.67% drives a car a few days a week, 10.18% drives a car a few days a month, 2.78% drives a car a few days a year, and the remaining 3.70% never drives a car;
- 66.67% declared to own the car they drive, 29.63% drive a family car, 1 person (0.9%) declared to utilize the car sharing service, and the remaining 2.80% selected "None of the above".

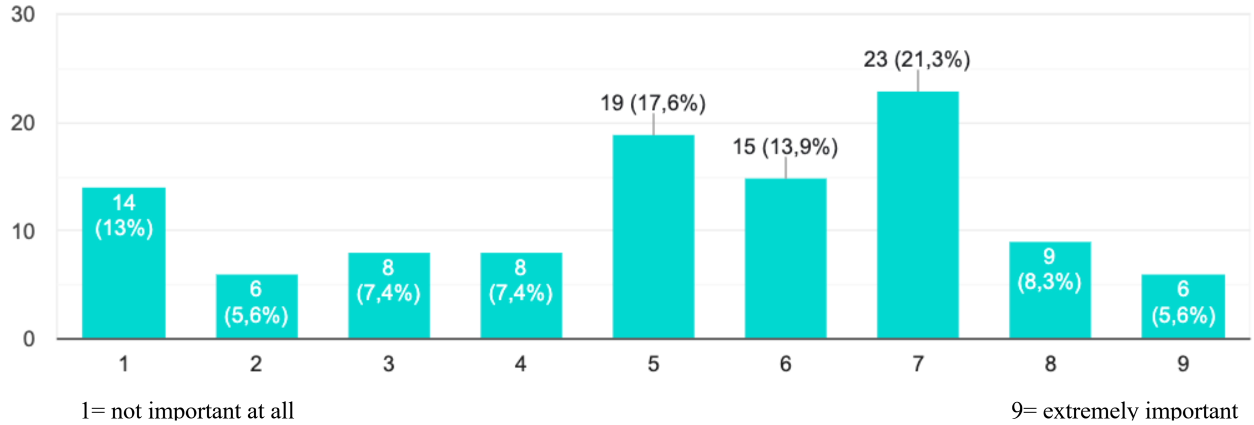
The above statements help to have an idea of the needs and habits that the sample of this survey has. Briefly, most of the people interviewed are in the age range 18-30, own or have the availability of a personal car, which is fundamental to move in their own town. The majority of interviewees utilizes the car as a means of transport to reach the place of work or study and they usually drive a car every day.
The result of the composition of the sample is given by the fact that the survey was spread mainly in Emilia-Romagna region (Italy), where small towns or very small towns are predominant. However, the survey also reached other regions and therefore the sample presents answers from people living in bigger cities as well.
In the next paragraphs the answers of the first section of the survey will be analyzed, trying to understand, subsequently, the interconnections among the answers, depending especially on the place where people live.

3.3 Descriptive analysis of the answers

In this paragraph, answers of the first section of the survey will be analyzed singularly.
First, let us see how much importance the interviewees give to various aspects of a vehicle when buying a car.

In the following charts, the results to the questions related to the level of importance that a person gives to different aspects of a vehicle when buying it are shown. On the vertical axis, values represent the number of interviewees that voted for a specific value, while on the horizontal axis the values represent the scale from 1 to 9 that a user could choose from.

Figure 3.3: Survey results to the question "*When buying a car, how much importance do you give to the vehicle CO_2 emissions*?"



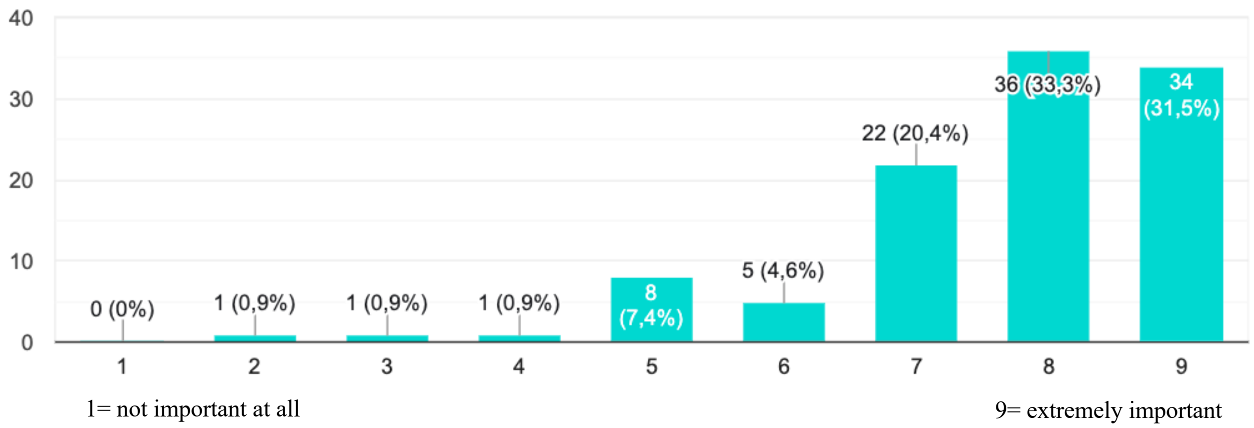
Source: own survey results.

As the chart above shows, only 5.6% demonstrated the maximum interest in the CO_2 emissions of a vehicle, choosing 9 as answer. The most popular values were 7 (21.30%) and 5 (17.60%). People choosing 7 probably care about CO_2 emissions, but this is not the main aspect they look at; people choosing 5, the middle value of the scale, are likely to be neutral to this feature.

It is interesting to highlight that about one out of three people chose 7 or more (the highest value), while 36 people (representing 33.40% of the total) chose a value from 1 to 4, showing low interest in this characteristic of the car. Moreover, 13% of the total declared to give no importance to this aspect, choosing 1 as answer.

Answers to this question were therefore heterogeneous.

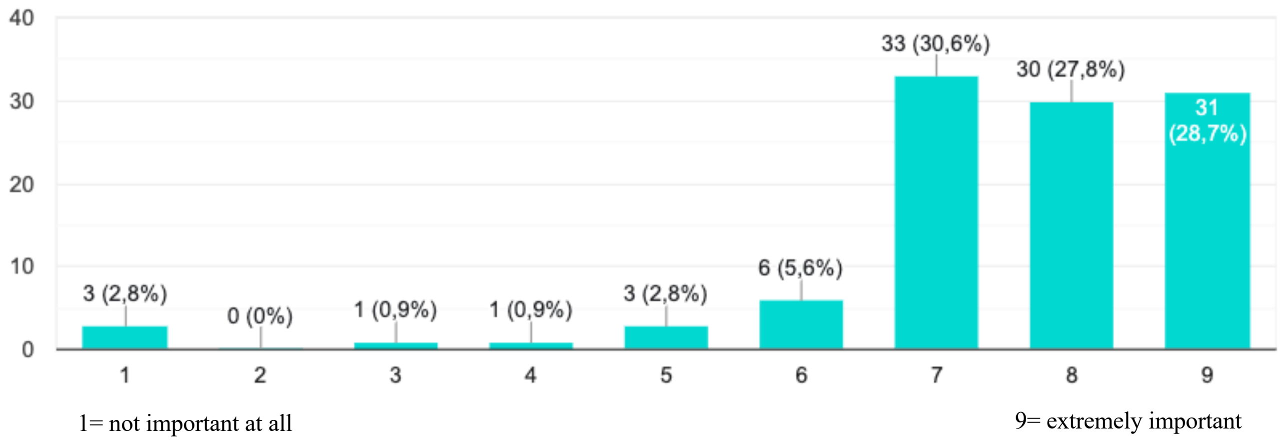
Figure 3.4: Survey results to the question "*When buying a car, how much importance do you give to the vehicle efficiency?*"



Source: own survey results.

The figure above shows that answers to this question were more concentrated to the last values of the scale, representing the highest levels of importance. In total, 64.80% of the interviewees chose 8 or 9 (33.30% chose 8 and 31.50% chose 9). 20.40% of people voted for value 7. A low percentage (7.40%) declared to be neutral, choosing value 5.
It is interesting to specify that efficiency means also less CO_2 emissions, but the perception of the question on this category is very different, since the percentage of respondents declaring 7 or more is much higher compared to the one of the previous question related to CO_2 emissions. In general, most people consider the vehicle efficiency a crucial aspect when buying a car.

Figure 3.5: Survey results to the question "*When buying a car, how much importance do you give to the vehicle type of fuel?*"

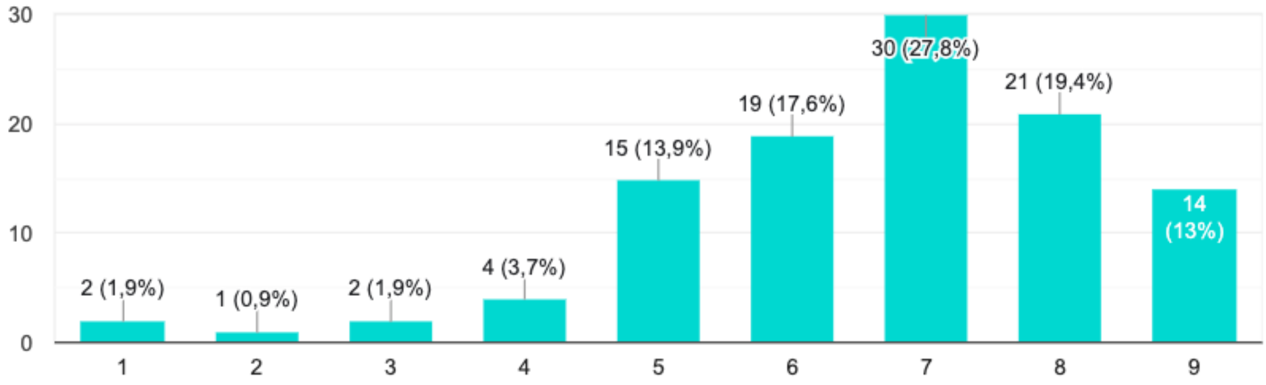


Source: own survey results.

As in the previous question, the answers reported from the above graph are more concentrated to the highest values of the scale. 30.60% voted 7, 27.80% voted 8, and 28.70% voted 9. There is a minority that do not consider the type of fuel of a vehicle important, but most people declared to be interested in this characteristic of the car.

Let us move on to the vehicle power and vehicle size and weight.

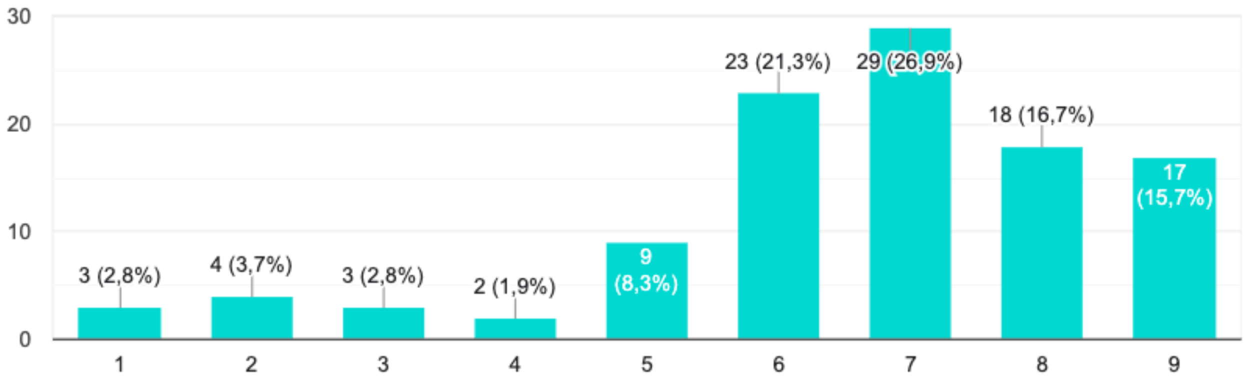
Figure 3.6: Survey results to the question "*When buying a car, how much importance do you give to the vehicle power?*"



1= not important at all 9= extremely important

Source: own survey results.

Figure 3.7: Survey results to the question "*When buying a car, how much importance do you give to the vehicle size and weight?"*



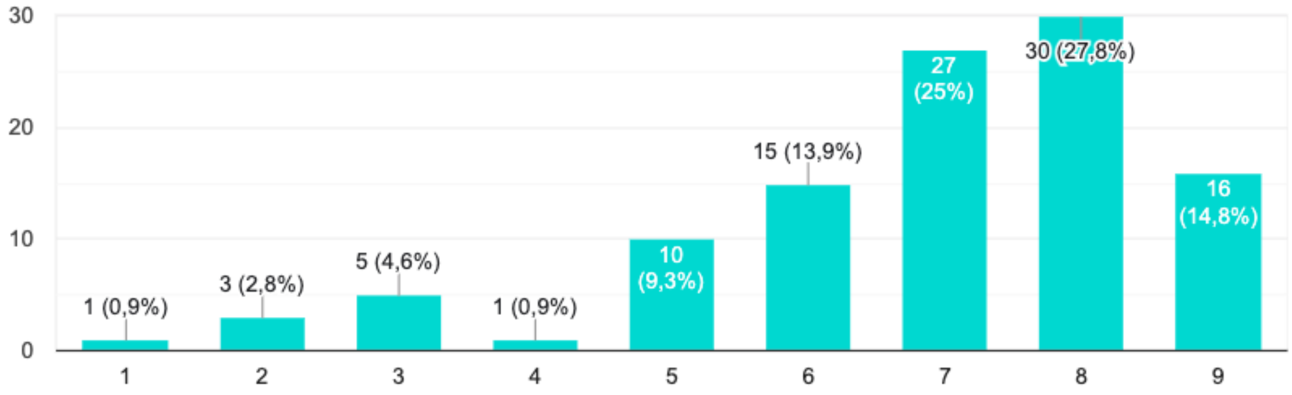
1= not important at all 9= extremely important

Source: own survey results.

Both these two questions show a similar path of the responses. 7 is the most popular answer, the value chosen by 27.80% of people for the vehicle power, and by the 26.90% of the people for the vehicle size and weight.

In general, there are some people that do not consider vehicle power, size, and weight a priority, but they are a minority. Many people, instead, do consider these car features, even if by attributing them to a different level of importance.

Figure 3.8: Survey results to the question "*When buying a car, how much importance do you give to the technological features of the vehicle?*"

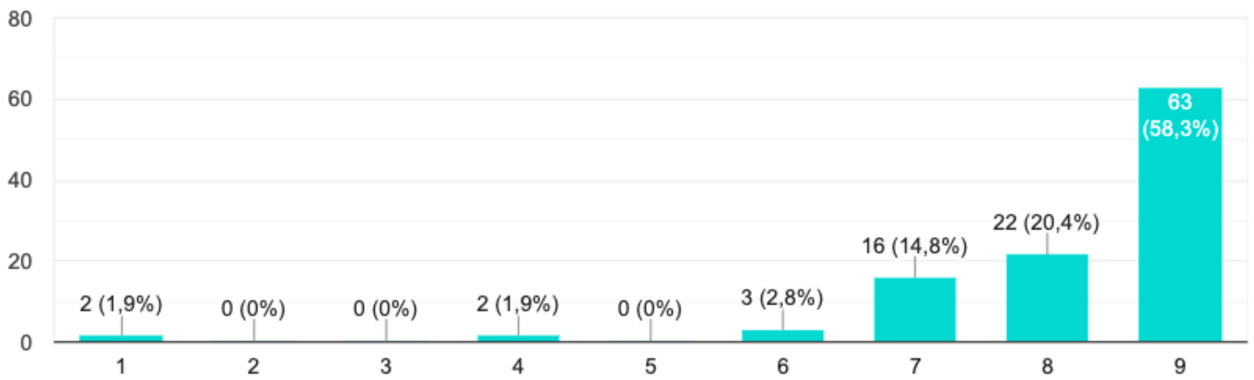


1= not important at all 9= extremely important

Source: own survey results.

As the above graph reports, generally the technology that characterizes a vehicle plays an important role. 27.80% of people voted 8, 25% voted 7 and 14.80% voted 9. Some technological features of vehicles are useful to improve passengers' safety, therefore many interviewees selected a high value to this question.

Figure 3.9: Survey results to the question "*When buying a car, how much importance do you give to the vehicle quality-price ratio?*"



1= not important at all 9= extremely important

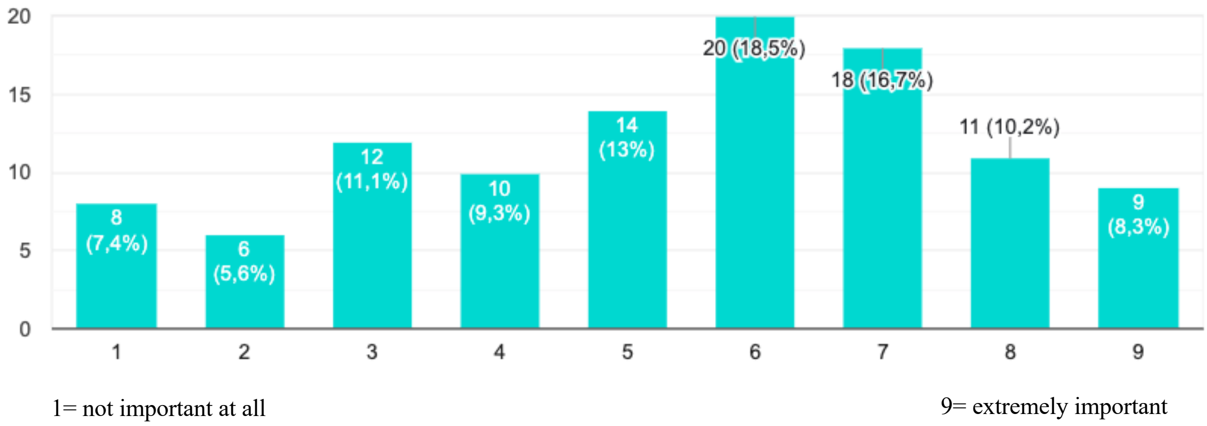
Source: own survey results.

The above figure shows that the question related to the quality-price ratio collected the most concentrated answer. Indeed, 58.30% of interviewees selected the highest level of importance, and very few people declared not to be interested in it.

Prices are increasing, and people look for the best opportunities that allow them to buy an affordable car, but at the same time a car that makes them feel safe.

The last question related to vehicle features was about the status symbol that a vehicle could attribute to the owner.

Figure 3.10: Survey results to the question "*When buying a car, how much importance do you give to the possible status symbol that gives you that vehicle?*"



Source: own survey results.

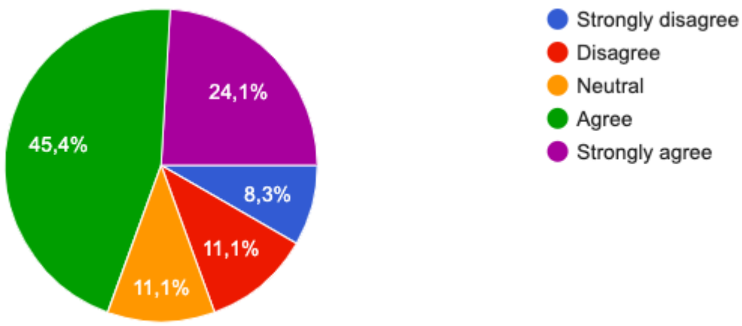
Answers to this question were the most various. The most popular value was 6, chosen by 18.50% of interviewees. 16.70% selected value 7, 13% selected value 5, and 11.10% selected value 3.

There is not a strong concentration of answers. However, the majority chose a value in the second half of the scale, that is the highest value. There are people that do not care about the status symbol deriving from a car, but generally, nowadays, people probably give importance to how they show in public and the image that their car could give them.

The second part of this paragraph will analyze some selected answers regarding the interviewees' opinions and habits concerning the use of vehicles. The selected answers are considered the most relevant for the survey final objectives.

First, let us see how many people owning a car is a priority.

Figure 3.11: Level of agreement with the statement "*Currently, owning a car is a priority in my life.*"



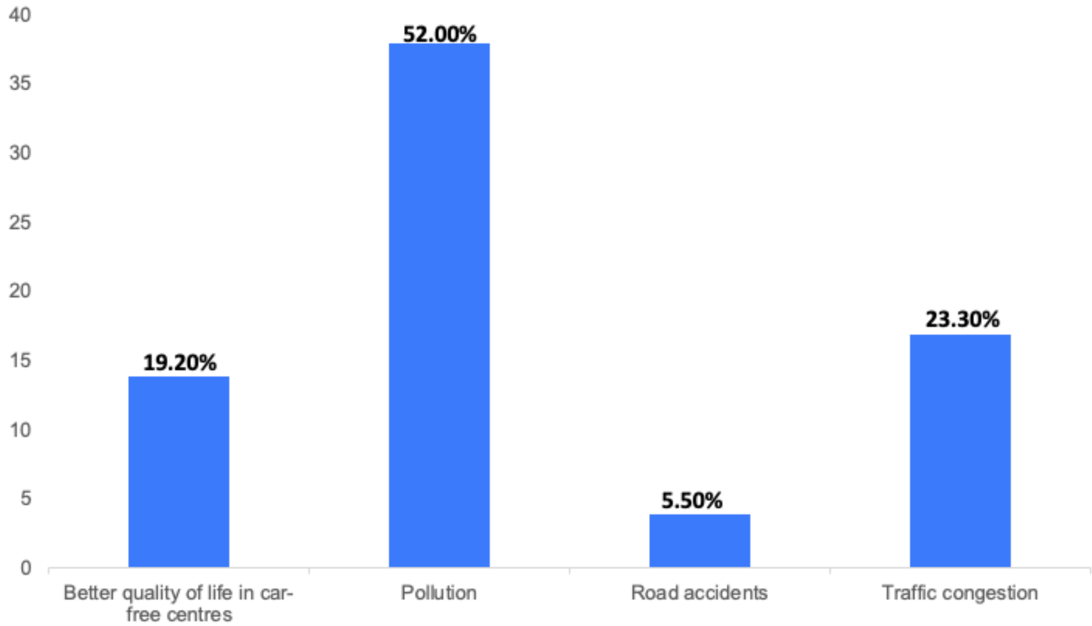
Source: own survey results.

From the results of this question, it can be stated that, for most people, owning a car is a priority in their lives. Indeed, 45.40% of people declared to agree and 24.10% declared to strongly agree with the statement regarding this fact.
If the same question is posed about the future ("If I think about my future 20 years from now, owning a car would be a priority in my life."), percentages increase: 51.90% declared to agree and 28.70% declared to strongly agree with the statement. Indeed, 11.10% of people disagree and 8.30% strongly disagree with the statement regarding the current situation, while 6.50% disagree and 2.80% strongly disagree with the statement regarding their future.
Summarizing, the great majority shared the content of the statement, but it is interesting to highlight that if thinking about the future (in this case in 20 years from now), people that share this idea increase.

Let us now see what people think about the limitation of cars circulation.
To the question "In your opinion, should the use of cars be limited?", 67.60% of interviewees expressed a positive answer and 32.40% responded negatively.
Only people who agreed to the fact that car use should be limited should have answered to the next question "If yes, in your opinion, which is the main reason why the use of cars should be limited?", that is 73 people. However, answers have been 81, and therefore the answers given by people that responded that they did not agree with cars circulation limitation have been excluded.

The following graph shows the main reasons why people, who think that cars should be limited, would impose limits to vehicle circulation.
The graph reports on the vertical axis the number of people who chose a specific reason, while the horizontal axis reports the different choices selected.

Figure 3.12: Answers to the question "*If yes, in your opinion, which is the main reason why the use of cars should be limited?*"

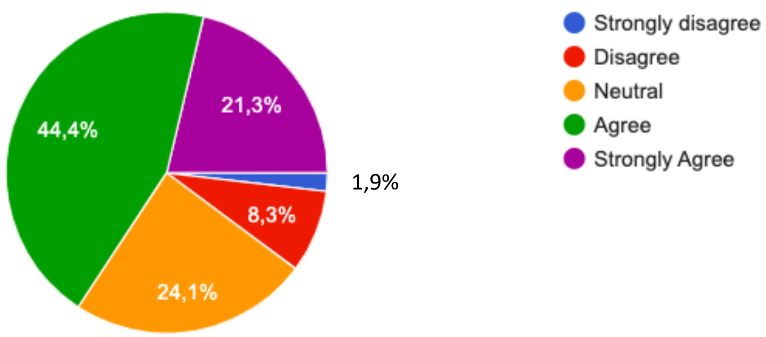


Source: own elaboration from survey data

Most people (52%) who agree with the statement concerning the limitation of car use, think that the main reason to reduce the use of cars is for environmental issues (pollution). The second main reason is related to traffic congestion problems (23.30%), 19.20% think that car-free centers offer a better quality of life, and the remaining 5.50% would limit the use of the car mainly for safety reasons (road accidents).

Another relevant statement is related to the opinion that people have concerning the city centers that do not allow cars to circulate.

Figure 3.13: Level of agreement with the statement "*I prefer a city center without cars circulation.*"

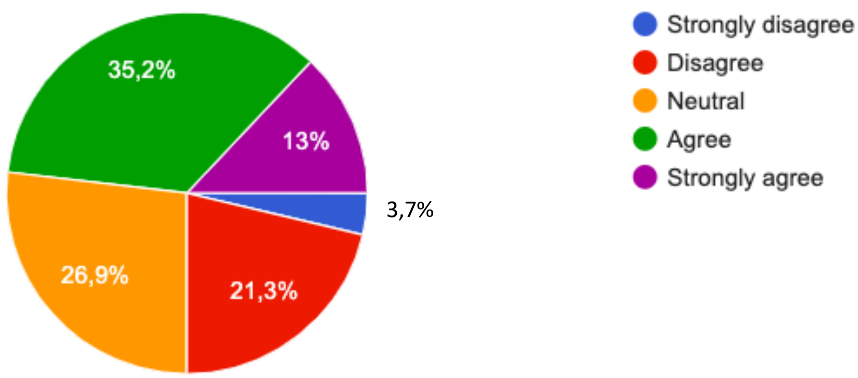


Source: own survey results.

As the above figure clearly shows, most people agree (44.40%) or strongly agree (21.30%) with the statement. But there are people who declared to be neutral (24.10%), to disagree (8.30%) or to strongly disagree (1.90%) with the statement. Anyway, the general idea is that people would prefer that cars did not circulate in the city centers. Indeed, 65.70% agree or strongly agree with the statement, against only 10.20% of people who disagree or strongly disagree.

A related statement affirms "In my future 20 years from now, I would like to live in a place where cars were not needed in order to live my life normally." This statement is important to know if, in the future, people would like to live normally without the need of a car.
Results are reported in the next graph.

Figure 3.14: Level of agreement with the statement "*In my future 20 years from now, I would like to live in a place where cars were not needed in order to live my life normally.*"



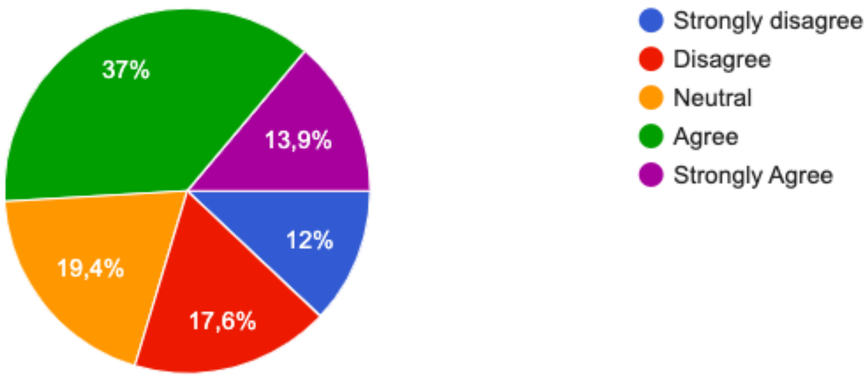
Source: own survey results.

Less than a half gave a positive response to this statement. 35.20% of people agreed and 13% of people strongly agreed, but 26.90% were neutral, 21.30% disagreed and 3.7% strongly disagreed with the statement. Hence, the idea of living a life without using a car regularly is not shared among many people.
It is interesting to highlight that this question is contradictory to the previous question, where many people declared to prefer a city without car circulation. Hence, people would like to live in a city without car circulation, but at the same time they declared that in the future they would like to continue to use their car.

Indeed, to the statement "If I could, I'd never use the car", the most popular answer has been "Disagree", chosen by 30.60% of people. Only 9.30% strongly agreed, 23.10% agreed, 23.10% was neutral, and 13.90% strongly disagreed.
Reasons for this result can be various, but they will be discussed later in this chapter.

A significant statement asked for the opinion concerning the new fuel types of vehicles: "Nowadays I would choose an electric or hybrid vehicle rather than a traditional fueled car."

Figure 3.15: Level of agreement with the statement "*Nowadays I would choose an electric or hybrid vehicle rather than a traditional fueled car*."



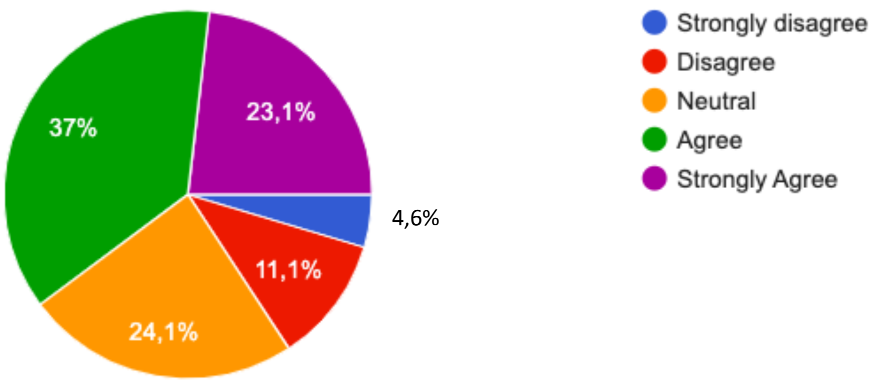
Source: own survey results.

37% of interviewees declared to agree with the statement, that is they would choose an electric or hybrid vehicle rather than a traditional fueled car. Another 13.90% strongly agree with this idea.
However, almost half of the people were neutral (19.40%), disagreed (17.60%) or strongly disagreed with the statement (13.90%). This could be a sign that about half of the people are

still not ready to make this switch, and this could be due to different reasons such as the lack of charging infrastructure, the fewer emotions that an electric vehicle gives while driving, and the questions that people have related to battery disposal.

The last statements to consider regard safety issues.

Figure 3.16: Level of agreement with the statement "*I feel safer when I travel by train rather than by car.*"



Source: own survey results.

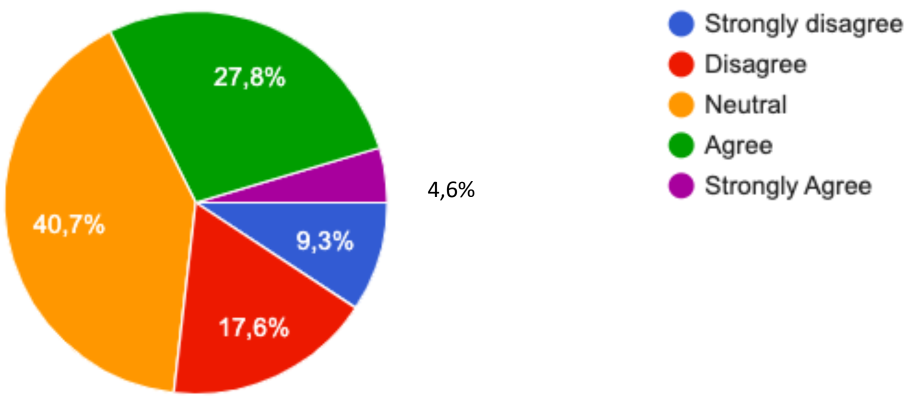
The majority would feel safer when traveling by train than by car: 37% agree and 23.10% strongly agree with the statement. 24.10% was neutral and a minority disagreed or strongly disagreed. Similar results have been collected for the statement "I feel safer when I travel with a big car rather than a small car".

The results tell us that generally the train is perceived safer with respect to a car, and that big cars are perceived safer compared with small cars.

Finally, let us analyze the interviewees' opinion regarding autonomous driving.

The first statement was "I think that autonomous vehicles would be an important solution to improve road safety".

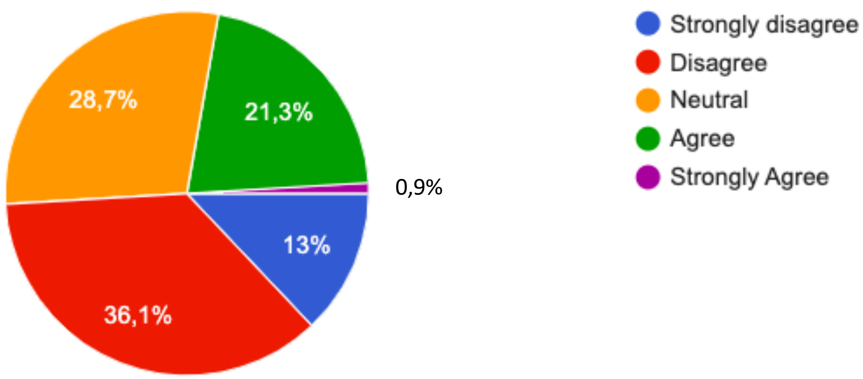
Figure 3.17: Level of agreement with the statement "*I think that autonomous vehicles would be an important solution to improve road safety*."



Source: own survey results.

40.70% of people declared to be neutral to this statement. 4.60% strongly agreed and 27.80% agreed with the statement; 17.60% disagreed and 9.30% strongly disagreed.
From these results it can be said that many people do not think about autonomous vehicles as a solution to improve road safety. But let us see if people would feel safe inside of a driverless car.

Figure 3.18: Level of agreement with the statement "*I would feel safe when traveling inside of a driverless car*."



Source: own survey results.

As it can be seen from the above graph, only a minority expressed in favor of this statement (21.30% agreed and 0.9% strongly agreed). The most popular answer was "Disagree", chosen by 36.10%. 13% strongly disagreed and 28.70% were neutral.

This result could be caused by the perception that an autonomous vehicle is not controlled, since none of the passengers drives it.

In the next paragraph, a cross analysis among the most relevant questions and answers will be presented.

3.4 Analysis by category of respondent

Since the objectives of this final chapter is, with the help of the survey, wondering and discussing about the future of the automotive industry, some of the questions related to the current trends will be crossly analyzed.

In the previous paragraphs it has been stated that most people own a car, drive a car every day and it is fundamental for living in their towns. However, this fact could depend a lot on the size of the city where a person lives, and since the majority lives in a small or very small town, results could be different if considering only people living in bigger cities.
It is therefore interesting to see how the answers change with respect to the number of inhabitants of the living city.
The table below only shows answers given by people living in a very big town (>1,000,000 inh.).

Table 3.1: Answers to selected questions, filtered for people living in a very big town (>1,000,000 inh.).

Where do you live?	Is the car indispensable to move in the place where you live?	How do you usually reach the place where you work/study?	Usually, how often do you drive a car?
A very big town (>1,000,000 inh.)	No	Bus/tram/metro	A few days a month
A very big town (>1,000,000 inh.)	No	Bus/tram/metro	A few days a month
A very big town (>1,000,000 inh.)	No	Train	Never
A very big town (>1,000,000 inh.)	No	Bus/tram/metro	A few days a year
A very big town (>1,000,000 inh.)	No	Bus/tram/metro	A few days a week

A very big town (>1,000,000 inh.)	No	Bus/tram/metro	A few days a week
A very big town (>1,000,000 inh.)	No	Bike	A few days a year
A very big town (>1,000,000 inh.)	No	Bus/tram/metro	A few days a month

Source: own elaboration from survey data.

The table reports that 100% of people living in a very big city declared that the car is not indispensable to move in their cities, and that nobody utilizes the car every day. Moreover, nobody drives a car to reach the working/studying place.

On the other hand, people who answered "yes" to the question "Is the car indispensable to move in the place where you live?" all live in very small, small, or medium cities, where public transports are not developed enough to guarantee all the inhabitants' wants and needs.

But there are some people not living in very big cities that stated that the car is not indispensable.

The table below shows only people living in very small, small, or medium towns and declaring that a car is not indispensable to move in their city.

Table 3.2: Answers to selected questions, filtered for people living in a very small, small, or medium town and that declared that cars are not indispensable to move in their cities.

Where do you live?	Is the car indispensable to move in the place where you live?	How do you usually reach the place where you work/study?	Usually, how often do you drive a car?
A small town (50,000 – 200,000 inh.)	No	Walking	A few days a year
A small town (50,000 – 200,000 inh.)	No	Walking	A few days a month
A medium town (200,000 – 500,000 inh.)	No	Other	A few days a month
A small town (50,000 – 200,000 inh.)	No	Walking	A few days a month
A small town (50,000 – 200,000 inh.)	No	Bike	A few days a month
A small town (50,000 – 200,000 inh.)	No	Car	Everyday
A medium town (200,000 – 500,000 inh.)	No	Bike	A few days a week

A medium town (200,000 – 500,000 inh.)	No	Walking	A few days a month
A very small town (<50,000 inh.)	No	Other	Everyday
A small town (50,000 – 200,000 inh.)	No	Bike	A few days a month
A small town (50,000 – 200,000 inh.)	No	Walking	Never
A very small town (<50,000 inh.)	No	Walking	A few days a week
A medium town (200,000 – 500,000 inh.)	No	Car	Everyday
A small town (50,000 – 200,000 inh.)	No	Bike	A few days a week
A small town (50,000 – 200,000 inh.)	No	Bus/tram/metro	A few days a month
A very small town (<50,000 inh.)	No	Car	Everyday
A small town (50,000 – 200,000 inh.)	No	Car	Everyday
A small town (50,000 – 200,000 inh.)	No	Bike	Never
A medium town (200,000 – 500,000 inh.)	No	Car	Everyday
A very small town (<50,000 inh.)	No	Car	Everyday
A small town (50,000 – 200,000 inh.)	No	Car	Everyday
A small town (50,000 – 200,000 inh.)	No	Car	Everyday
A small town (50,000 – 200,000 inh.)	No	Car	Everyday
A small town (50,000 – 200,000 inh.)	No	Car	Everyday
A very small town (<50,000 inh.)	No	Car	Everyday
A very small town (<50,000 inh.)	No	Bus/tram/metro	A few days a week

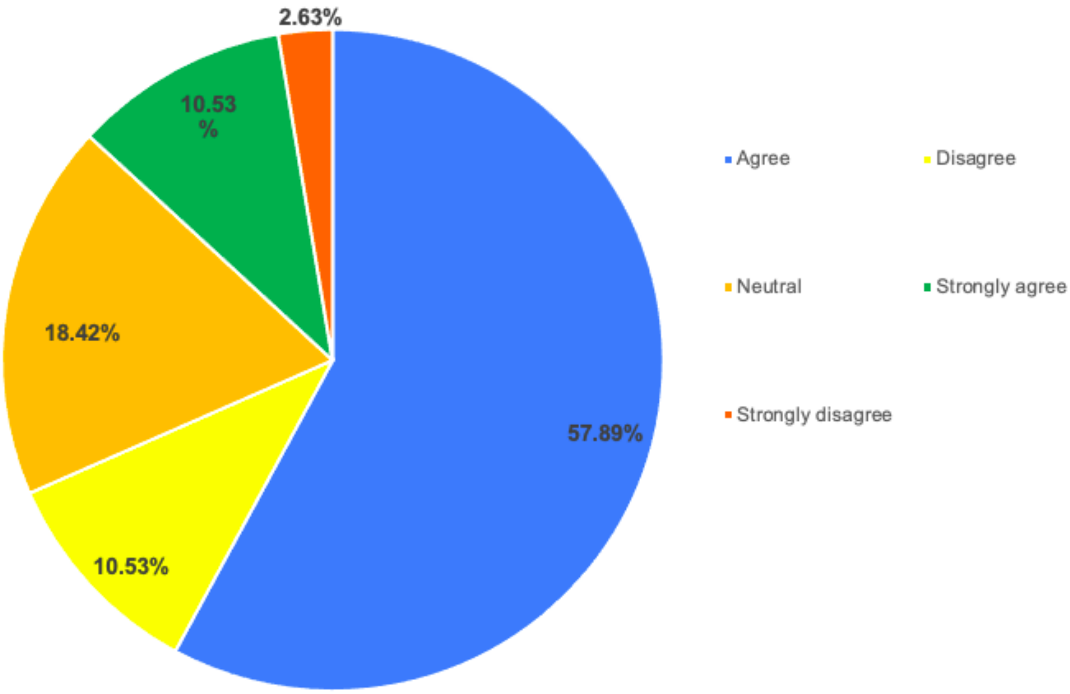
Source: own elaboration from survey data.

Most of the people in this case move with private means of transport or walking. Even if not indispensable, in this context the car is driven every day by some people.
This could be due to different reasons such as: the comfort in terms of time flexibility that a car gives, especially in cities where public transports offer limited services; the culture and habit that people have of driving the car to commute; the higher level of privacy that a car gives; the fact that in smaller towns the various services are usually distant from each other and combining them by using a car is simpler and less time wasting.

Let us now analyze the answers related to the damages that the use of vehicles causes to the environment, such as air pollution.
From the previous paragraph, it has been stated that 52% of interviewees are in favor of car limitation because of the pollution. However, other related questions show that even if declaring that, not everyone tries to use their car the least possible or give very much importance to CO_2 vehicle emissions when buying a car.

Let us see the results of the survey to the question “Vehicles are the main source of air pollution, therefore I try to use my car the least possible” filtered for people who said “Yes” to question on the limitation of the car use and that said “Pollution” as the main reason to limit it.

Figure 3.19: Level of agreement with the statement "*Vehicles are the main source of air pollution, therefore I try to use my car the least possible*", only for people who are in favor of car limitation because of the pollution.



Source: own elaboration from survey data.

Most people (57.89%) in favor of limiting cars circulation because of pollution declared to agree with the statement affirming that they use their car the least possible (and 10.53% strongly agreed). However, 10.53% disagreed, 2.63% strongly disagreed and 18.42% was neutral with this statement. This means that some people, even if they think that cars lead to pollution issues, would not renounce the comfort of driving a car.

This can be due to several reasons, such as the rooted culture of people regarding car use and the people's aversion to change their habits (especially when they are not forced to), the absence in many cities of a valid mobility structure that can satisfy people's needs, and so on.

The last aspect that is interesting to analyze crossly regards the interest that people have in CO_2 emissions of a car and in its efficiency with respect to the importance that they give to the status symbol that a vehicle could represent for the.

It is indeed interesting to see that people who prioritize the status symbol of a car give at the same time importance to the other two variables, or if the importance of the status symbol cancels the interest on the aspects related to the environment.

Table 3.3: Crossed answers to the survey questions "*When buying a car, how much importance do you give to the vehicle CO2 emissions?*" and "*When buying a car, how much importance do you give to the possible status symbol that gives you that vehicle?*"

Level of importance of a vehicle CO_2 emissions	Level of importance of vehicle status symbol								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	3	1	2		1	2	2	1	2
2			1		2	1	1	1	
3	2	1	1	1	1		1		1
4		1			1	3	1	1	1
5		1	3	3	1	4	3	2	2
6	1	1	1	1	3	2	3	2	1
7	1	1	3	3	5	4	3	2	1
8				2		4	2	1	
9	1		1				2	1	1

Source: own elaboration from survey data.

The above table reports the crossed answers related to the level of importance that interviewees gave to vehicle CO_2 emissions and the status symbol that a vehicle could give them.
The table is structured as follows: on the left column there are reported the levels of importance related to the vehicle CO_2 emissions, while on the second row on the right side there are reported the values related to the vehicle status symbol. For example, among people who voted 1 for vehicle CO_2 emissions, 3 people voted 1 for status symbol, 1 person voted 2, 2 people voted 3, and so on.
The results are very different, and it is difficult to identify a common trend.
There are people that do not care about both vehicle CO_2 emissions and vehicle status symbol; on the other hand, there are people who declared to be very interested in vehicle CO_2 emissions and at the same time also to vehicle status symbol.
Anyway, a good part of the results is on the bottom-center of the table, signifying a relatively high interest in vehicle CO_2 emissions and a moderate interest on vehicle status symbol.

It is important to define the meaning that "status symbol" could have. If "status symbol" corresponded to polluting and powerful cars, then the results in this table do not correspond to expectations (we should have many "1" on status symbol corresponding to high values of importance of CO_2 emissions, and many "1" on CO_2 emissions corresponding to high values of importance of status symbol). The reality is that for some people it could be that having a low-polluting or electric car is a form of status, this is likely to be the reason why the expected distribution does not correspond to the actual distribution.

Let us see the same idea but considering the vehicle efficiency instead of the vehicle CO_2 emissions.

Table 3.4: Crossed answers to the survey questions "*When buying a car, how much importance do you give to the vehicle CO2 emissions?*" and "*When buying a car, how much importance do you give to the possible status symbol that gives you that vehicle?*"

Level of importance of a vehicle efficiency	Level of importance of status symbol								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1									
2					1				
3								1	
4								1	
5	1	1	1	1		2	1		1
6				1	2	2			
7	1	2	3	4	2	1	4	3	2
8	4	2	6	3	6	7	4	1	3
9	2	1	2	1	3	8	9	5	3

Source: own elaboration from survey data.

This second table differs a lot from the previous one, since the efficiency of a vehicle is generally much more important for people.
Indeed, the values of the table are almost all on the lower half of the table. The most popular combination indicates that in general people that care about the vehicle efficiency, relatively care about the vehicle status symbol (for example, 9 people voting the maximum for vehicle efficiency, voted 7 for the vehicle status symbol). But the combinations are the most various, hence from this survey there are no demonstrations that the interest in having a car because of its status symbol make people less careful about other ecological features.

3.5 Survey conclusions

From the analysis of the answers to the survey, there are different considerations to be done.

First, let us consider if car makers have been working to the evolution of the right vehicle features. If considering the analysis of Chapter 2 of this elaborate on the evolution of car features, it can be stated that characteristics such as the vehicle efficiency, the vehicle power, the size, and the weight are priorities for many people when purchasing a car.
Hence, the evolution that we have seen in the previous chapter seems to be in line with people's requirements. These requirements could be related to the need of people to save money (with fuel economy) and to feel safe (with bigger cars and consequently more powerful cars). This leads to the fact that people generally give very much importance to the quality-price ratio. Technological features are also a priority for users, probably for the benefits that technology gives, especially related to the improvement in safety. This could be important for car manufacturers that are investing many resources in providing vehicles with always more technologically advanced software. It seems to be therefore confirmed that new trends regarding interconnections and assisted driving systems are appreciated by users.

However, from the survey emerges the fact that less than half of interviewees support the idea of autonomous cars as a solution for reducing road accidents. It could be that a driverless car gives the feeling of not being controlled and perceived to be less safe. But usually, technology mistakes are less numerous than human mistakes. For this reason, car makers could continue to invest in developing autonomous vehicles, but they should prepare people for it in advance. For example, by spreading driverless public transports (as already in some cities exist), and by organizing, in the future, dedicated events and demonstrations where people have the possibility to test this car proposal and consequently rely on it.

Most people also share the opinion that car circulation should be limited and that pollution deriving from its use is the main reason to take this decision. This confirms the trend that some cities mentioned in the previous chapter, such as Madrid, Paris, Oslo, and Hamburg, have already started, that is restricting the use of cars in the center of towns. It is likely that, during the next years, more cities will follow this example. Driving a car in urban centers is stressful, there is traffic congestion, there are few parking areas, they cause air and noise pollution, therefore the quality of life decreases.

The trend related to car limitation could be further strengthened if people would choose to use the car the least possible. From the survey it emerged that people generally would not reduce their car use to the least possible, but with some interventions this result could be reversed.

It is not likely that cars will disappear in the future, especially in areas where services are scarce, and the number of inhabitants is low.
However, there could be various solutions to bring people make different decisions when speaking about inhabited centers.
One proposal could be, for example, to make public transport much more convenient in economic terms. If saving much of the money that people would spend for traveling by car, it would be more probable for them to opt for public transport. Another aspect is to improve the availability of public transport services, both in trip frequency and enlarging the covered areas, limiting to a few situations the need of a car. Economic incentives, together with a strengthened and functioning mobility system could be a potential solution to discourage cars use and participate in the reduction of effects that vehicles cause to the planet.

The willingness of helping the environment is confirmed by the fact that more than a half of interviewees would choose to buy an electric or hybrid vehicle. This supports the current trend of electric vehicles proposed by car makers, and even if some people are reluctant, with some interventions the percentage of people who would buy an electric car could increase.
To make it possible, it would be important to develop an adequate charging infrastructure which permits travel anywhere, to clarify to potential users the process of battery disposal, and to explain the real benefits that the choice of an electric vehicle could bring.

Summarizing, from the answers of the survey, it seems that in general people’s opinions are aligned with the current automotive trends, and since the sample was represented for more than 90% by people included in the age category 18-30, it is likely to be less difficult to change their habits.

CONCLUSION

This thesis has been developed with the aim of drawing the temporal evolution of the offering strategies of the world's most important car manufactures, discussing the main current trends that the automotive industry is experiencing, and suggesting some possible scenarios about how the automotive industry will evolve in the future.

Cars have been present in our lives since their existence, but there are some signs that habits are changing or could change in people's future.
The necessity to change them mostly comes from the damages that the circulation of vehicles is causing to the environment. For this reason, car manufacturers are trying to develop solutions that limit these damages, and the advent of electric cars is an example.
Another challenge that car makers have is to improve road safety. Technological progress plays a fundamental role in this sense, and nowadays more vehicles are supported by assisted driving systems with the aim to help drivers to avoid accidents.
Autonomous driving is the long-term goal of the automotive industry, which aims at reducing to zero the number of road accidents.

Automotive sector is working to respond to the worldwide ongoing challenges (environmental issues, road accidents, customers' requirements, and so on), but there are still various obstacles it must face.
First, the planet needs everybody's effort to reduce CO_2 emissions and pollution. Many car makers and governments worked and are working to set some environmental goals for the next years. Car manufacturers are investing in more ecological products, that means not only producing electric vehicles, but also producing them in the most sustainable way. Moreover, companies offering different services could contribute to the target achievement. For example, some firms now offer several possibilities to get a car, including renting or sharing, optimizing trips among users.

Governments are another important player in this sense. Even if vehicles are not likely to be completely eliminated, at least in the near future, it would be an effective solution to strengthen the mobility system at least in each city, limiting car use to the most remote areas.

It is not a simple task, and this could require a long time especially because people are strongly influenced by the culture of driving a car and in many cases, as it emerged from the survey, they would not renounce it. Moreover, people are generally too used to take the car whenever they desire (because of the time flexibility, the more space available, the more privacy, and so on), and it would be a great effort for them to start to adapt to public transports, especially for those who give much importance to the status symbol related to vehicles. But economic advantages and functional public transports, together with the commitment of governments to limit cars circulation as much as possible, could be key elements to allow us to cut car utilization.

APPENDIX

Table 1 Summary data by vehicle type 1975-2022 (US Environmental Protection Agency, 2023)

Model Year	Regulatory Class	Vehicle Type	Production Share	Real-World MPG	Real-World MPG_City	Real-World MPG_Hwy	Real-World CO2 (g/mi)	Real-World CO2_City (g/mi)	Real-World CO2_Hwy (g/mi)	Weight (lbs)	Horsepower (HP)	Footprint (sq. ft.)
1975	All	All	1.000000	13.05970	12.01552	14.61167	680.59612	739.73800	608.31160	4060.399	137.3346	-
1975	Car	All Car	0.806646	13.45483	12.31413	15.17266	660.63740	721.82935	585.84724	4057.494	136.1964	-
1975	Car	Sedan/Wagon	0.805645	13.45833	12.31742	15.17643	660.46603	721.63673	585.70185	4057.565	136.2256	-
1975	Truck	All Truck	0.193354	11.63431	10.91165	12.65900	763.86134	814.45060	702.03002	4072.518	142.0826	-
1975	Truck	Pickup	0.131322	11.91476	11.07827	13.12613	745.88139	802.20090	677.04643	4011.977	140.9365	-
1975	Truck	Minivan/Van	0.044700	11.10606	10.55642	11.86084	800.19398	841.85725	749.27220	4195.690	143.2245	-
1975	Truck	Truck SUV	0.017331	11.02071	10.62298	11.54921	806.39097	836.58258	769.49011	4213.574	147.8221	-
1975	Car	Car SUV	0.001001	11.12929	10.13552	12.64456	798.52390	876.81716	702.83214	4000.000	112.7733	-
1976	All	All	1.000000	14.22136	13.18117	15.73946	625.02238	674.34147	564.74348	4079.198	135.0839	-
1976	Car	All Car	0.789164	14.86139	13.69643	16.58558	598.14122	649.00991	535.96838	4058.859	133.5588	-
1976	Car	Sedan/Wagon	0.788239	14.86845	13.70380	16.59191	597.85756	648.66127	535.76413	4058.944	133.5710	-
1976	Truck	All Truck	0.210836	12.24713	11.55419	13.21586	725.63932	769.15824	672.44953	4155.327	140.7925	-
1976	Truck	Pickup	0.151303	12.44161	11.74027	13.42155	714.29673	756.96715	662.14399	4121.843	139.4000	-
1976	Truck	Minivan/Van	0.040716	11.78392	11.05859	12.81092	754.16317	803.62893	693.70503	4199.864	145.6272	-
1976	Truck	Truck SUV	0.018816	11.76894	11.21251	12.52886	755.12304	792.59652	709.32212	4328.199	141.5282	-
1976	Car	Car SUV	0.000925	10.58091	9.39272	12.51605	839.90887	946.15820	710.04857	3986.237	123.1064	-
1977	All	All	1.000000	15.06743	14.00580	16.60587	589.99880	634.71366	535.34732	3981.818	135.9847	-
1977	Car	All Car	0.801419	15.58566	14.38805	17.35080	570.43304	617.90315	512.41403	3943.613	133.1736	-
1977	Car	Sedan/Wagon	0.800086	15.59297	14.39484	17.35887	570.16605	617.61231	512.17617	3943.519	133.1881	-
1977	Truck	All Truck	0.198581	13.28478	12.64952	14.15353	668.96080	702.55623	627.89973	4136.002	147.3296	-
1977	Truck	Pickup	0.143450	13.55757	12.89811	14.46125	655.50112	689.01573	614.53882	4091.847	146.3648	-
1977	Truck	Minivan/Van	0.036422	12.51297	11.94984	13.27770	710.22334	743.69176	669.31749	4252.284	152.3661	-
1977	Truck	Truck SUV	0.018710	12.84559	12.23607	13.67836	691.83285	726.29512	649.71230	4248.173	144.9224	-
1977	Car	Car SUV	0.001333	12.16264	11.21446	13.56437	730.68014	792.45908	655.17255	4000.000	124.4603	-
1978	All	All	1.000000	15.83777	14.68193	17.52390	561.62442	605.82637	507.59981	3715.238	129.0248	-
1978	Car	All Car	0.774581	16.93760	15.50860	19.08715	525.16335	573.54066	466.03553	3588.111	124.1651	-

1978	Car	Sedan/Wagon	0.773459	16.94899	15.51976	19.09866	524.81130	573.12958	465.75562	3587.514	124.1623	-
1978	Truck	All Truck	0.225419	12.94860	12.40906	13.67532	686.91120	716.76589	650.42214	4152.067	145.7236	-
1978	Truck	Pickup	0.156942	13.32817	12.77741	14.06939	667.61907	696.38001	632.46682	4104.366	144.1520	-
1978	Truck	Minivan/Van	0.043273	12.08009	11.63892	12.66691	735.67345	763.55852	701.59170	4249.551	149.1321	-
1978	Truck	Truck SUV	0.025204	12.28640	11.64185	13.17816	723.31987	763.36688	674.37352	4281.723	149.6580	-
1978	Car	Car SUV	0.001122	11.57282	10.36991	13.48465	767.91977	856.99842	659.04587	4000.000	126.0851	-
1979	All	All	1.000000	15.91271	14.87711	17.39245	559.69495	598.63764	512.09833	3655.465	123.5922	-
1979	Car	All Car	0.778704	17.24016	15.92465	19.17632	516.66826	559.32169	464.53628	3484.556	119.4334	-
1979	Car	Sedan/Wagon	0.777556	17.24547	15.92812	19.18475	516.51143	559.20195	464.33413	3484.872	119.4639	-
1979	Truck	All Truck	0.221296	12.52042	12.08076	13.10326	711.09852	736.98373	679.46103	4256.863	138.2265	-
1979	Truck	Pickup	0.158977	13.21499	12.71707	13.87917	674.27896	700.68356	642.00666	4142.085	135.6823	-
1979	Truck	Minivan/Van	0.034615	11.48461	11.05875	12.05184	773.81839	803.61714	737.39769	4540.969	144.2939	-
1979	Truck	Truck SUV	0.027704	10.53097	10.31087	10.81307	844.01701	862.03193	821.99878	4560.526	145.2456	-
1979	Car	Car SUV	0.001147	14.26603	13.87578	14.77387	622.94839	640.46833	601.53512	3270.859	98.7179	-
1980	All	All	1.000000	19.16493	17.61932	21.46650	465.93524	506.80269	415.98614	3227.876	103.8276	-
1980	Car	All Car	0.835255	20.01181	18.29782	22.59914	446.32303	488.12280	395.23441	3101.498	100.4593	-
1980	Car	Sedan/Wagon	0.835223	20.01210	18.29804	22.59955	446.31675	488.11703	395.22751	3101.464	100.4585	-
1980	Truck	All Truck	0.164745	15.77936	14.83106	17.11704	565.36885	601.50942	521.19705	3868.606	120.9049	-
1980	Truck	Pickup	0.127076	16.51884	15.51081	17.94417	540.59043	575.71912	497.65538	3739.957	118.0136	-
1980	Truck	Minivan/Van	0.021373	14.13642	13.26730	15.36678	628.65990	669.84255	578.32554	4352.742	130.5904	-
1980	Truck	Truck SUV	0.016297	13.18631	12.49306	14.14570	675.57737	712.99565	629.84392	4236.831	130.7478	-
1980	Car	Car SUV	0.000032	14.57638	13.92621	15.45846	609.68513	638.14935	574.89552	4000.000	122.1928	-
1981	All	All	1.000000	20.52057	18.83051	23.04893	436.03635	475.18566	388.18720	3201.759	102.1236	-
1981	Car	All Car	0.827505	21.41607	19.54990	24.24470	417.98580	457.90679	369.19347	3075.888	98.7092	-
1981	Car	Sedan/Wagon	0.827485	21.41631	19.55010	24.24499	417.98127	457.90220	369.18902	3075.865	98.7082	-
1981	Truck	All Truck	0.172495	17.09200	16.00519	18.63890	522.62948	558.07683	479.30496	3805.596	118.5032	-
1981	Truck	Pickup	0.136419	17.88228	16.71899	19.54434	500.35941	535.11618	457.87891	3679.450	115.4839	-
1981	Truck	Minivan/Van	0.023204	14.84219	13.98387	16.04595	598.76601	635.51792	553.84701	4323.985	129.0355	-
1981	Truck	Truck SUV	0.012872	14.30158	13.42825	15.53659	621.39972	661.81391	572.00460	4208.028	131.5149	-
1981	Car	Car SUV	0.000020	14.68025	13.71600	16.06020	605.37116	647.92943	553.35550	4000.000	140.0000	-
1982	All	All	1.000000	21.07205	19.20172	23.91969	424.63837	465.95156	374.14447	3201.843	102.9528	-

1982	Car	All Car	0.804687	22.20740	20.07855	25.51363	402.49487	445.13497	350.37920	3053.387	98.7165	-
1982	Car	Sedan/Wagon	0.803384	22.21184	20.07840	25.52699	402.41852	445.14251	350.20030	3054.073	98.7342	-
1982	Truck	All Truck	0.195313	17.40582	16.27374	19.02325	515.86923	551.71556	472.05705	3813.483	120.4064	-
1982	Truck	Pickup	0.148038	18.48502	17.24861	20.26003	486.37369	521.16934	443.84567	3628.863	116.5468	-
1982	Truck	Minivan/Van	0.031904	14.72404	13.89743	15.87836	604.50911	640.35993	560.69145	4342.080	132.2636	-
1982	Truck	Truck SUV	0.015371	14.69788	13.68198	16.16485	615.95999	661.91624	559.79123	4494.407	132.9675	-
1982	Car	Car SUV	0.001303	19.76697	20.17557	19.28949	449.58844	440.48314	460.71714	2629.999	87.8139	-
1983	All	All	1.000000	20.95239	19.04058	23.88334	425.53494	468.23629	373.34441	3257.340	106.9483	-
1983	Car	All Car	0.779970	22.08496	19.92518	25.45765	403.41590	447.12116	349.99835	3112.012	103.8189	-
1983	Car	Sedan/Wagon	0.776709	22.09123	19.92703	25.47247	403.30599	447.08443	349.79900	3111.960	103.8318	-
1983	Truck	All Truck	0.220030	17.72939	16.45150	19.58913	503.94351	543.08612	456.10255	3772.506	118.0416	-
1983	Truck	Pickup	0.158063	18.87651	17.51564	20.85710	473.06528	509.78789	428.18209	3543.619	112.3953	-
1983	Truck	Minivan/Van	0.037141	15.06647	14.06695	16.49935	592.64477	634.80734	541.11276	4414.280	136.1429	-
1983	Truck	Truck SUV	0.024826	15.79468	14.51766	17.69734	567.83767	617.86997	506.68709	4269.657	126.9095	-
1983	Car	Car SUV	0.003262	20.68730	19.49465	22.35918	429.58726	455.86872	397.46547	3124.431	100.7415	-
1984	All	All	1.000000	21.00023	19.05715	23.98980	424.02812	467.23590	371.21860	3261.576	108.5963	-
1984	Car	All Car	0.765372	22.42303	20.18462	25.93880	397.02956	441.03192	343.24889	3100.501	105.7755	-
1984	Car	Sedan/Wagon	0.761433	22.44190	20.20085	25.96213	396.70005	440.68196	342.94437	3098.504	105.7600	-
1984	Truck	All Truck	0.234628	17.39887	16.11990	19.26725	512.09938	552.71521	462.45782	3787.013	117.7982	-
1984	Truck	Pickup	0.145760	18.25999	16.91418	20.22702	488.08367	526.88826	440.65585	3618.901	114.0118	-
1984	Truck	Minivan/Van	0.048234	16.11388	14.98634	17.74573	552.24250	593.78972	501.46256	4074.744	126.0343	-
1984	Truck	Truck SUV	0.040634	16.19242	14.94432	18.03317	550.59585	596.60330	494.36453	4048.509	121.6039	-
1984	Car	Car SUV	0.003940	19.28953	17.47103	22.10116	460.71629	508.67055	402.10552	3486.502	108.7714	-
1985	All	All	1.000000	21.31942	19.31764	24.41114	417.30522	460.53346	364.47071	3271.127	114.1306	-
1985	Car	All Car	0.752349	22.98880	20.62796	26.72747	386.97474	431.24405	332.86780	3095.975	110.7365	-
1985	Car	Sedan/Wagon	0.746275	23.01593	20.65662	26.75019	386.52221	430.64982	332.58846	3092.936	110.7520	-
1985	Truck	All Truck	0.247651	17.46626	16.19283	19.32358	509.44751	549.51304	460.47854	3803.231	124.4415	-
1985	Truck	Pickup	0.143697	18.20137	16.90865	20.07745	488.92435	526.29619	443.24766	3642.380	122.8821	-
1985	Truck	Minivan/Van	0.059159	16.54583	15.45961	18.10020	537.31517	575.07565	491.16347	3975.166	129.0611	-
1985	Truck	Truck SUV	0.044795	16.53857	15.08883	18.73913	538.48011	590.23082	475.22923	4092.154	123.3431	-
1985	Car	Car SUV	0.006074	20.08032	17.62417	24.20283	442.57267	504.25066	367.18847	3469.242	108.8355	-

1986	All	All	1.000000	21.84433	19.75389	24.99472	407.03768	450.10437	355.74272	3237.974	114.3758	-
1986	Car	All Car	0.720726	23.69184	21.19061	27.56863	375.22688	419.51117	322.46786	3043.023	110.9135	-
1986	Car	Sedan/Wagon	0.716867	23.72402	21.21784	27.60920	374.71873	418.97358	321.99473	3040.673	110.8588	-
1986	Truck	All Truck	0.279274	18.18471	16.81223	20.14168	489.13227	529.05669	441.61562	3741.088	123.3111	-
1986	Truck	Pickup	0.164807	18.86250	17.48612	20.81179	471.48289	508.59063	427.32740	3574.005	120.3470	-
1986	Truck	Minivan/Van	0.067977	17.46989	16.13264	19.38228	508.95915	551.13757	458.75336	3997.909	127.4910	-
1986	Truck	Truck SUV	0.046490	17.03397	15.63894	19.05810	522.70900	569.32282	467.20897	3957.881	127.7072	-
1986	Car	Car SUV	0.003860	18.92466	17.11181	21.65796	469.60984	519.36056	410.34432	3479.487	121.0844	-
1987	All	All	1.000000	21.97197	19.75719	25.26006	404.60524	449.95539	351.94510	3220.507	117.6397	-
1987	Car	All Car	0.728276	23.75972	21.17190	27.69136	374.16179	419.88692	321.04759	3034.936	112.6106	-
1987	Car	Sedan/Wagon	0.721907	23.80659	21.21636	27.74058	373.42650	419.00840	320.47924	3030.906	112.4524	-
1987	Truck	All Truck	0.271724	18.28459	16.75628	20.44816	486.19972	530.54488	434.75655	3717.872	131.1187	-
1987	Truck	Pickup	0.144401	19.03851	17.49579	21.20711	466.95388	508.12549	419.20765	3526.440	123.3883	-
1987	Truck	Minivan/Van	0.074941	17.65937	16.16028	19.78938	503.29963	549.98832	449.12644	3972.056	141.7261	-
1987	Truck	Truck SUV	0.052382	17.27386	15.75200	19.45536	514.79052	564.53141	457.06174	3881.943	137.2537	-
1987	Car	Car SUV	0.006369	19.42471	17.10779	23.05481	457.50994	519.47108	385.47272	3491.782	130.5429	-
1988	All	All	1.000000	21.86353	19.57179	25.20576	406.51876	454.11969	352.61548	3283.465	123.4690	-
1988	Car	All Car	0.709052	24.08680	21.38115	28.11743	368.95975	415.64909	316.06965	3051.051	116.1658	-
1988	Car	Sedan/Wagon	0.701911	24.14857	21.43647	28.18853	368.01608	414.57652	315.27247	3046.537	115.9074	-
1988	Truck	All Truck	0.290948	17.84859	16.22555	20.12653	498.05145	547.87398	441.67903	3849.867	141.2671	-
1988	Truck	Pickup	0.160745	18.14217	16.53318	20.38628	489.98944	537.67551	436.05057	3736.914	137.6928	-
1988	Truck	Minivan/Van	0.074067	17.87781	16.15447	20.33366	497.17367	550.21327	437.12417	4052.761	146.9449	-
1988	Truck	Truck SUV	0.056136	17.02310	15.49013	19.16950	522.29497	573.99058	463.80568	3905.607	144.0111	-
1988	Car	Car SUV	0.007141	19.24756	17.05493	22.53121	461.72090	521.08109	394.43060	3494.767	141.5664	-
1989	All	All	1.000000	21.42049	19.07833	24.78156	414.92705	465.86478	358.65232	3351.457	128.7480	-
1989	Car	All Car	0.700602	23.64929	20.84659	27.77744	375.79709	426.32004	319.94878	3103.504	121.2814	-
1989	Car	Sedan/Wagon	0.693142	23.70987	20.89662	27.85522	374.83716	425.29953	319.05561	3099.266	120.9978	-
1989	Truck	All Truck	0.299398	17.55009	15.91868	19.78756	506.49258	558.40091	449.21999	3931.676	146.2200	-
1989	Truck	Pickup	0.154396	17.80206	16.18576	20.00544	499.32816	549.19102	444.33240	3803.156	142.8300	-
1989	Truck	Minivan/Van	0.088398	17.79679	16.05678	20.21530	499.40914	553.52836	439.66043	4057.266	146.0862	-
1989	Truck	Truck SUV	0.056604	16.55267	15.03970	18.61918	537.09712	591.13200	477.48102	4086.103	155.6757	-

1989	Car	Car SUV	0.007460	19.11214	17.05288	22.05536	464.99236	521.14362	402.94060	3497.227	147.6344	-
1990	All	All	1.000000	21.15752	18.72132	24.61039	420.08667	474.75185	361.14877	3426.038	135.3422	-
1990	Car	All Car	0.703538	23.29344	20.43092	27.44050	381.54137	434.99706	323.88033	3178.419	128.6336	-
1990	Car	Sedan/Wagon	0.698357	23.33429	20.46276	27.49645	380.87347	434.32026	323.22144	3175.900	128.5061	-
1990	Truck	All Truck	0.296462	17.37636	15.61965	19.77130	511.55886	569.09429	449.59082	4013.663	151.2622	-
1990	Truck	Pickup	0.145428	17.41153	15.68860	19.74637	510.53577	566.60404	450.16806	3928.038	151.5798	-
1990	Truck	Minivan/Van	0.100071	17.84376	15.96497	20.43541	498.09174	556.70915	434.92221	4094.990	148.8218	-
1990	Truck	Truck SUV	0.050964	16.43622	14.80517	18.64847	540.92197	600.51950	476.74653	4098.310	155.1478	-
1990	Car	Car SUV	0.005181	18.84529	16.88798	21.53370	471.57682	526.23232	412.70199	3518.094	145.8198	-
1991	All	All	1.000000	21.25642	18.75908	24.71816	418.15476	473.82065	359.59491	3409.555	137.9169	-
1991	Car	All Car	0.695754	23.25777	20.35495	27.36521	382.16421	436.66149	324.80589	3168.471	132.5287	-
1991	Car	Sedan/Wagon	0.677964	23.42825	20.48348	27.60558	379.38525	433.92348	321.97946	3153.670	132.2115	-
1991	Truck	All Truck	0.304246	17.76132	15.90708	20.24081	500.45833	558.79663	439.15081	3960.869	150.2386	-
1991	Truck	Pickup	0.152737	18.18688	16.30479	20.69693	488.75720	545.17665	429.48148	3779.345	146.0197	-
1991	Truck	Minivan/Van	0.082203	17.91037	16.01590	20.45351	496.24510	554.94474	434.54250	4132.591	148.5607	-
1991	Truck	Truck SUV	0.069307	16.73325	14.98104	19.07888	531.24220	593.38068	465.92564	4157.233	161.5263	-
1991	Car	Car SUV	0.017790	18.20849	16.42682	20.54704	488.06901	541.00543	432.51980	3732.531	144.6175	-
1992	All	All	1.000000	20.79365	18.19781	24.36403	427.42784	488.39741	364.79234	3512.305	145.2572	-
1992	Car	All Car	0.686017	22.87528	19.81979	27.18294	388.52677	448.42169	326.95925	3253.611	140.8622	-
1992	Car	Sedan/Wagon	0.666086	23.06995	19.95943	27.47112	385.24953	445.28566	323.53032	3239.880	140.5106	-
1992	Truck	All Truck	0.313983	17.34505	15.43754	19.86345	512.42228	575.73986	447.45337	4077.522	154.8598	-
1992	Truck	Pickup	0.151158	17.48087	15.54243	20.04642	508.47858	571.89705	443.40180	3976.449	150.6981	-
1992	Truck	Minivan/Van	0.100328	17.92191	15.94818	20.52874	495.91014	557.28442	432.93642	4151.208	151.9530	-
1992	Truck	Truck SUV	0.062497	16.20331	14.45837	18.49312	548.46809	614.66124	480.55714	4203.692	169.5920	-
1992	Car	Car SUV	0.019931	17.84349	16.06389	20.12662	498.05274	553.22828	441.55461	3712.507	152.6120	-
1993	All	All	1.000000	20.87940	18.22812	24.44455	425.63491	487.54351	363.55755	3518.930	146.8406	-
1993	Car	All Car	0.675907	22.99937	19.89986	27.25888	386.40192	446.58613	326.02214	3241.070	140.4357	-
1993	Car	Sedan/Wagon	0.640123	23.45914	20.26584	27.86440	378.82894	438.52128	318.93740	3207.167	138.2942	-
1993	Truck	All Truck	0.324093	17.51282	15.51064	20.11366	507.45679	572.96166	441.83904	4098.419	160.1983	-
1993	Truck	Pickup	0.151559	17.58531	15.59249	20.16668	505.36495	569.95370	440.67729	3995.899	156.0455	-
1993	Truck	Minivan/Van	0.109102	18.20216	16.03783	21.04927	488.23886	554.12725	422.19997	4105.496	155.0834	-

1993	Truck	Truck SUV	0.063432	16.29119	14.50835	18.57674	545.50973	612.54383	478.39402	4331.199	178.9183	-
1993	Car	Car SUV	0.035785	17.02920	15.04102	19.62872	521.86822	590.85098	452.75487	3847.533	178.7425	-
1994	All	All	1.000000	20.37752	17.77373	23.78827	436.12068	500.01065	373.58978	3603.432	152.2823	-
1994	Car	All Car	0.619235	23.01968	19.81413	27.35476	386.06548	448.52346	324.88321	3268.106	143.5859	-
1994	Car	Sedan/Wagon	0.595743	23.27300	19.99754	27.72141	381.86337	444.40988	320.58643	3249.686	142.8141	-
1994	Truck	All Truck	0.380765	17.17211	15.22414	19.62672	517.52519	583.74400	452.80102	4148.771	166.4252	-
1994	Truck	Pickup	0.188962	17.44093	15.47527	19.91268	509.54846	574.27121	446.29854	4056.457	163.3181	-
1994	Truck	Minivan/Van	0.100378	17.83757	15.71845	20.54695	498.21818	565.38668	432.52155	4156.485	159.4923	-
1994	Truck	Truck SUV	0.091424	16.00656	14.25391	18.19219	555.20998	623.47823	488.50642	4331.104	180.4590	-
1994	Car	Car SUV	0.023492	18.03998	16.07515	20.48420	492.62795	552.84100	433.84657	3735.241	163.1584	-
1995	All	All	1.000000	20.48563	17.72570	24.06812	433.83372	501.38187	369.25888	3612.509	158.1889	-
1995	Car	All Car	0.634935	23.27497	19.84992	27.87744	381.85388	447.74032	318.81225	3274.091	152.7547	-
1995	Car	Sedan/Wagon	0.620390	23.44355	19.97490	28.11524	379.10881	444.93985	316.11648	3262.620	152.4623	-
1995	Truck	All Truck	0.365065	16.95219	14.94424	19.44650	524.23891	594.67719	456.99746	4201.098	167.6403	-
1995	Truck	Pickup	0.149951	16.89032	14.91546	19.33340	526.15950	595.82456	459.67076	4182.348	167.1794	-
1995	Truck	Minivan/Van	0.109724	18.07800	15.77474	21.00924	491.59189	563.36889	423.00428	4109.512	158.8926	-
1995	Truck	Truck SUV	0.105390	15.99832	14.20465	18.18927	555.49574	625.64038	488.58484	4323.131	177.4035	-
1995	Car	Car SUV	0.014545	17.81180	15.66853	20.48666	498.93879	567.18801	433.79450	3763.367	165.2253	-
1996	All	All	1.000000	20.43168	17.60332	24.03690	435.00690	504.89874	369.76297	3658.786	163.9606	-
1996	Car	All Car	0.622110	23.11874	19.67145	27.64414	384.44203	451.81134	321.50968	3296.772	154.5761	-
1996	Car	Sedan/Wagon	0.600276	23.33458	19.82557	27.95744	380.88755	448.30062	317.90822	3281.749	154.1331	-
1996	Truck	All Truck	0.377890	17.15010	15.00609	19.78639	518.25065	592.29526	449.20121	4254.760	179.4102	-
1996	Truck	Pickup	0.148759	17.14796	15.07040	19.67613	518.39705	589.86033	451.79020	4189.857	178.2257	-
1996	Truck	Truck SUV	0.121923	16.22709	14.21598	18.69328	547.67933	625.15861	475.42483	4386.100	188.6074	-
1996	Truck	Minivan/Van	0.107208	18.33961	15.91797	21.37399	484.57944	558.29971	415.78567	4195.450	170.5941	-
1996	Car	Car SUV	0.021835	18.43161	16.20748	21.13336	482.16073	548.32698	420.51996	3709.791	166.7538	-
1997	All	All	1.000000	20.15038	17.35297	23.62041	441.06037	512.16145	376.26591	3727.285	169.2409	-
1997	Car	All Car	0.601421	23.16579	19.67400	27.63955	383.65375	451.74448	321.55638	3285.482	156.1660	-
1997	Car	Sedan/Wagon	0.576479	23.37244	19.80466	27.96814	380.26313	448.76571	317.77992	3274.061	156.0286	-
1997	Truck	All Truck	0.398579	16.84238	14.73071	19.37028	527.68181	603.32525	458.81769	4393.927	188.9698	-
1997	Truck	Pickup	0.166543	16.83729	14.71118	19.38849	527.86627	604.15396	458.40921	4414.615	195.5758	-

1997	Truck	Truck SUV	0.144517	16.13144	14.20220	18.40626	550.92239	625.76027	482.83455	4463.251	190.4155	-
1997	Truck	Minivan/Van	0.087520	18.17550	15.73749	21.16269	488.95485	564.70255	419.93723	4240.090	174.0118	-
1997	Car	Car SUV	0.024941	19.23496	17.07087	21.73689	462.02338	520.59451	408.84412	3549.458	159.3404	-
1998	All	All	1.000000	20.09648	17.22728	23.59384	442.26071	515.91793	376.70460	3744.005	171.4710	-
1998	Car	All Car	0.582843	23.01887	19.48574	27.45167	386.13753	456.14885	323.78768	3333.932	159.5920	-
1998	Car	Sedan/Wagon	0.551403	23.36801	19.73128	27.95777	380.37277	450.47757	317.93046	3305.987	159.0853	-
1998	Truck	All Truck	0.417157	17.06881	14.82634	19.72156	520.67477	599.42595	450.63895	4316.950	188.0681	-
1998	Truck	Pickup	0.167035	16.99566	14.79891	19.57973	522.93624	600.56030	453.92115	4282.279	189.7748	-
1998	Truck	Truck SUV	0.147127	16.16263	14.11935	18.54879	549.85500	629.42713	479.12048	4450.325	191.7499	-
1998	Truck	Minivan/Van	0.102995	18.69673	16.02041	21.96325	475.32365	554.73004	404.63049	4182.655	180.0408	-
1998	Car	Car SUV	0.031440	18.23943	15.99494	20.83641	487.24121	555.61322	426.51304	3824.049	168.4785	-
1999	All	All	1.000000	19.69506	16.87145	23.04703	451.26399	526.78681	385.63273	3835.375	178.9020	-
1999	Car	All Car	0.582653	22.70095	19.16469	27.03981	391.53942	463.78366	328.71444	3390.274	164.2873	-
1999	Car	Sedan/Wagon	0.550547	23.00469	19.36456	27.50105	386.37387	459.00129	323.20514	3364.561	163.9751	-
1999	Truck	All Truck	0.417347	16.62228	14.45643	19.10792	534.64475	614.74476	465.09568	4456.774	199.3054	-
1999	Truck	Pickup	0.167236	16.28507	14.22532	18.62601	545.71648	624.73342	477.13023	4486.464	204.7477	-
1999	Truck	Truck SUV	0.153947	16.07409	14.06198	18.35305	552.87737	631.98791	484.22482	4518.425	203.7447	-
1999	Truck	Minivan/Van	0.096163	18.27843	15.59755	21.48991	486.20154	569.76915	413.54283	4306.442	182.7340	-
1999	Car	Car SUV	0.032106	18.51002	16.28276	21.00012	480.11843	545.79187	423.18814	3831.203	169.6394	-
2000	All	All	1.000000	19.76896	16.93153	23.04602	449.58574	524.92714	385.65762	3821.286	180.9861	-
2000	Car	All Car	0.587890	22.51440	19.00073	26.70778	394.79769	467.80104	332.81386	3400.909	168.2936	-
2000	Car	Sedan/Wagon	0.550664	22.91435	19.27419	27.29134	387.91299	461.17064	325.70324	3369.209	167.9300	-
2000	Truck	All Truck	0.412110	16.83964	14.65487	19.27593	527.74294	606.41966	461.04121	4420.970	199.0925	-
2000	Truck	Pickup	0.157633	16.65304	14.59966	18.90595	533.65646	608.71276	470.06369	4340.005	202.7504	-
2000	Truck	Truck SUV	0.152432	16.00646	14.00116	18.21771	555.21340	634.73290	487.82200	4601.991	206.1898	-
2000	Truck	Minivan/Van	0.102045	18.60865	15.85311	21.83005	477.57348	560.58389	407.09943	4275.636	182.8401	-
2000	Car	Car SUV	0.037226	17.89427	15.70471	20.29007	496.63933	565.88102	437.99759	3869.824	173.6734	-
2001	All	All	1.000000	19.62363	16.80797	22.78645	452.92118	528.79289	390.05579	3879.288	186.9203	-
2001	Car	All Car	0.586189	22.63423	19.09501	26.74363	392.71862	465.50450	332.37724	3410.949	169.3082	-
2001	Car	Sedan/Wagon	0.538570	23.04554	19.37077	27.34719	385.71846	458.88733	325.04965	3379.627	168.4034	-
2001	Truck	All Truck	0.413811	16.51239	14.36991	18.83792	538.20191	618.44488	471.76111	4542.719	211.8690	-

2001	Truck	Truck SUV	0.173438	16.41337	14.38656	18.57948	541.44899	617.72930	478.32339	4545.642	212.8739	-
2001	Truck	Pickup	0.161400	15.95330	13.91933	18.14886	557.06333	638.46478	489.67255	4551.472	215.7755	-
2001	Truck	Minivan/Van	0.078973	18.04383	15.34620	21.12216	492.52304	579.10106	420.74300	4518.412	201.6780	-
2001	Car	Car SUV	0.047619	18.83276	16.44690	21.40144	471.89051	540.34487	415.25248	3765.195	179.5406	-
2002	All	All	1.000000	19.45354	16.63745	22.54129	456.90374	534.23893	394.31726	3950.932	195.4821	-
2002	Car	All Car	0.552494	22.78274	19.22165	26.80270	390.20579	462.49264	331.68524	3415.317	173.3268	-
2002	Car	Sedan/Wagon	0.515107	23.08460	19.42998	27.23154	385.11456	457.54616	326.47198	3391.217	172.9148	-
2002	Truck	All Truck	0.447506	16.48031	14.26903	18.84264	539.24945	622.81737	471.64316	4612.207	222.8351	-
2002	Truck	Truck SUV	0.222654	16.30933	14.11631	18.65377	544.90294	629.55527	476.41834	4636.362	228.6712	-
2002	Truck	Pickup	0.147705	15.75266	13.76730	17.83204	564.15882	645.51495	498.37265	4689.839	226.2520	-
2002	Truck	Minivan/Van	0.077147	18.69997	15.87208	21.85229	475.24129	559.91414	406.68509	4393.857	199.4496	-
2002	Car	Car SUV	0.037387	19.30479	16.74756	22.02409	460.35213	530.64452	403.51278	3747.361	179.0031	-
2003	All	All	1.000000	19.58451	16.67734	22.71480	453.84039	532.95120	391.29896	3998.835	198.5784	-
2003	Car	All Car	0.538633	23.01383	19.31663	27.11813	386.27663	460.20417	327.81870	3437.169	176.4361	-
2003	Car	Sedan/Wagon	0.502186	23.27673	19.48933	27.50336	381.92366	456.13713	323.23612	3416.898	176.1243	-
2003	Truck	All Truck	0.461367	16.68234	14.38302	19.09498	532.71917	617.88131	465.41036	4654.564	224.4289	-
2003	Truck	Truck SUV	0.226424	16.42410	14.13498	18.83505	541.09524	628.72370	471.83304	4753.709	233.4263	-
2003	Truck	Pickup	0.156838	16.07718	14.02019	18.18506	552.77106	633.87142	488.69791	4641.510	222.8414	-
2003	Truck	Minivan/Van	0.078106	18.98231	16.03164	22.21587	468.17267	554.34124	400.02930	4393.361	201.5338	-
2003	Car	Car SUV	0.036447	19.91469	17.21481	22.73126	446.25356	516.24142	390.95947	3716.469	180.7326	-
2004	All	All	1.000000	19.29860	16.34174	22.43337	460.55651	543.88909	396.19983	4111.072	210.5212	-
2004	Car	All Car	0.520447	22.85655	19.05831	27.01504	388.91999	466.42802	329.05421	3492.267	183.6760	-
2004	Car	Sedan/Wagon	0.479792	23.14043	19.25776	27.40872	384.15892	461.60890	324.33677	3461.634	182.5044	-
2004	Truck	All Truck	0.479553	16.50950	14.15243	18.94614	538.30200	627.95582	469.07145	4782.648	239.6558	-
2004	Truck	Truck SUV	0.259388	16.47329	14.08662	18.95305	539.49009	630.89534	468.90451	4755.849	240.1446	-
2004	Truck	Pickup	0.159491	15.73684	13.66672	17.82082	564.72565	650.26564	498.68633	4938.797	248.7484	-
2004	Truck	Minivan/Van	0.060673	19.16282	15.96249	22.67460	463.76265	556.74287	391.93637	4486.746	213.6638	-
2004	Car	Car SUV	0.040655	19.96597	16.98260	23.09951	445.10733	523.30042	384.72676	3853.779	197.5021	-
2005	All	All	1.000000	19.88375	16.78872	23.09573	447.07229	529.49006	384.89749	4059.441	209.0953	-
2005	Car	All Car	0.556205	23.14616	19.35826	27.15454	384.11839	459.27944	327.41794	3498.114	183.0839	-
2005	Car	Sedan/Wagon	0.505059	23.49079	19.59842	27.63056	378.50244	453.67402	321.79405	3462.705	182.1716	-

2005	Truck	All Truck	0.443795	16.89862	14.39415	19.45181	525.97200	617.48456	456.93622	4762.950	241.6952	-
2005	Truck	Truck SUV	0.205865	16.73488	14.29760	19.20456	531.19980	621.74787	462.89160	4755.554	243.8898	-
2005	Truck	Pickup	0.144749	15.84874	13.61025	18.09372	560.73845	652.96396	491.16482	4987.822	259.7066	-
2005	Truck	Minivan/Van	0.093181	19.30215	16.07195	22.75175	460.41503	552.95091	390.60726	4429.968	208.8673	-
2005	Car	Car SUV	0.051146	20.21725	17.26864	23.20650	439.57513	514.63224	382.95310	3847.772	192.0927	-
2006	All	All	1.000000	20.13330	16.98233	23.41006	441.57021	523.49373	379.76825	4066.533	213.1841	-
2006	Car	All Car	0.578934	23.02417	19.20794	27.08348	386.21242	462.93245	328.33591	3563.457	193.7930	-
2006	Car	Sedan/Wagon	0.529181	23.29940	19.39112	27.47722	381.67414	458.58613	323.65282	3534.091	193.9650	-
2006	Truck	All Truck	0.421066	17.16932	14.64863	19.73060	517.68289	606.76083	450.48375	4758.224	239.8453	-
2006	Truck	Truck SUV	0.199005	17.16238	14.68071	19.67089	517.97437	605.52790	451.92521	4715.404	239.5535	-
2006	Truck	Pickup	0.144862	16.13873	13.89294	18.38011	550.66301	639.67737	483.51183	4967.739	255.5367	-
2006	Truck	Minivan/Van	0.077199	19.52993	16.21207	23.09562	455.04508	548.17191	384.79150	4475.457	211.1533	-
2006	Car	Car SUV	0.049753	20.45422	17.45421	23.50149	434.48250	509.16083	378.14622	3875.797	191.9628	-
2007	All	All	1.000000	20.60390	17.38117	23.95452	431.37448	511.35658	371.03710	4093.315	216.9897	-
2007	Car	All Car	0.589234	23.70115	19.83548	27.78629	374.98305	448.06263	319.85285	3550.977	191.2876	-
2007	Car	Sedan/Wagon	0.529061	24.10789	20.12869	28.33333	368.65941	441.53930	313.67984	3507.310	189.4010	-
2007	Truck	All Truck	0.410766	17.35129	14.76118	19.99850	512.26648	602.15007	444.45956	4871.283	253.8586	-
2007	Truck	Truck SUV	0.216970	17.67824	15.07100	20.33166	502.87029	589.86112	437.24563	4797.280	251.7269	-
2007	Truck	Pickup	0.138334	16.16854	13.83998	18.51907	549.64751	642.12526	479.88360	5144.497	268.6433	-
2007	Car	Car SUV	0.060173	20.63947	17.58347	23.75390	430.58272	505.41799	374.12804	3934.913	207.8760	-
2007	Truck	Minivan/Van	0.055462	19.49807	16.14297	23.12361	455.78861	550.51837	384.32581	4479.337	225.3215	-
2008	All	All	1.000000	20.96833	17.67455	24.39839	423.90716	502.90278	364.31396	4085.003	218.5559	48.85985
2008	Car	All Car	0.593057	23.87867	19.97661	28.00541	372.20131	444.90363	317.35570	3568.989	194.0660	45.31546
2008	Car	Sedan/Wagon	0.526586	24.26732	20.24886	28.54007	366.24424	438.92634	311.41388	3526.893	192.8650	45.20013
2008	Truck	All Truck	0.406943	17.80566	15.13308	20.54251	499.26062	587.42779	432.74855	4837.016	254.2462	54.02526
2008	Truck	Truck SUV	0.221038	18.18794	15.50367	20.92042	488.89608	573.53459	425.04597	4727.397	249.9136	48.74836
2008	Truck	Pickup	0.129071	16.47549	14.06863	18.91691	539.40726	631.68897	469.79124	5161.204	276.3228	63.00788
2008	Car	Car SUV	0.066471	21.19014	18.05363	24.38625	419.39320	492.25570	364.42674	3902.476	203.5805	46.22913
2008	Truck	Minivan/Van	0.056834	19.81953	16.42873	23.47455	448.39610	540.94270	378.58024	4527.106	220.9599	54.14838
2009	All	All	1.000000	22.40281	18.91546	26.03912	396.92541	470.10420	341.49614	3914.193	207.7209	47.93705
2009	Car	All Car	0.670303	24.97415	21.00573	29.15699	356.09500	423.36668	305.01171	3501.629	186.0019	45.04628

2009	Car	Sedan/Wagon	0.605014	25.33789	21.26862	29.64854	351.01316	418.16868	299.98139	3464.462	183.8245	44.92996
2009	Truck	All Truck	0.329697	18.52504	15.73258	21.38903	479.93722	565.12572	415.67221	4752.972	251.8775	53.81424
2009	Truck	Truck SUV	0.183972	19.27740	16.41652	22.19533	461.37905	541.78742	400.72010	4547.633	243.5964	48.61423
2009	Truck	Pickup	0.106215	16.89988	14.39181	19.45798	525.86159	617.50394	456.72789	5175.939	277.8993	62.56857
2009	Car	Car SUV	0.065289	22.04188	18.84696	25.27400	403.18697	471.53495	351.62621	3846.047	206.1788	46.12419
2009	Truck	Minivan/Van	0.039511	20.06585	16.67391	23.70344	442.89188	532.98828	374.92443	4572.033	220.4829	54.49287
2010	All	All	1.000000	22.59206	19.11219	26.18930	393.65429	465.33221	339.58148	4001.323	213.6361	48.54913
2010	Car	All Car	0.627501	25.70318	21.66984	29.90173	346.08157	410.49947	297.48562	3536.415	190.1856	45.43572
2010	Car	Sedan/Wagon	0.545198	26.16218	22.01937	30.48967	340.06486	404.04838	291.79659	3474.093	186.6923	45.21904
2010	Truck	All Truck	0.372499	18.76570	15.94241	21.65931	473.79406	557.70201	410.49508	4784.495	253.1402	53.79389
2010	Truck	Truck SUV	0.207388	19.68205	16.79938	22.60871	451.91844	529.47109	393.41382	4555.242	243.1933	48.30706
2010	Truck	Pickup	0.114812	16.85202	14.32492	19.43903	527.35529	620.38751	457.17309	5308.759	288.9247	63.53787
2010	Car	Car SUV	0.082303	23.02703	19.60801	26.51481	385.93780	453.23313	335.17114	3949.247	213.3254	46.87108
2010	Truck	Minivan/Van	0.050298	20.11859	16.73587	23.73819	441.73066	531.01527	374.37560	4533.047	212.4705	54.17514
2011	All	All	1.000000	22.28844	18.83713	25.86317	398.99558	472.11781	343.83319	4125.934	229.9718	49.54439
2011	Car	All Car	0.578225	25.38827	21.32795	29.64592	350.28393	417.00325	299.95181	3616.517	200.0428	45.99051
2011	Car	Sedan/Wagon	0.477828	25.82170	21.62453	30.25109	344.45887	411.35565	293.99288	3559.086	198.5117	45.80972
2011	Truck	All Truck	0.421775	19.09259	16.23742	22.01257	465.77588	547.67607	403.99153	4824.309	271.0024	54.41651
2011	Truck	Truck SUV	0.255377	19.82269	16.91384	22.77790	448.83211	526.02240	390.60083	4665.320	257.2685	49.65835
2011	Truck	Pickup	0.123051	17.23687	14.63211	19.91075	515.58096	607.36296	446.34191	5267.786	303.8330	63.92867
2011	Car	Car SUV	0.100397	23.51011	20.02107	27.06871	378.00765	443.88237	328.31269	3889.853	207.3301	46.85096
2011	Truck	Minivan/Van	0.043347	20.94922	17.56974	24.50498	424.21625	505.81271	362.66103	4502.072	258.7179	55.44647
2012	All	All	1.000000	23.56593	19.94669	27.30319	377.31888	445.79746	325.65960	3978.812	221.7796	48.81134
2012	Car	All Car	0.643820	26.87389	22.70013	31.20175	330.77861	391.62352	284.87806	3519.494	191.9836	45.65266
2012	Car	Sedan/Wagon	0.549736	27.59971	23.27884	32.09360	322.10411	381.91993	276.97990	3451.780	188.7913	45.44823
2012	Truck	All Truck	0.356180	19.27687	16.35979	22.27286	461.44382	543.72082	399.37521	4809.062	275.6382	54.52088
2012	Truck	Truck SUV	0.206068	20.00681	17.06347	22.99968	444.93342	521.68201	387.03537	4639.557	260.5694	49.66824
2012	Truck	Pickup	0.100867	17.20749	14.58427	19.90889	516.46123	609.35496	446.38350	5334.678	316.8917	64.31795
2012	Car	Car SUV	0.094084	23.29446	19.82097	26.84315	381.46382	448.32175	331.02714	3915.148	210.6364	46.84717
2012	Truck	Minivan/Van	0.049244	21.26883	17.72060	25.05315	417.84159	501.50662	354.72587	4441.761	254.1958	54.75999
2013	All	All	1.000000	24.17888	20.49116	27.97717	367.53789	433.74031	317.59572	4002.973	225.8506	49.08053

2013	Car	All Car	0.640886	27.64926	23.39324	32.04776	321.23666	379.76841	277.08113	3542.972	197.0041	45.90822
2013	Car	Sedan/Wagon	0.541262	28.35773	23.97274	32.89718	313.18409	370.57230	269.89123	3465.189	193.9407	45.68693
2013	Truck	All Truck	0.359114	19.75404	16.77686	22.80728	450.16838	530.06009	389.89920	4823.903	277.3308	54.74191
2013	Truck	Truck SUV	0.217773	20.82639	17.78126	23.91618	427.18930	500.36065	371.98985	4584.101	256.6584	49.69878
2013	Truck	Pickup	0.103765	17.47393	14.79418	20.23960	508.58612	600.70936	439.08965	5428.998	328.0566	65.32018
2013	Car	Car SUV	0.099623	24.34480	20.67754	28.10508	364.98702	429.73172	316.14453	3965.578	213.6480	47.11052
2013	Truck	Minivan/Van	0.037577	21.05797	17.52555	24.83404	422.02553	507.08809	357.85552	4542.733	257.0599	54.75788
2014	All	All	1.000000	24.11047	20.44020	27.88816	368.65513	434.90361	318.67820	4059.639	230.2484	49.72043
2014	Car	All Car	0.593428	27.62624	23.38527	32.00481	321.56604	379.96795	277.50845	3559.296	198.1914	46.07330
2014	Car	Sedan/Wagon	0.492449	28.38531	23.99001	32.93776	312.95857	370.39561	269.62888	3496.549	197.0531	45.99471
2014	Truck	All Truck	0.406572	20.33351	17.26636	23.48000	437.38578	515.08702	378.76905	4789.934	277.0384	55.04374
2014	Truck	Truck SUV	0.238926	21.59169	18.42380	24.80986	412.14498	483.02338	358.67530	4482.893	250.4819	49.23501
2014	Truck	Pickup	0.124349	18.03770	15.28095	20.87925	492.69032	581.57388	425.63781	5484.824	333.8904	66.19105
2014	Car	Car SUV	0.100979	24.43912	20.82520	28.12045	363.54246	426.64988	315.93511	3865.299	203.7429	46.45660
2014	Truck	Minivan/Van	0.043297	21.26902	17.73591	25.03059	417.83774	501.07390	355.04554	4488.559	260.3062	55.08304
2015	All	All	1.000000	24.64986	20.92874	28.46829	360.49589	424.68316	312.07392	4035.455	228.8536	49.41850
2015	Car	All Car	0.573573	28.23955	23.90781	32.71055	314.20079	371.29268	271.13147	3555.910	197.3586	46.10941
2015	Car	Sedan/Wagon	0.471935	29.00986	24.48679	33.70677	305.73846	362.41318	262.98385	3488.660	196.2541	46.04941
2015	Truck	All Truck	0.426427	21.05063	17.92452	24.23982	422.76600	496.49705	367.14433	4680.477	271.2166	53.86946
2015	Truck	Truck SUV	0.280602	21.94241	18.74179	25.18729	405.52620	474.78259	353.28015	4533.314	254.0220	49.40054
2015	Truck	Pickup	0.106699	18.80861	15.97440	21.71506	473.52257	557.52520	410.15216	5164.656	324.1680	65.33603
2015	Car	Car SUV	0.101638	25.13993	21.54266	28.76325	353.49382	412.52276	308.96321	3868.169	202.4874	46.38800
2015	Truck	Minivan/Van	0.039126	21.78246	18.29355	25.44309	407.98875	485.79962	349.28932	4415.510	250.1297	54.64930
2016	All	All	1.000000	24.70826	21.02000	28.47909	359.34510	422.45529	311.72153	4035.013	229.9970	49.51239
2016	Car	All Car	0.552937	28.52688	24.18872	32.99037	310.56651	366.39626	268.44933	3533.367	196.3766	46.13906
2016	Truck	All Truck	0.447063	21.19859	18.08914	24.35923	419.67547	491.79026	365.24147	4655.460	271.5793	53.68459
2016	Car	Sedan/Wagon	0.438051	29.20510	24.63590	33.95609	303.32070	359.71035	260.78113	3468.065	197.0935	46.16236
2016	Truck	Truck SUV	0.291228	22.21006	19.03551	25.40994	400.31728	467.03833	349.93531	4482.448	252.4301	49.11920
2016	Truck	Pickup	0.117136	18.92237	16.10266	21.80246	470.91563	553.37609	408.70861	5150.408	324.2175	64.54543
2016	Car	Car SUV	0.114886	26.20640	22.62297	29.76286	338.19432	391.88919	297.68767	3782.359	193.6434	46.05022
2016	Truck	Minivan/Van	0.038700	21.66192	18.07589	25.47444	410.25907	491.64926	348.85944	4459.328	256.3589	55.16716

2017	All	All	1.000000	24.86173	21.12898	28.68466	356.71804	419.80426	309.12662	4093.218	233.6287	49.82204
2017	Car	All Car	0.526242	29.18757	24.76856	33.72696	302.91761	357.11154	262.03437	3556.511	194.2882	46.22486
2017	Truck	All Truck	0.473758	21.34738	18.16418	24.59952	416.47854	489.44217	361.43581	4689.381	277.3275	53.81771
2017	Car	Sedan/Wagon	0.410182	30.18222	25.54201	34.97559	292.68457	346.01719	252.45119	3470.570	193.5764	46.13545
2017	Truck	Truck SUV	0.316822	22.33849	19.07424	25.64993	397.85817	465.91298	346.51858	4509.665	257.3096	49.42928
2017	Truck	Pickup	0.120699	18.91763	16.08738	21.81259	470.48611	553.27096	408.03437	5217.041	332.8031	64.78242
2017	Car	Car SUV	0.116060	26.14273	22.37406	29.94832	339.08337	396.32136	295.90337	3860.246	196.8039	46.54087
2017	Truck	Minivan/Van	0.036237	22.23448	18.40065	26.38102	399.38706	482.55590	336.64567	4503.103	267.5649	55.66431
2018	All	All	1.000000	25.10552	21.47104	28.78077	352.71519	412.58019	307.55383	4136.747	240.6382	50.35453
2018	Truck	All Truck	0.520257	21.87867	18.73352	25.05150	406.31743	474.50873	354.87488	4647.477	276.5302	53.89797
2018	Car	All Car	0.479743	29.88553	25.51427	34.32145	294.58631	345.42188	256.23659	3582.887	201.7153	46.51184
2018	Car	Sedan/Wagon	0.366685	30.76312	26.11862	35.52928	285.55007	336.79567	246.89111	3534.827	205.8925	46.67691
2018	Truck	Truck SUV	0.350080	23.12897	19.90307	26.35092	384.17925	446.43217	337.21651	4426.111	249.7993	49.15120
2018	Truck	Pickup	0.138948	19.10974	16.29858	21.96815	465.99329	546.37019	405.35809	5233.055	345.6733	65.49679
2018	Car	Car SUV	0.113058	27.35458	23.73320	30.91304	323.89382	373.39952	286.54708	3738.760	188.1673	45.97647
2018	Truck	Minivan/Van	0.031229	22.75932	18.84621	26.98635	388.97187	469.51539	328.21097	4523.587	268.5461	55.50305
2019	All	All	1.000000	24.90835	21.32168	28.52865	355.65779	415.66172	310.39167	4155.624	245.0604	50.76888
2019	Truck	All Truck	0.555707	21.97225	18.78717	25.19449	404.28032	472.83600	352.56287	4627.726	280.1252	54.22052
2019	Car	All Car	0.444293	29.90688	25.64972	34.18742	294.84241	344.15011	257.64537	3565.134	201.2025	46.45169
2019	Truck	Truck SUV	0.365134	23.48195	20.16314	26.81109	378.06599	440.32197	331.10095	4444.482	254.6321	49.47699
2019	Car	Sedan/Wagon	0.327121	30.87470	26.31413	35.51857	284.92422	334.79233	247.30441	3511.966	204.1421	46.48327
2019	Truck	Pickup	0.156191	19.02718	16.22906	21.87200	467.41611	548.00736	406.61920	5084.835	342.6648	65.11229
2019	Car	Car SUV	0.117172	27.50025	23.96072	30.94921	322.53195	370.27508	286.51520	3713.568	192.9958	46.36354
2019	Truck	Minivan/Van	0.034381	22.42918	18.62580	26.51345	395.85951	476.64236	334.91807	4497.203	266.7527	55.11702
2020	All	All	1.000000	25.38325	21.91254	28.82778	348.76917	404.24868	306.91621	4166.247	245.8668	50.91736
2020	Truck	All Truck	0.560537	22.36613	19.31524	25.39173	397.46822	460.21861	350.13020	4624.154	278.7972	54.29176
2020	Car	All Car	0.439463	30.65837	26.44893	34.84154	286.65330	332.85875	251.79655	3582.184	203.8639	46.61330
2020	Truck	Truck SUV	0.387245	23.75010	20.56269	26.89512	373.88993	431.82429	330.18506	4447.901	256.7141	49.98036
2020	Car	Sedan/Wagon	0.309382	31.73102	27.07571	36.46014	276.70049	324.90144	240.33837	3509.661	205.5109	46.62108
2020	Truck	Pickup	0.144008	19.19349	16.54507	21.82954	464.56201	538.90647	408.47760	5125.986	342.3512	65.64498
2020	Car	Car SUV	0.130081	28.37686	25.06873	31.51412	310.32488	351.78428	279.04849	3754.670	199.9465	46.59480

2020	Truck	Minivan/Van	0.029284	23.35398	19.73243	27.10708	379.31915	448.74033	326.94878	4487.058	258.2838	55.47374
2021	All	All	1.000000	25.42454	22.16934	28.59160	346.85170	398.13436	308.16477	4289.420	253.4292	51.54670
2021	Truck	All Truck	0.629305	22.72430	19.87594	25.47878	390.65786	446.47781	348.54807	4677.180	276.3308	54.29863
2021	Truck	Truck SUV	0.446674	24.05591	21.12546	26.86749	368.02817	418.90941	329.64408	4492.592	256.7829	50.10093
2021	Car	All Car	0.370695	31.84930	27.56982	36.07345	272.48467	316.06467	239.60853	3631.144	214.5504	46.87492
2021	Car	Sedan/Wagon	0.256894	32.24863	27.58872	36.95782	270.19125	316.88038	234.96963	3562.350	214.4267	46.89220
2021	Truck	Pickup	0.161056	19.32618	16.73546	21.88157	462.58010	534.07175	408.64781	5200.655	337.2059	65.74694
2021	Car	Car SUV	0.113801	30.98324	27.52725	34.22472	277.66181	314.22329	250.08034	3786.440	214.8296	46.83592
2021	Truck	Minivan/Van	0.021576	27.26434	24.12931	30.22703	322.27528	363.35539	291.28503	4591.068	226.6128	55.74402
Prelim. 2022	Car	Sedan/Wagon	-	33.71184	29.17329	38.19438	253.95467	295.33058	222.74126	3628.309	243.0523	47.16722
Prelim. 2022	Car	All Car	-	33.26706	29.19933	37.17375	256.49108	294.15683	228.07656	3695.103	251.7537	47.22416
Prelim. 2022	Car	Car SUV	-	32.38793	29.25306	35.23655	261.70942	291.74199	239.05328	3832.524	269.6559	47.34132
Prelim. 2022	All	All	-	26.35965	23.17949	29.40284	330.81160	377.18480	295.82831	4328.963	272.3535	51.67437
Prelim. 2022	Truck	Minivan/Van	-	25.59317	22.10621	29.04996	344.29378	398.02669	303.75842	4557.279	245.0592	56.21571
Prelim. 2022	Truck	Truck SUV	-	24.75038	21.90441	27.43990	354.13291	400.54552	319.11989	4534.261	268.1756	50.02365
Prelim. 2022	Truck	All Truck	-	23.40912	20.60126	26.09186	375.92690	427.58585	336.95612	4713.739	284.8583	54.37582
Prelim. 2022	Truck	Pickup	-	20.06288	17.49366	22.56268	442.43019	508.03215	392.94099	5239.220	339.0876	65.91698

Table 2 Main car producers worldwide, 1999–2022 (Oica, 2023)

YEAR	CHINA	JAPAN	GERMANY	U.S.	BRAZIL	INDIA	RUSSIA	MEXICO	FRANCE	SPAIN	CZECH REPUBLIC	ARGENTINA	ITALY	SOUTH KOREA	TURKEY
1999	565,366	8,100,169	5,309,524	5,637,949	1,107,751	533,149	943,732	993,772	2,784,469	2,281,617	348,482	224,733	1,410,459	2,361,735	222,041
2000	604,677	8,359,434	5,131,918	5,542,217	1,351,998	517,957	969,235	1,279,089	2,879,810	2,366,359	428,224	238,921	1,422,284	2,602,008	297,476
2001	703,521	8,117,563	5,301,189	4,879,119	1,501,586	654,557	1,021,682	1,000,715	3,181,549	2,211,172	456,927	169,580	1,271,780	2,471,444	175,343
2002	1,101,696	8,618,354	5,123,238	5,018,777	1,520,285	703,948	980,061	960,097	3,292,797	2,266,902	441,312	111,340	1,125,769	2,651,273	204,198
2003	2,018,875	8,478,328	5,145,403	4,510,469	1,505,139	907,968	1,010,436	774,048	3,220,329	2,399,374	436,279	109,364	1,026,454	2,767,716	294,116
2004	2,480,231	8,720,385	5,192,101	4,229,625	1,862,780	1,178,354	1,110,079	903,313	3,227,416	2,402,501	443,065	171,400	833,578	3,122,600	447,152
2005	3,941,767	9,016,735	5,350,187	4,321,272	2,011,817	1,264,111	1,068,511	846,048	3,112,961	2,098,168	596,774	182,761	725,528	3,357,094	453,663
2006	5,233,132	9,756,515	5,398,508	4,366,220	2,092,029	1,473,000	1,177,918	1,097,619	2,723,196	2,078,639	848,922	263,120	892,502	3,489,136	545,682
2007	6,381,116	9,944,637	5,709,139	3,924,268	2,391,354	1,713,479	1,288,652	1,209,097	2,550,869	2,195,780	925,060	350,735	910,860	3,723,482	634,883
2008	6,737,745	9,928,143	5,532,030	3,776,641	2,545,729	1,846,051	1,469,429	1,217,458	2,145,935	1,943,049	934,046	399,236	659,221	3,450,478	621,567
2009	10,383,831	6,862,161	4,964,523	2,195,588	2,575,418	2,175,220	599,265	942,876	1,819,497	1,812,688	976,435	380,067	661,100	3,158,417	510,931
2010	13,897,083	8,310,362	5,552,409	2,731,105	2,584,690	2,831,542	1,208,362	1,386,148	1,924,171	1,913,513	1,069,518	508,401	573,169	3,866,206	603,394
2011	14,485,326	7,158,525	5,871,918	2,976,991	2,519,389	3,040,144	1,744,097	1,657,080	1,931,030	1,839,068	1,191,968	577,233	485,606	4,221,617	639,734
2012	15,523,658	8,554,503	5,388,459	4,109,013	2,589,236	3,296,240	1,970,087	1,810,007	1,682,814	1,539,680	1,171,774	497,376	396,817	4,167,089	577,296
2013	18,084,169	8,189,323	5,439,904	4,368,835	2,722,979	3,155,694	1,927,578	1,771,987	1,458,220	1,754,668	1,128,473	506,539	388,465	4,122,604	633,604
2014	19,928,505	8,277,070	5,604,026	4,253,098	2,502,293	3,162,372	1,682,921	1,915,709	1,499,464	1,898,342	1,246,506	363,711	401,317	4,124,116	733,439
2015	21,079,427	7,830,722	5,707,938	4,163,679	2,018,954	3,378,063	1,214,849	1,968,054	1,553,800	2,218,980	1,298,236	308,756	663,139	4,135,108	791,027
2016	24,420,744	7,873,886	5,746,808	3,934,357	1,778,464	3,677,605	1,124,774	1,993,168	1,626,000	2,354,117	1,344,182	241,315	713,182	3,859,991	950,888
2017	24,806,687	8,347,836	5,645,581	3,033,216	2,269,468	3,952,550	1,348,029	1,900,029	1,748,000	2,291,492	1,413,881	203,700	742,642	3,735,399	1,142,906
2018	23,529,423	8,358,220	5,120,409	2,795,971	2,386,758	4,064,774	1,563,572	1,575,808	1,763,000	2,267,396	1,345,041	208,573	670,932	3,661,730	1,026,461
2019	21,360,193	8,328,756	4,661,328	2,512,780	2,448,490	3,623,335	1,523,594	1,382,714	1,675,198	2,248,019	1,427,563	108,364	542,007	3,612,587	982,642
2020	19,994,081	6,960,025	3,515,372	1,926,795	1,608,870	2,851,268	1,260,517	967,479	927,718	1,800,664	1,152,901	93,001	451,826	3,211,706	855,043
2021	21,407,962	6,619,242	3,096,165	1,563,060	1,707,851	3,631,095	1,352,740	708,242	917,907	1,662,174	1,105,223	184,106	442,432	3,162,727	782,835
2022	23,836,083	6,566,356	3,480,357	1,751,736	1,824,833	4,439,039	448,897	658,001	1,010,466	1,785,432	1,217,787	257,505	473,194	3,438,355	810,889

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