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School of Industrial and Information Engineering

Master of Science in Mechanical – Mobility Engineering

The Role of Infrastructure in the Automotive Value Chain

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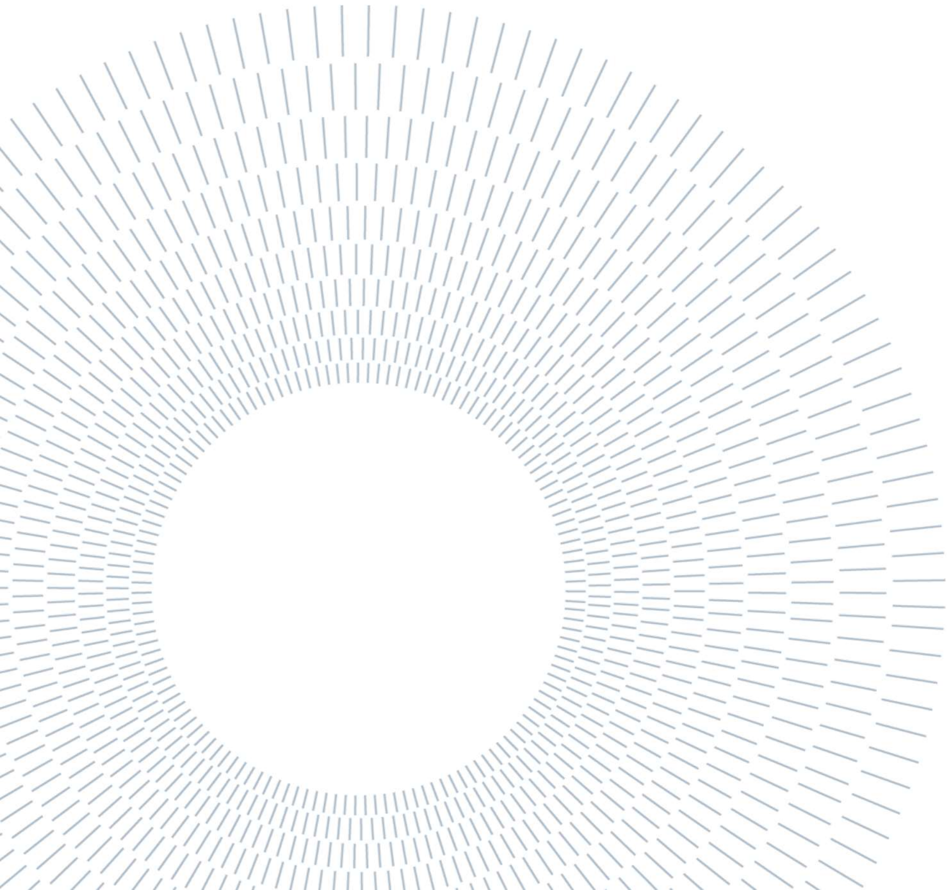

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EXECUTIVE SUMMARY OF THE THESIS

The Role of Infrastructure in the Automotive Value Chain

TESI MAGISTRALE IN MECHANICAL – MOBILITY ENGINEERING

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1. Introduction

The automotive industry has been in continuous progress from its origin to the present, despite the ups and downs of global or territorial crises, and it has had a direct impact on the economies of many countries as well as society itself. The automotive sector became the fundamental core of Western countries' development due to the continuous technological research associated with the production of increasingly advanced cars [1]. In recent years, the government has provided incentives for customers to buy new alternative-fuel-based vehicles [2]. The importance of the automotive sector is thus enormous in modern economies, especially because of the value chain that is part of this great industry. Vehicles were the first to shift to more environmentally and sustainably friendly changes as a result of rising oil prices and CO_2 emissions [3] [4]. This vehicle modernisation has generated new approaches to the road and its applications. New cars, whether electric or hybrid, require, among other things, adequate parking space, the establishment of charging stations, proper signage, and innovative infrastructures. With the emergence of new electric, autonomous, connected, and shared cars, road infrastructure may play a critical part in the Green Deal, the European Union's green energy transformation [5] [6]. The common vision of automotive infrastructure was related to building new roads and taking care of the maintenance, and the role of infrastructure was to connect different parts of the country, from cities to villages, and provide fuel in the filling stations. Nowadays, with the development of new technologies, the role of infrastructure is not only to build and maintain roads, but also to manage the demand for energy, to find innovative solutions to increase kilometres by recharging vehicles as they travel on them, making them competitive with conventional ones, and to increase safety on the roads through smart and integrated solutions. The mobility of the future will also make it possible to realise the concept of Vision Zero [7], which pushes society to have zero crashes, zero pollution caused by means of transport and zero traffic in cities. Future mobility will be built on new paradigms aligned with increasing consumer needs and new technology accessible on the market, both of which will enable new business models and consumer services. Consumer preferences are continually changing, and new consumption habits, lifestyles, and awareness of environmental sustainability challenges are emerging. It is clear that technology is the enabling component in the change of traditional mobility into a model that is more linked, close to consumer needs, and plays a vital role in smart society [8]. The new mobility models will be built on systems that optimise city and vehicle fleet management. The platforms will enable the development of the MAAS model [9]: the platform addressing the mobility service user will become a one-stop-shop for all of the individual's mobility needs, integrating micro-mobility systems, local public transportation, and individual mobility with shared vehicles. In the Italian scenario, this entire process will be supported by the PNRR, where the government underlines that it is a priority to pursue an "ecological transition towards complete climate neutrality and sustainable environmental development to mitigate the threats to natural and human systems; without a substantial reduction in climate-altering emissions, global warming will reach and exceed 3-4 °C before the end of the century, causing irreversible and catastrophic changes to our ecosystem and significant socio-economic impacts". The main objective of this dissertation is to comprehend how the role of automotive infrastructures may truly transform the environment and influence the future of the automotive value chain supported by the visions of automotive experts. As automotive infrastructure is indeed a broad topic, the focus is on the key trends that are shaping the automotive transformation, such as charging infrastructure, H_2 fuelling, 5G telecommunications, smart roads and smart cities, and shared mobility. The focus is on the infrastructure related to passenger cars. This paper is divided into five major sections: first, a description of the state of the art will be presented, followed by an analysis of the value chain, then a qualitative analysis, after that an explanation of the survey methodology with the analysis of the results and lastly the discussion and conclusions.

2. The state of art

The petrol stations are widespread across Europe, especially in Italy, which has the highest number. Environmental issues are increasingly capturing global attention, and many businesses and governments around the world are taking action to help change the trends. Transport accounts for more or less one-fifth of the global CO_2 [10] and road transport is responsible for almost three quarters of the total emissions, which means around 15% of the total. On some day in future the non-renewable resources get exhausted, and it is required to look for some alternatives that can sustain the future of automotive sector, such as HEV, PHEV, BEV, and FCEV. HEV and PHEV are useful for people transitioning from ICE to different options because they can reduce the CO_2 emission and dependency of petrol. Electrically chargeable vehicles, PHEV and BEV, need the use of CCS plugs for DC fast charging, and they are intended to charge EVs quickly in public environments. The presence of CCS in Europe is denser in the northern part and the same situation happens in Italy. FCEV requires the production of hydrogen, which now uses hydrocarbons as the main feedstock, but an increased integration of renewable technology, such as electrolysis, will become necessary. SMR is now the most cost-effective method of producing H_2. However, alternative techniques must be developed in order to lessen reliance on fossil fuels, so that commodities may confront an increase in hydrogen demand, at least in the transportation sector, as a result of population growth and fossil fuel depletion in the next years [11]. Thus, there are extremely few hydrogen-based fuelling stations, which is due to the high cost of transportation and manufacture of green hydrogen fuel, as well as the limited number of vehicles produced now, resulting in a lower demand than for other fuels. Europe focuses more on the manufacture of clean hydrogen technologies and is well positioned to benefit the worldwide growth of clean hydrogen as an energy carrier [12]. In Italy the hydrogen infrastructure is too low to consider FCEV as an alternative. The table below summarizes the different infrastructures for each type of vehicles, highlighting the availability of stations across Europe.

	PETROL	ELECTRIC	HYDROGEN
	 Petrol station	 Charging station	 H_2 fuelling station
Suitable powertrains	▪ ICE ▪ HEV ▪ PHEV	▪ PHEV ▪ BEV	▪ FCEV
Availability in Europe	Widely available	Limited	Very limited

Table 1: Energy infrastructures

Apart from energy transition, other trends, such as connected and autonomous car, are evolving and acquiring new features. They are widely regarded as a technology with significant potential to improve transportation safety, traffic functional ability, dependability, and urban sustainability. Connected cars used to be the linkage between phone and the automobile system, however things have evolved, and connected cars now connect one car to another, allowing various vehicles to communicate with each other. Autonomous cars drive themselves from a starting point to a predefined destination using a variety of technologies and sensors. Europe began with controlled environment testing and is now concentrating on public transit initiatives. Autonomous vehicles can happen only if the cars are well and safely connected with each other and with the infrastructure, which means that connecting car is the first step to go further in the growth of autonomous vehicle also developing the 5G telecommunication infrastructures, smart roads, and smart cities. In this process it should be discussed and create the best policies to construct a new vision of the car and not just a mean of transportation to go from one to another location. The last infrastructure considered is shared mobility, which refers to passengers using a vehicle collectively for transportation without owning it. The cars used in shared mobility may run on any sort of fuel and the main goal is to limit the usage of private vehicles, which can cut emissions by a specific proportion and reduce traffic congestions. The emphasis is on car sharing, especially focusing on e-autos. The primary objectives are to minimize emissions and increase passenger comfort. The number of trips in car sharing is globally increasing, and new companies are getting involved in this movement investing time, effort, and money to earn a share in the market. Germany is the biggest European car sharing market, while in Italy, Milan is the center for free floating, where Sharenow, Enjoy and Share'ngo are the leading companies in the market.

3. Automotive value chain

The value chain is a primary tool for understanding and interpreting the resources and capabilities in a structured manner by studying all a firm's operations and how they connect [13]. The value chain represents overall value and is made up of value activities and margin. This section helps us to describe all the elements in the automotive value chain, understanding the role of infrastructures in the future value chain, which create value in the process and interact among them. Actors, technologies, and infrastructures create interactions in all the key trends considered, like in electric mobility.

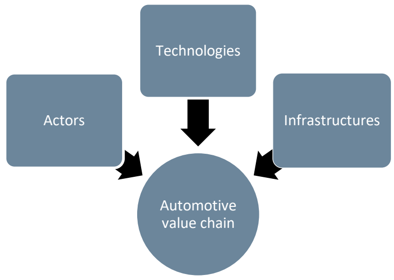

Figure 1: Automotive value chain elements

The actors considered are: the manufacturers, the suppliers, the automotive consumers, the service providers, government, and substitutes [14]. Most businesses use a wide range of technologies, from those needed to prepare paperwork and convey items to those embedded in the product itself. Filters, next-generation batteries, ultracapacitors, charging sockets, radar, lidar, and cameras are among the technologies chosen. Infrastructures are especially important in the automotive business, because without good infrastructures, it is extremely difficult for manufacturers to attract customers. In this section, the infrastructures considered are energy and communication. In the energy infrastructure, the value is created by public charging facilities, either in AC home charging and public charging or DC, Gigafactories, battery swapping, dynamic charging, and H_2 refuelling stations. Most users who have a separate garage prefer home charging infrastructure as a safe mode of charging their vehicle, reducing charging vehicle reliance on charging stations. V2G is a technique that allows the transfer of energy back to the electrical grid from an EV's battery. Europe has decided to play a significant role in the global manufacturing of batteries for the automotive industry, and the European network of Gigafactories will evolve over the next several years. Together with Northvolt, among the most popular European initiatives in this era has been Tesla's proposed venture in Germany. The business plans to establish a European Gigafactory, with the goal of eventually reaching a capacity of 40 GWh. As EVs gain popularity, numerous stakeholders are seeking ways to make them more affordable, simple to recharge, and cost-effective to run. Battery swapping is a type of infrastructure that provides all these advantages to fleet operators. A switching unit is built in a prime location, with numerous batteries regularly recharged. An EV user may find a swapping depot and exchange the depleted battery with a fully charged one. Instead of waiting for the charge to be completed or the time to swap the battery users may opt for the dynamic charging technology, which can recharge an EV on the go and increase the range. In the case of FCEVs, the infrastructure studied is H_2 refuelling stations. Hydrogen can be used to convert surplus electricity for use in other sectors, for cost-effective mid and long-term storage of energy and for cost-effective transport leveraging existing gas infrastructure. Italy can become a European hydrogen hub and it has significant potential to use its solar and wind resources for the low-cost production of hydrogen [15]. The process of refilling hydrogen with a hydrogen pump is like refuelling with gasoline at a regular petrol station. The hydrogen refuelling station is an innovative technology and it features a tank that may be above or below ground. In the communication infrastructure, the value is generated by the spread of 5G telecommunication infrastructure, the design of smart roads, and smart cities. A connected car employs many communication technologies, where automotive and information technology collaborate. The main connectivity infrastructures are: V2I, V2V, V2C, V2P, and V2X. The automotive environment is experiencing considerable upheaval because of connectivity; V2X is a vital component of this development, enabling capabilities such as safety warnings and improved traffic management. These services will support a growing number of future mobility models as well as continued evolution in connected ecosystems, which will necessitate communication standards to ensure data interoperability and security to maximize the benefits of V2X infrastructure. Wi-Fi DSRC, cellular C-V2X, and 5G C-V2X standards have emerged as the leading candidates for V2X data transmission, and major industry stakeholders have differing perspectives on the best solution and the ultimate winning solution is likely to have a transformative influence across the ecosystem. With increased demand on communities to build more efficient motorways and highways, smart infrastructure is critical for modernization. Smart roads based on IoT technology enable cities to gather and analyse data to enhance day-to-day traffic management and adapt to long-term transportation demands. Data from IoT sensors, cameras, and radar may be processed in near real time and used to enhance congested streets and streamline traffic flow. Data may also be transferred to the cloud for long-term study, offering important knowledge for initiatives such as lowering CO_2 emissions or improving road conditions. The smart infrastructure also includes smart cities, which have to develop a strong partnership between government and private industry to support a digital and data-driven society. Private companies may also be adopted to analyse the data, which will then be submitted back to the local administration. The desire for shared transportation services, as well as the opportunity to minimise personal car ownership in return for simple access to automobiles, is driving the shared mobility trend. Each user's vehicle experience must be tailored to their own demands. Eventually, each shared car will be able to be configured for the driver. Whether it is a livery service or a car-sharing vehicle leasing, easy access to mobility applications and cloud data makes it all possible. Sharing models can be free-floating or station-based. Car owners in P2P car sharing enable other drivers to make use of their vehicles for a fee. Private-car owners transport paying passengers to their destinations in P2P ridesharing. Infrastructures, actors, and technologies have a relationship with each other in the automobile value chain. The elements listed cannot work independently. To run a profitable organization, these factors must rely on one another to meet the consumer's demands. For example, considering network operators as actors, they may gather essential information from customers using Wi-Fi and 5G technologies, and this information can be kept in a data cloud management system. In case of connected and autonomous cars, infrastructure focuses on smart cities and telecommunications. With the help of IoT used in a connected world, smart cities ensure the safety and security of the driver and the people who live within it. Supporting the infrastructure, technologies such as lidar, radar, cameras, and other sensors can be installed to observe vehicles and the surroundings. It is important to underline that all the trends are connected to each other, and they can be pushed or discouraged by societal change and technology. Customer demand can also create interesting outcomes. Some tools to analyse future mobility trends are creating scenarios with the right methodology to find out the strategic decisions to support a particular trend.

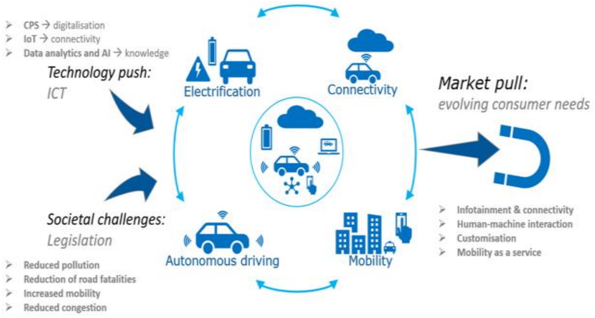

Figure 2: Correlation between the trends

4. Qualitative analysis

Forecast studies based on vehicle types and infrastructures, projects including connected and autonomous automobiles, socio-economic analyses, SWOT analyses, and finally some hypothetic scenarios are developed in this chapter to better comprehend the major essential elements in the automotive sector. The forecast analysis gives an idea on how the trends are going and what they could be in the future. The analyses give us some qualitative scenarios for the future. It is extremely hard to predict the future, especially when there are few data available and those automotive trends are quite new, so the level of uncertainty can be high if new regulations, political changes, or some disruptions happen. The data analysed are relative to infrastructures and vehicles, in particular passenger cars, located in Europe and Italy taking into consideration the path to 2050 to fight against climate change. The two models used to forecast are linear and exponential smoothing. The first infrastructure analysed is the European charging stations. The year over year growth rate has always been positive in the timeframe considered and the lowest value is 13% referred as 2018 [16]. The availability of the charging points distribution across Europe is unbalanced with 70% of the total located in just 3 countries: Germany, France, and Netherlands. Italy and Sweden are among the top 5 European countries for the total number of charging stations. The plot below depicts the forecasted number of charging stations in Europe according to historical data and considering 2035 as a reference year to understand the development of the infrastructure in a medium-term perspective. In case of linear growth, the forecasted values are around 1.8 million in 2035 and almost 5 million in 2050. In the exponential smoothing forecast model, the worst cases illustrate around 1.5 millions of charging points in 2035 and almost 4 million in 2050, while the best cases are their double with 2.9 million in 2035 and 7.5 million forecasted in 2050.

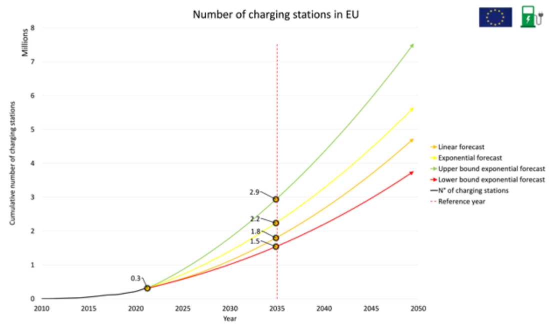

Figure 3: Forecasted number of charging stations

The forecast analyses have been done for all the infrastructures considered both from European and Italian perspectives, whenever the data were available to get a vision about the future, based on past observations. In order to have a deeper vision, the analyses also include the new cars registration from European and Italian perspectives. Studying the number of H_2 new cars registration in Europe it is clear the uptrend in the last years, however, considering the absolute values, the numbers are extremely low, that means that H_2 cars are still in the developing phase. The figure below illustrates the situation described above with a positive trend in all the forecasted number of hydrogen cars new registration with a maximum of three thousands in 2035 and almost five thousands in 2050. H_2 cars are highly dependent on how the infrastructure will be developed. Nowadays, this technology has been planned for heavy duty transport. Those forecasts are relative to private passenger cars; however, those numbers could highly increase after the hydrogen taxis fleets deployment in Europe.

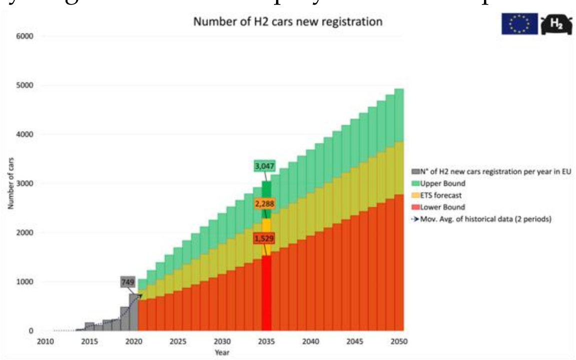

Figure 4: Forecasted number of H_2 new cars registration in Europe

Analysing the historical data, the correlation between cars and the related infrastructure is very strong. The highest value of Pearson Coefficient is obtained in case of hydrogen, followed by the robust relationship in the Italian case. This means that having a big increase in the development of the infrastructure can be interpreted into a higher level of decarbonization in the roads given by a greater presence of alternative fuels cars. Connected and autonomous technologies are currently evolving and, on their way, to become the dominant reality of future transportation systems and smart city infrastructure. Tech titans, such as Google, and car manufacturers, like BMW, Volvo, and Tesla, has already begun testing in several nations. Many pilot studies have been done in recent years to better understand the true effects of autonomous vehicles, analyse the technology, and collaborate with service providers. It is clear that the majority of pilot studies employed small-size shuttle buses, implying that the objective of the pilot research is to deploy AVs as a public transportation mode, addressing the first and last mile in an attempt to increase users and minimise automobile ownership. Additionally, pilot trials in Singapore began in 2015, and it is considered as one of the world's most AV-friendly countries, with data showing a 15% drop in car ownership by 2018, indicating a significant potential in a short period of time. The Swedish project is the only one focused on testing driverless trucks, with findings indicating a 10% reduction in fuel usage and three regular vehicles being substituted by one autonomous truck. In other words, the study revealed that the AV transportation business is very efficient. Anas, the state-owned firm in charge of managing Italy's main roads, is investing 140 million € on connected car technology for around 2,500 kilometres of its network, with special work on roads such as Rome's Grande Raccordo Anulare ring freeway. Turin is also conducting a trial of an AV minibus service run by Local Motors, which uses Olli, an EV constructed completely of 3D printed parts. Smart roads and smart city infrastructure including 5G technology network management sensing devices, intelligent stoplights managing, can assist reduce the latency for notifications or advisories, permitting data to be transmitted in close time to support enhance the reliability and safety of driverless cars. The increased cost of automobiles affects consumer prices and reduces real income and expenditure. It shifts expenditure away from other areas of the economy and toward the value chain for producing cars and their component parts. Better fuel efficiency, on the other hand, decreases consumer operating costs, which benefits the economy. It moves expenditure away from oil supply networks and towards other sectors of the economy. Since oil is imported into Europe whereas decarbonised fuels are produced there, the shift in fuel spending benefits the European economy and improves the trade balance. Connected and autonomous cars are predicted to have a beneficial economic impact overall. However, certain industries will be badly impacted. For example, increased road safety is likely to result in significant economic losses for the insurance industry. In contrast, the digital industry is predicted to provide exceptional results. The SWOT analysis is the method used to delve deeply into the infrastructures research.

Figure 5: Shared mobility infrastructure SWOT analysis

Considering the shared mobility SWOT analysis as an example, strengths (S), weaknesses (W), opportunities (O), and threats (T) are summarized below:

S1) Decline in pollutant rate and traffic congestion: It is expected that each shared car decreases CO_2 emissions by using more fuel-efficient, low-emission automobiles. Using one car for a person may result in more pollution and also leads to traffic congestion. If individuals establish the practise of utilising shared transportation, it may lower overall emissions when compared to person using his own car. If the trend changes and people start to show interest in alternate fuel types such as electric or hydrogen cars including autonomous vehicles can eventually help to reduce pollution.

S2) Decrease in cost of travel: Shared mobility may be more appealing to persons who can commute in a range of choices. This is intended for individuals out there that could not afford to have their own automobile. They use this sort of trend to meet their needs instead of purchasing it also the owner doesn't have to purchase a parking permit or look for an affordable or free parking spaces because the value is added in the service charge that is collected for the travel. They also receive bonuses while utilising it, which is an added benefit for customers.

W1) Carsharing users are less: Several individuals prefer to drive in personal cars because they believe that car-sharing subscribers are paid additional taxes on with their membership and use costs, because there is no differentiation between standard car hire and car-sharing and the tariff would be as expensive. This rise is added to the original price plan; therefore, it increases the customer's financial cost and may affect low-income consumers also during covid pandemic, the users prevented utilizing this trend as it may lead to spread of the virus.

W2) Limitation towards plan changes: It is advised that the people use car sharing and also E-hailing need to stick with the plans and it cost them extra amount if they go beyond the travel range, and it is crucial to discern the economic efficiency of car-sharing since they only examine the gasoline expense per trip instead of the contribution margin and the price of the trip may vary also depending upon the environmental factors like when there is a demand for the vehicle due to heavy rain, unavoidable traffic congestion may lead to hike in the travel price as a result, an individual car-sharing trip appears to be economically high. It is a sort of problem that is mostly concerned by the users, and they lose their freedom and need to always be specific with the plans.

O1) Merging different trend with shared mobility: Besides the traditional automobiles, alternative fuels such as hydrogen and electric vehicles can be employed. This can also serve to accelerate the expansion of many of these vehicle types. The role of connected automobiles and self-driving cars in the future can be employed in the shared mobility industry to improve the user experience and future technologies.

O2) Growth of entrepreneurs: In the future, investment in shared mobility may rise. As driverless cars become more prevalent in the market, there may be a surge in the number of entrepreneurs. Everyone has access to this infrastructure and can learn about this field. Various business models will also be created in order to stabilise the economy.

T1) Insurance as additional cost: If a person rents a car from this type of company, insurance is required. It is required for the vehicle and the passengers within the automobile. Car-pooling firms sometimes charge an additional fee for insurance, which raises the cost of the journeys. Despite the fact that it is a safety risk for the passengers, it adds to the owner's charge.

T2) Reliability and availability of car sharing and services: In the event of a negative encounter, user trust might simply be broken. A particularly traumatic event of one customer might affect many other users in case the word is disseminated. Car sharing services are few, and they are not suited for persons who need to drive great distances or in rural areas. In the event of an emergency, it would be impossible for the corporation to trace the car.

The SWOT analyses have been performed for all the infrastructures studied. The last analysis is creating and studying scenarios. The main scenarios created are four with sub scenarios inside of them covering most of the cases which can happen in the future trends considered. The variables analysed are: the main actors in the value chain, the potential partnerships, incentives, CO_2 emissions, congestion, parking ownership, socio-economic and energy demand.

5. Q-methodology

The methodology used to support the vision about the future of automotive value chain is Q methodology, also known as Q sorting. It is a distinct set of psychometric and operational principles that, when combined with statistical applications of correlational and factor-analytic techniques, provides a systematic and rigorously quantitative procedure for examining the subjective components of human behaviour. The double premise that subjective opinions are communicable and advanced from a position of self-reference is a consequence. One essential premise aimed at preserving self-reference and subjective communicability is that “measurements and observations of a person’s subjectivity can only be made by himself” [17]. The concourse of communication is a key concept in Q technique, and it is analogous to a target population for sample in traditional survey research. Concourse refers to the number of notions about a topic and concourses provide the “raw material” for Q studies by providing “self-referent notions” [18] that enrich the methodology’s perspective on subjectivity. Even though a person sample of 25 to 50 participants is often considered adequate for such purposes, studies trying to assess the nature and range of points of view on a given topic are substantial by Q's standards [19]. Every effort is taken to guarantee as much variability in the composition of the P-set as is practical given the circumstances [20]. The variables that emerge are generalisations of views held by those who define the elements. As a result, they allow for direct comparisons of attitudes as attitudes, regardless of the number of people that fill them. The Q set is the selection of statements of crucial importance to answer to the research question. It is constituted 50 statements touching all the infrastructure trends considered. The participants in Q, named P-set, are not chosen at random; rather, they are purposely chosen to be as diverse as possible. Q methodology often entails “a structured sample of respondents who are theoretically relevant to the problem under consideration; for instance, persons who are expected to have a clear and distinct viewpoint regarding the problem”. In this analysis the P-set is constituted by 25 experts, who are classified according to their position in the automotive value chain. After the P-set was constructed, participants were instructed to sort the statements by rank, with their responses ranging from 11 (completely agree) to 1 (strongly disagree). This Q-sorting is characterised by a quasi-normal forced distribution, in which only a restricted number of items may be placed in each column. The software used to collect the data was Q-tip. After the completion of the Q-sorting procedure, different statistical analyses were performed. In Q methodology, data analysis entails the sequential use of three sets of statistical procedures: correlation, factor analysis or PCA (Principal Components Analysis), factors score computation. In the analysis the correlations are expressed in percentage and most of the participants have a positive correlation among them with some exceptions with slightly negative values. In the factor extraction, with the help of Kaiser criterion and scree test 4 factors that express more than 50% of the variance were selected. Applying an orthogonal rotation, also known as varimax, the P-set was divided into 4 groups according to each factor. The goal of interpreting the Q methodology results was to discover the similarities and contrasts between the four mindsets, as well as the features in their component makeup. For each factor, distinguishing statements were discovered and studied. These were the statements with the highest z-scores in a specific factor when compared to the other factors. Finally, consensus statements (similar z-scores among components) provided a crucial information about which themes were agreed upon by all experts. Furthermore, the post-surveys, in which participants were asked to determine the motivations behind their rankings and to add some comments, were useful to have a clearer vision. A composite or “idealised” Q-sort for each of the four factors is computed based on the standardised z-scores of each statement, which are similar across all variables. We turned them into the following mindsets after a thorough investigation of the factors: “socially oriented”, “safety concerned”, “development enthusiast”, and "electro smart”. In the table below, the largest connections occur between development enthusiast and electro smart (0.5246), as well as between socially oriented and safety concerned (0.4316). Socially oriented and development enthusiast have the lowest correlation (0.2628).

	Factor 1 (socially oriented)	Factor 2 (safety concerned)	Factor 3 (development enthusiast)	Factor 4 (electro smart)
Factor 1 (socially oriented)	1	0.4316	0.2628	0.3834
Factor 2 (safety concerned)	0.4316	1	0.2892	0.3146
Factor 3 (development enthusiast)	0.2628	0.2892	1	0.5246
Factor 4 (electro smart)	0.3834	0.3146	0.5246	1

Table 2: Correlation matrix

In the first factor, the experts here want to encourage the government and society to construct infrastructure for all of the alternatives that were considered, so that they can adapt to any type of alternate vehicle if the infrastructure for that specific vehicle is enhanced in the future. Furthermore, these experts feel that investing in charging infrastructure in this decade could not yield a high return on assets, and with that of smart roads and smart cities, they feel it would not improve customer willingness to spend additional money for the purchase of autonomous cars. When it comes to safety concerned mindset, everyone in this world is mostly concerned about safety. In this way, experts in various fields are more concerned about these factors. They are mainly focused on the infrastructure and its development with proper care in such a way that it does not harm any individual. It can be seen that they are focused on the emission of CO_2 and also suggest that the infrastructure for both electric vehicles and fuel cell electric vehicles is perceived to be unsafe. It is to be noted that this particular group does not think that cities are the best places for the development of autonomous car infrastructure, and they also think that a private place may not promote the growth of electric infrastructure. The mindset development enthusiast show much more interest in the field of technological development than others. They believe that particular technologies can help the automotive sector shape up in a better way. As can be seen, experts are more focused on the statement "cities are the best people to develop e-autos for car sharing", and they also have a greater interest in dynamic charging technology, as well as the development of smart cities and smart roads. So basically, the mindset of these experts here is clearly seen in such a way that if the technology is developed, then the transition from fossil fuel vehicles and their infrastructure can be changed to other alternative fuel-based vehicles. From the negative perspective, the experts believe the 5G telecommunication infrastructure does not much enhance road safety and also, in the case of CO_2 emissions, it is clear from the table that the experts are more negative towards the statement that charging stations are perceived as unsafe by the users. The last factor shows experts who perceive that electric vehicles and their charging infrastructure are the most concerning aspects that might help with CO_2 emissions reduction. They also feel that the concept of Gigafactories can help to accelerate the expansion of electric vehicles. Experts also believe that battery swapping technology, which can be employed for e-autos for car sharing, can assist in boosting the range and utilization of this trend. On the other hand, we can certainly see that they are in a position where specialists believe that charging stations throughout Europe will not be balanced until 2035. They also feel that charging stations are secure but feel that privacy for car sharing is always an issue.

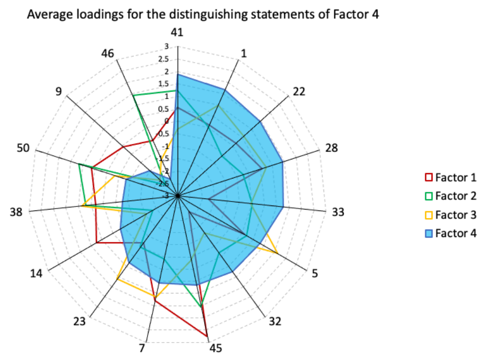

Figure 6: Average loadings for the distinguishing statements of electro smart

Consensus statements identify themes on which experts gave comparable scores and agreed. The three assertions in the table demonstrate the experts focus, which implies that the majority of the experts concur with the three claims in the table. As we can see, the majority of them disagree with the remarks about hydrogen. For example, experts anticipate that by the year 2050, the Italian hydrogen infrastructure will not be spread much. Furthermore, experts believe that deploying new hydrogen stations on highways before 2035 is still a debate. There is always a dispute over whether alternative fuel-based cars, such as battery electric vehicles and hydrogen electric vehicles, will not be slowed down with the expansion of hybrid electric vehicles.

		Z-Score			
No.	Statement	Factor 1	Factor 2	Factor 3	Factor 4
15	Hydrogen fuelling stations will be installed across Italy by 2050.	-0.76	-1.4	-0.71	-0.76
20	New hydrogen stations will be deployed only on the highways before 2035.	-0.24	-0.68	-0.93	-0.73
26	The transition from gasoline infrastructure to electric and hydrogen infrastructures will be slowed down by the adoption of hybrid vehicles.	-0.55	-0.18	-0.52	-0.69

Table 3: Consensus statements

The majority of respondents in the automotive value chain have a mindset towards technological development, in particular they believe that it is the right time to invest in innovative technologies to create smart roads and smart cities and step by step follow the transition towards a more sustainable future mobility. Nonetheless, the other mindsets also consider in the process the social aspects being careful about the safety.

Group	Socially oriented	Safety concerned	Development enthusiast	Electro smart	Total
Car manufacturer				1	1
Finance and insurance	1		1	2	4
Infrastructure mobility		1		3	4
Integrators	1		3		4
Other	1			1	2
Start-up		1			1
Universities / consulting		1		1	2
Vertical solutions	1	1	4	1	7
Total	4	4	8	9	25

Table 4: Associations

In this process experts think that it is critical that purchasing incentives coexist with those for charging infrastructure. They also think that 5G technology is established and ready for widespread use and V2X is a key enabler to enhance road safety. These comments highlight their point of views:

"It is important that incentives to purchase go hand in hand with those for charging infrastructure."

"5G technology is already mature and ready for mass market deployment."

"The application of 5G technology in V2X systems could significantly increase safety on the roads."

6. Discussion

As extensively documented in the scientific literature [21], the market penetration of electric vehicles is rising, and survey findings revealed that the majority of experts agreed with this assessment, stating that the expansion of charging infrastructure is strong. Another key insight is the criticality in the process to balance charging infrastructure availability across Europe. This will benefit the value chain by generating more interest to EVs and speeding up the energy transition process. In transport, where electrification is difficult, hydrogen is a possible alternative. Regional or local electrolysers can readily provide hydrogen refuelling stations, but their implementation will need to be based on a precise understanding of fleet demand and varied needs for light- and heavy-duty vehicles. To encourage hydrogen deployment and build a market in which new producers have access to customers, hydrogen infrastructure should be open to everybody without discrimination. This aspect of the hydrogen EU plan is also accepted by experts who believe that hydrogen infrastructure should work in harmony with charging infrastructure and are doubtful about the deployment of more hydrogen stations across Italy. This means that hydrogen infrastructure for passenger cars is nowadays weak, and it needs a good planning for the following years. Moreover, the literature suggests us that FCEV has the greatest value of technological maturity among the four choices, which are ICE, BEV, HEV and FCEV, implying that its growth is nearly flat. However, BEV has the lowest technological maturity, whereas HEV has a similar technology maturity. This means that BEV and HEV have a bigger potential for technical advancement and quick expansion, while FCEV has very little [22]. With reference to another literature [23], The future of hydrogen transportation in Europe is also described in a roadmap paper produced in 2019 by the "fuel cells and hydrogen 2 joint undertaking". The paper includes a projection for the number of HRSs needed to meet the demand of the emerging FCEV industry. The number of cars expected for 2050 was calculated using a no-consolidated scenario and an ambitious scenario, yielding 2.5 million and 53.4 million FCEVs, respectively. In the case of smart city, how a city might become smart is frequently depicted in literature. To that aim, successful examples of smart cities with high-quality plans are presented, as well as insights into how they achieved their goals and became smart cities, where 5G is classified as a technology [24]. From the experts' point of view, investing in 5G communications infrastructure this decade is the greatest choice that will expand even more in the future. The majority of experts also believe that consumers are willing to pay a premium to incorporate the safety and privacy problems related with the expansion of smart cities and smart roads, as well as the development of 5G. As a result, it is clear that infrastructure for autonomous and connected vehicles is on its way to the market. According to the relevant literature, most vehicle sales after 2040 will be electric and capable of autonomous driving, with connection being a key condition for autonomous driving and a possible factor for shared ownership [25]. Although the majority of experts believe in the infrastructure for autonomous and connected cars, other experts argue that it raises concerns about safety and privacy due to the possibility of data breaches. Even if there has been a less negative reaction to this kind of infrastructure, many experts claim it is safe. For example, the use of 5G technology in V2X systems might considerably improve road safety; some believe they are currently in use on a large scale. According to the literature [26], experience with car-sharing services, particularly electric vehicle as sharing, can lead to greater awareness of EV technology, resulting in greater market dispersion. Car sharing, particularly e-autos, is always a viable alternative for expanding the infrastructure of both car sharing and electric automobiles. According to experts, car sharing could minimize CO_2 emissions and traffic congestion. They also anticipated that investing in e-autos now will yield a profit and a strong return on assets in the future. With the advancement of this trend, it may become more beneficial for all individuals to use e-autos in the future. This thesis enables a new holistic vision of the infrastructures integrating the researchers' scientific publications with a broad vision given by SWOT and Q-methodology with experts from companies. SWOT analysis get a complete overview of the main aspects of each infrastructure by summarising the key points. Analyses with Q-methodology, which have previously been applied in the literature in other areas, allowed us to compare and sometimes even support the views of the researchers. It is of vital importance to plan the infrastructure well together with all players in the value chain. In this process, Q-methodology can show concordant or diametrically opposed points of view regarding the different actors and try to understand what mindsets could characterise and shape the automotive sector in different time perspectives. Coopetition between energy and transport sectors could be the key to a sustainable, innovative, and brilliant development for future mobility.

7. Conclusions

The thesis focuses on various trends that can serve as an upgrade for the conventional car and its infrastructure. Study and methodology used shows that each alternative investigated has its own set of advantages and disadvantages. The fundamental issue with the trends discussed here is the infrastructure that is currently under development. The infrastructure for FCEVs is designed in such a way that they are very low because the investment for establishment is high. In terms of connected cars and autonomous cars, the infrastructure requires a significant change in the market and increases vehicle costs, but it can be developed as soon as possible and is also showing faster development. Regarding e-autos as car sharing, this initiative also increases the growth of the EV and its infrastructure supporting technologies such as dynamic charging and battery swapping. The analysis is based on individual perception, so asking experts about the future of automotive infrastructure is a wise way to understand it. Thus, a survey with 50 statements was conducted with Q methodology, which makes the experts opt for the best statements according to what they believe is being agreed or disagreed. It was possible to comprehend each expert's perspective on the various trends under investigation. Each expert was classified based on how similar they thought the future trend will be. It could also be noted that many experts believe that if the infrastructure is developed for any trend considered so far, people will be ready to hop on the trend to replace the conventional vehicle and its infrastructure. Some experts believe that the infrastructure for connected and autonomous cars is established and ready to use. According to our analyses and our mindsets, the nearest and most interesting opportunity is the electrification of car sharing fleets together with the implementation of MAAS apps. This will be followed by the massive spread of electric charging infrastructures, in particular dynamic charging and gigafactories will be the game changer in the future mobility landscape. In the development of smart road and smart cities safety and privacy should be the pillars. In the case of hydrogen, public and private investors should cooperate and plan wisely for the infrastructural development. This thesis can be considered as the first step to try to understand the right timing to deploy each infrastructure.

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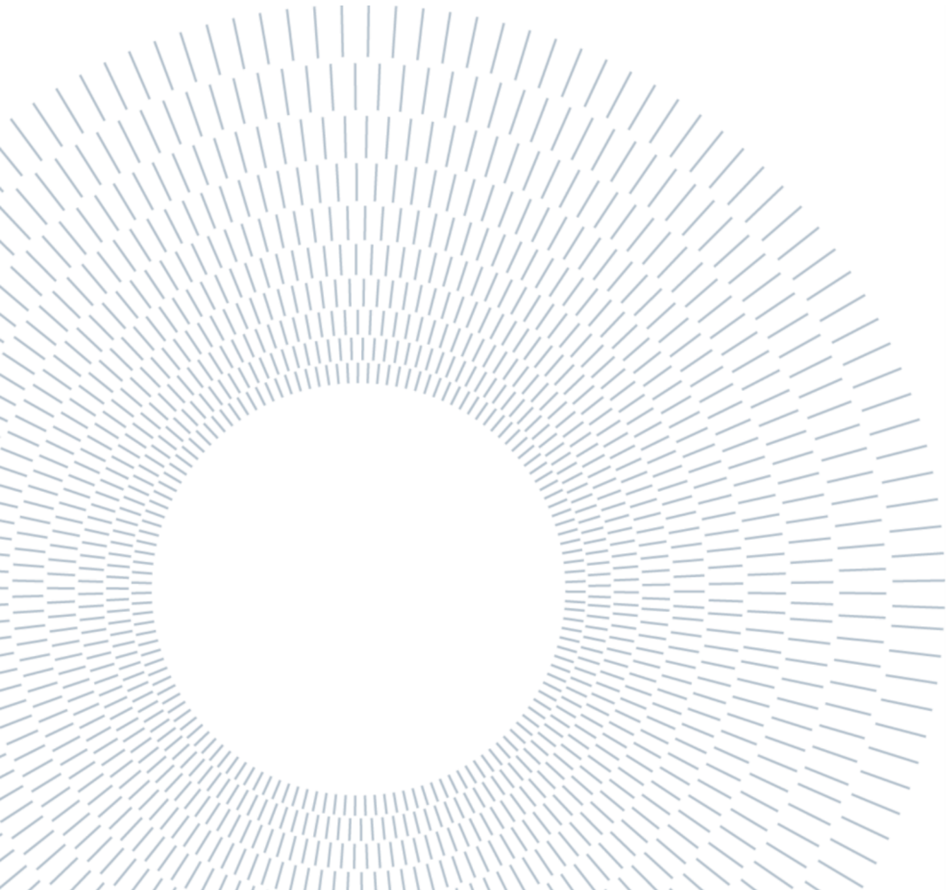

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

The Role of Infrastructure in the Automotive Value Chain

TESI DI LAUREA MAGISTRALE IN
MECHANICAL – MOBILITY ENGINEERING

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Academic Year:	2021-2022

Abstract

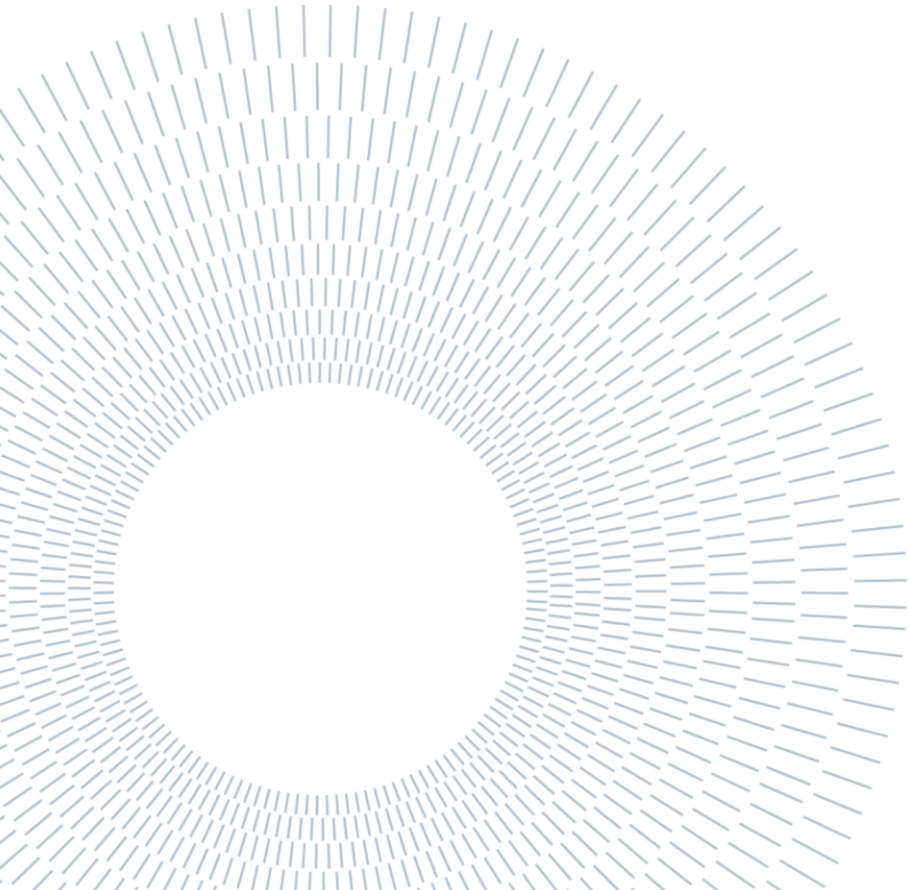
Infrastructures are the backbone of the automotive value chain. This thesis focuses on the role of infrastructure in the future automotive value chain by focusing on different trends, which include electric, hydrogen, communication, and car sharing infrastructure, focusing only on passenger cars. Initially, the state of art topic was executed in order to get a better picture of the past and present market for all the trends that were considered in the thesis. Afterward, the value chain in the automotive sector shows the necessity of the actors, technologies, and infrastructure and how they depend on each other to shape the automotive sector. For understanding the past and the current situation, qualitative analysis comprises of forecast analysis, which predicts the growth of each trend in coming years, and SWOT analysis, carried out to identify the potential of each trend and determine the capabilities between them. Upon analysis, scenarios were created by giving priority to each trend and understanding their impacts on various variables with main actors in value chain analysis, key technologies, and partnerships to comprehend the effects of combining variables and different hypothetic scenarios. Then, the methodology is carried out to get a clear vision of the future of the automotive value chain. Thus, a Q methodology, also known as Q sorting, was carried out. For this, various statements were made, and these were then sent to experts in the automotive industry to find out which trend, according to them, could dominate in the future and which still needs development. This was done in the Q methodology by making the experts place the 50 statements from most positive to most negative according to them. Therefore, after collecting experts' opinions and grouping experts according to similarity shown among them, different statistical analyses were performed with the opinions of experts also highlighting some comments.

Keywords: value chain, automotive infrastructure, energy transition, connected and autonomous, car sharing, SWOT, Q-methodology

Abstract in lingua italiana

Le infrastrutture sono la spina dorsale della catena del valore (Value Chain) del settore dell'auto. Questa tesi si concentra sul ruolo delle infrastrutture nella futura Value Chain del settore automotive, focalizzandosi su specifiche infrastrutture, tra cui elettriche, a idrogeno, di comunicazione e di car sharing, con particolare attenzione solo a quelle collegate alle autovetture. Inizialmente, è stato affrontato lo stato dell'arte per avere un quadro chiaro della situazione storica e attuale delle infrastrutture considerate nella tesi. Successivamente nell'analisi della Value Chain, si analizzano gli attori, le tecnologie e le infrastrutture che ne fanno parte e come questi dipendano l'uno dall'altro per dare forma al settore automotive. L'analisi qualitativa comprende l'analisi previsionale, che intuisce la crescita di ogni infrastruttura nei prossimi anni, e le analisi SWOT, effettuate per identificare il potenziale di ogni infrastruttura e le eventuali sinergie che si possono creare tra di esse. Dopo queste analisi, sono stati creati possibili scenari dando priorità a ciascuna infrastruttura e comprendendo il loro impatto su diverse variabili con i principali attori nell'analisi della Value Chain, le tecnologie chiave e le partnership per cogliere gli effetti della combinazione delle variabili e dei diversi scenari ipotetici. Infine, è stata quindi applicata la Q-methodology per ottenere una visione più chiara del futuro supportata da esperti del settore. A tal fine, sono state formulate varie affermazioni, che sono state poi inviate agli esperti per scoprire quale infrastruttura, secondo loro, potrebbe dominare in futuro e quale ha ancora bisogno di essere sviluppata, evidenziando quali potrebbero esser aspetti importanti da considerare. Questo è stato fatto in modo che gli esperti classificassero le 50 affermazioni proposte dalla più positiva alla più negativa. Quindi, dopo aver raccolto le opinioni degli esperti e averli raggruppati in base alla loro somiglianza nella forma mentis, sono state effettuate analisi statistiche evidenziando opinioni comuni e commenti personali.

Parole chiave: value chain, automotive infrastructure, energy transition, connected and autonomous, car sharing, SWOT, Q-methodology



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Introduction

The automotive industry has been in continual progress from its origin to the present despite the ups and downs of global or territorial crises, and it has had a direct impact on the economies of many countries as well as society itself. The automotive sector became the fundamental core of Western countries' development due to the continuous technological research associated with the production of increasingly advanced cars [1]. In recent years, the government has provided incentives for customers to buy new alternative fuel-based vehicles [2]. The importance of the automotive sector is thus enormous in modern economies, especially because of the value chain which is part of this great industry. Vehicles were the first to shift to more environmentally and sustainably friendly changes as a result of rising oil prices and CO_2 emissions [3] [4]. This vehicle modernisation has generated new approaches to the road and its applications. New cars, whether electric or hybrid, require, among other things, adequate parking space, the establishment of charging stations, proper signage, and innovative infrastructures. With the emergence of new electric, autonomous, connected, and shared cars, road infrastructure may play a critical part in the Green Deal, the European Union's green energy transformation [5] [6]. The common vision of automotive infrastructure was related to building new roads and taking care of the maintenance and the role of infrastructure was to connect different parts of the countries from cities to villages and provide fuel in the filling stations. Nowadays, with the development of new technologies, the role of infrastructure is not only to build and maintain roads, but also to manage the demand for energy, to find innovative solutions to increase kilometres by recharging vehicles as they travel on them making them competitive with conventional ones, and to increase safety on the roads through smart and integrated solutions.

Figure 0.1: The evolution of the infrastructure

The mobility of the future will also make it possible to realise the concept of Vision Zero [7], which pushes the society to have zero crash, zero pollution caused by means of transport and zero traffic in cities. Future mobility will be built on new paradigms aligned with increasing consumer needs and new technology accessible on the market, both of which will enable new business models and consumer services. Consumer preferences are continually changing, and new consumption habits, lifestyles, and awareness of environmental sustainability challenges are emerging. It is clear that technology is the enabling component in the change of traditional mobility into a model that is more linked, close to consumer needs, and plays a vital role in the smart society [8]. The new mobility models will be built on systems that optimise city and vehicle fleet management. The platforms will enable the development of the MAAS model [9]: the platform addressing the mobility service user will become a one-stop-shop for all of the individual's mobility needs, integrating micro-mobility systems, local public transportation, and individual mobility with shared vehicles. The Figure 0.2 displays the main technologies for the development of the connected mobility ecosystem [10].

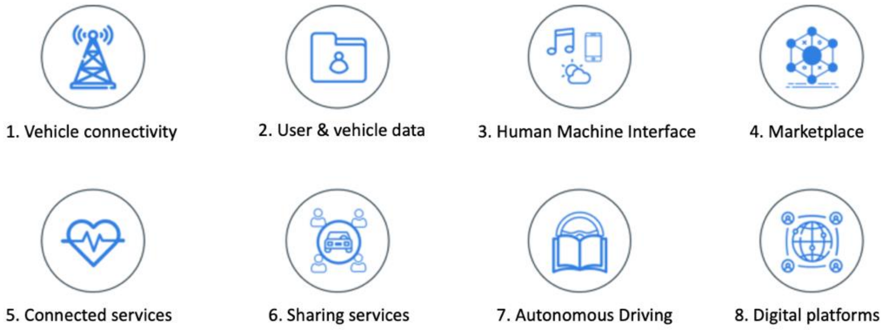

Figure 0.2: The main technologies to develop the Connected Mobility ecosystem

In the Italian scenario, this entire process will be supported by the PNRR, where the government underlines that it is a priority to pursue an "ecological transition towards complete climate neutrality and sustainable environmental development to mitigate the threats to natural and human systems: without a substantial reduction in climate-altering emissions, global warming will reach and exceed 3-4 °C before the end of the century, causing irreversible and catastrophic changes to our ecosystem and significant socio-economic impacts".

Motivations

The major motivations to do the research in the automotive sector were determined primarily by the interest in the area of emerging technologies and innovative visions, in which this sector is a key actor. The automotive industry is not just talking about a vehicle with four wheels; it is also about sustainable mobility, connected and autonomous cars, and future mobility paradigms. Because technology and new expectations have permeated this industry, changes have become increasingly quick and disruptive, and people who operate in these contexts must constantly plan for the future. Studying the past and present has contributed to understanding the vision for the future, but it is critical to carefully weigh the changes, and being able to interact with experts from private companies has helped even more to clarify the vision and the strategies to be implemented in response to these future changes.

Literature selection

In this final section of the introduction, it is provided an overview of the thesis' structure. It will be a dissertation divided into five major sections: first, a description of the state of the art will be presented, followed by an analysis of the value chain, a qualitative analysis based on various aspects, an explanation of the survey methodology and the analysis if the results, and lastly discussion and conclusions. In terms of the strategy for selecting literature, the materials used were books, scientific articles, and white papers. Technical and economic books were utilised to comprehend the major themes. Some of the scientific publications were contributed by professors, while others were identified in two databases, Scopus and Science Direct, by filtering with keywords related to the topic and by number of citations and selecting the most cited ones. As references for white papers, company and consulting firm websites were used.

1. The state of art

The term mobility is related to transportation of good or people from one place to another with the use of most appropriate means of transport [11]. In this thesis, car is considered as a mode of transportation which has four wheels and an engine to power it with its infrastructure.

1.1 Internal Combustion Engine vehicles

Internal Combustion Engine (ICE) vehicles [12] uses gasoline or diesel as a fuel and they play a significant role converting energy from the heat of burning gasoline into mechanical work, or torque, which is applied to the wheels to make the car move. These kinds of vehicles are being used for so many years and they are upgrading day by day.

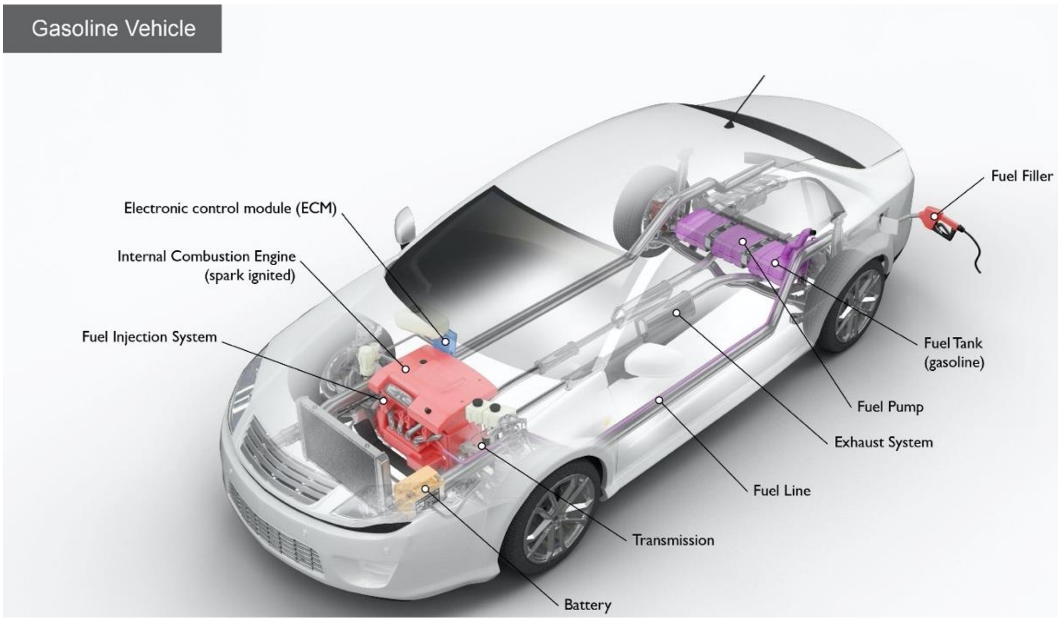

Figure 1.1: Internal Combustion Engine (ICE) vehicle

There are several factors that entice users to purchase an ICE vehicle, including the following ones: the price of the automobiles adheres to the customers' budgets, the fuelling stations are available within the range of the user's requirements, and the time to fuel is short. As a result, these benefits attract customers to choose ICE automobiles. These are merely common user opinions. However, there are certain drawbacks that make them the worst option, for example these vehicles are not particularly energy efficient; they are not environmentally friendly because they are powered by fossil fuels, they use a lot of non-renewable energy sources, which means that the fuel will no longer be available at some point in the future, the mileage is not so good, and the price of petrol and diesel will rise further as demand rises. To control the emissions, the government is taking necessary steps by implementing rules, e.g., usage of Euro 7 [13].

1.1.1 History of gasoline and other non-renewable resources

Fuel prices are steadily rising in tandem with rising demand and these resources are depleted at some point. Many years ago, the demand for fuel was lower since the population was lower than it is now, and the number of people who own a vehicle was much lower, thus the world could control the fuel demand. As the world's population grows, so does the cost of fuel. Since these resources are used not only for vehicles but also for a variety of other industrial purposes, there may be a scarcity of them in the future, necessitating the search for alternatives. The fuel cost per litre and road fuel excise duties in Europe [14] are depicted in the Figure 1.2 and Figure 1.3. In the next days the price will eventually rise, and the road excise increases the price to the final customers. Italy has one of Europe's highest excise rates in both cases: petrol and diesel.

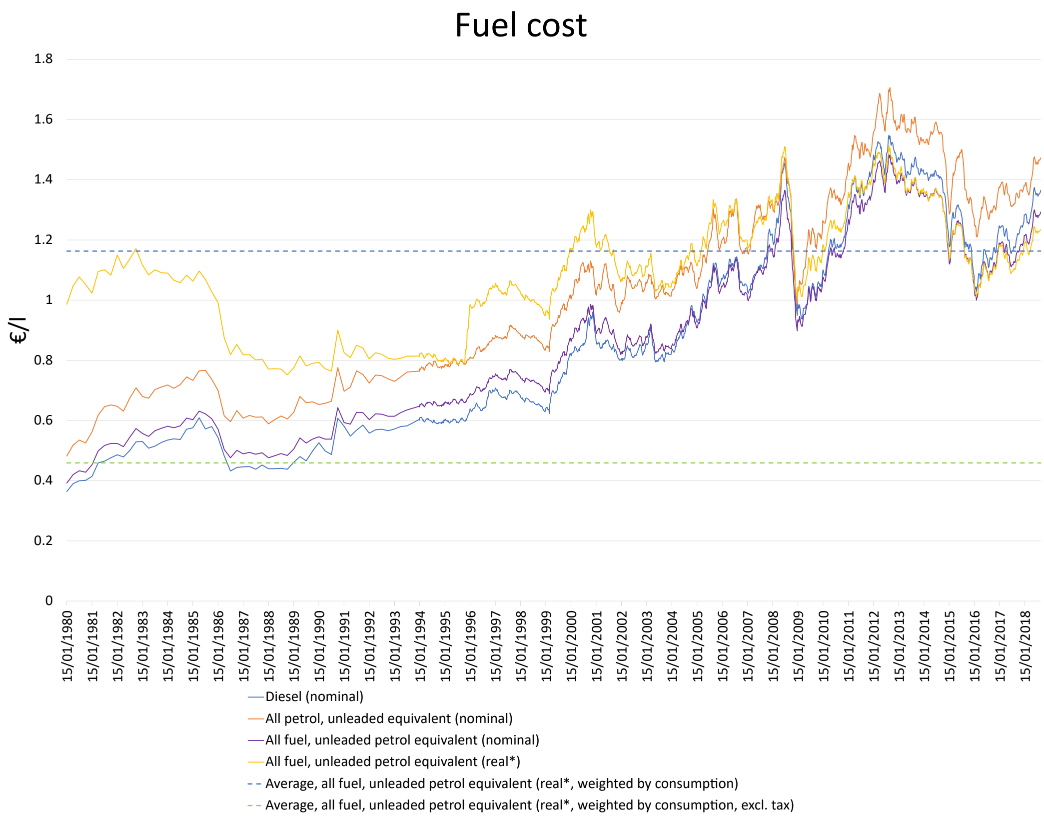

Figure 1.2: Fuel cost per litre in Europe

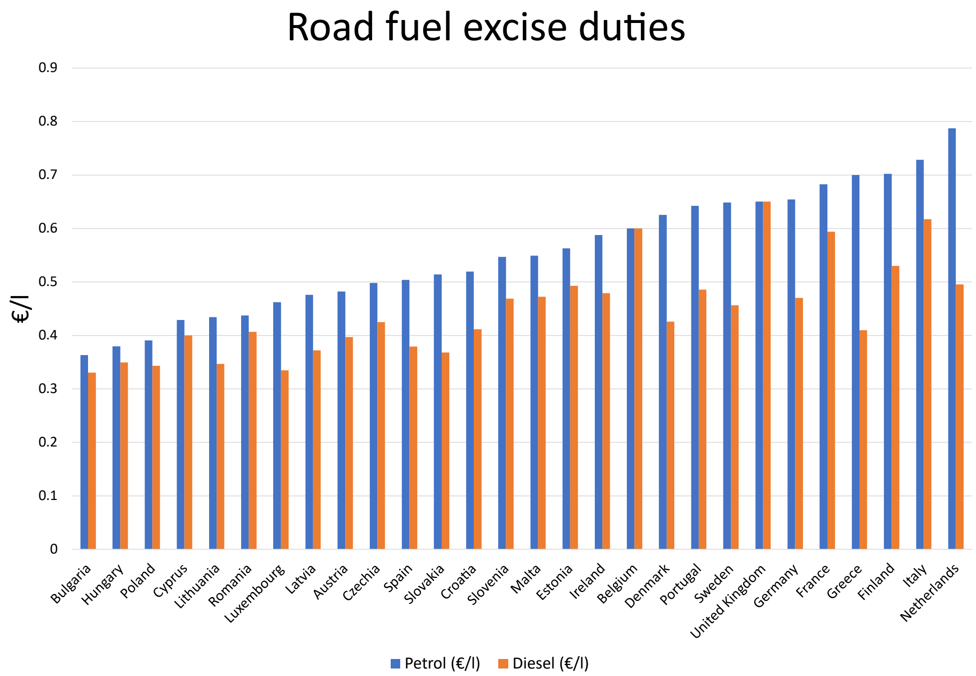

Figure 1.3: Road fuel excise duties in Europe

1.1.2 Transportation of gasoline from refinery to gasoline stations

An oil refinery is a facility that converts crude oil into useful petroleum products such as gasoline, kerosene, or jet fuel. To hedge their exposure to crude oil prices, refineries and oil traders use the crack spread, which is the relative difference between production cost and market price, of various petroleum products in the derivatives market. It is usually used in conjunction with pipelines, large trucks, and more. Gasoline is transported to distribution facilities with the assistance of skilled workers. This is transported from the distribution channels to the local service stations.

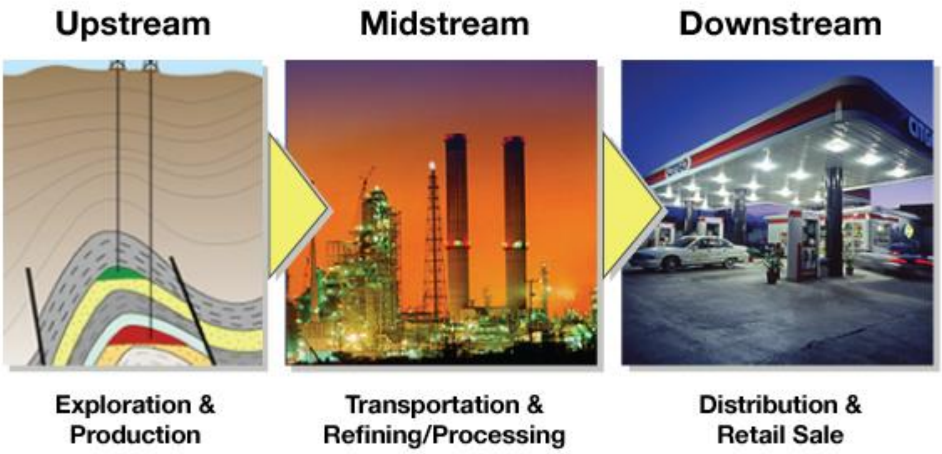

Figure 1.4: Steps from refinery to gasoline stations

The Figure 1.5 represents the number of fuelling stations in Europe [15], it clearly shows that Italy has the most fuel stations in comparison to other countries. Indeed, Italy is more focused on ICE vehicles and shifting ICE car consumers to other options is a significant difficulty. The focus should be more on incentives and other benefits that make individuals to think of moving.

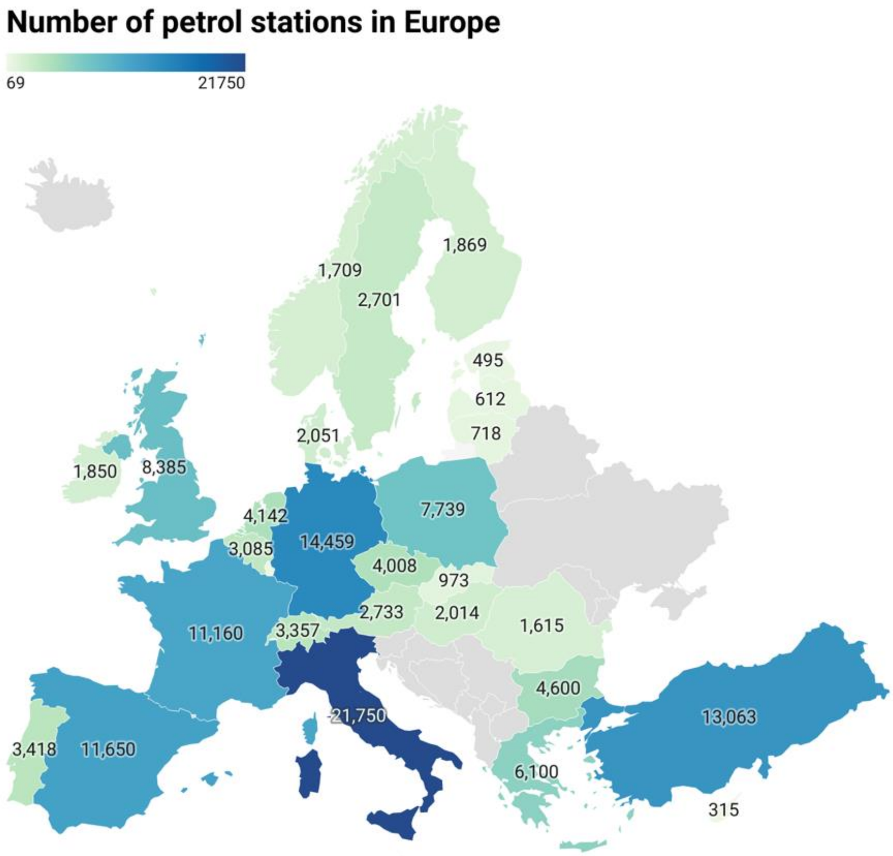

Figure 1.5: Fuelling stations in Europe

1.1.3 Emissions from Internal Combustion Engine Vehicles

Environmental issues are increasingly capturing global attention, and many businesses and governments around the world are taking action to help change the trends. This worldwide awareness has resulted in increased interest in and development of modern technologies in recent years. The main pollutants produced by transport sector are [14]: CO, which cause poisoning and cardiovascular problem, NMVOCs, NO_x and SO_x, which impact on smog and acid rains, PM, which are responsible of lung damages and physiological harms and CO_2, which is one of the main causes of global warming and climate changes. It is also easy to see the level of pollution from the satellites [16], for example, there can be different concentration of NO_2 in the world and immediately realize a high presence of nitrogen oxides in the most developed and urbanized part of the world. The Figure 1.6 below shows the NO_2 level in the world, focused on that part of Europe, the red colour shows the concentration being high in the areas of the country. The Northern part of Italy has higher NO_2 compared to that of other areas.

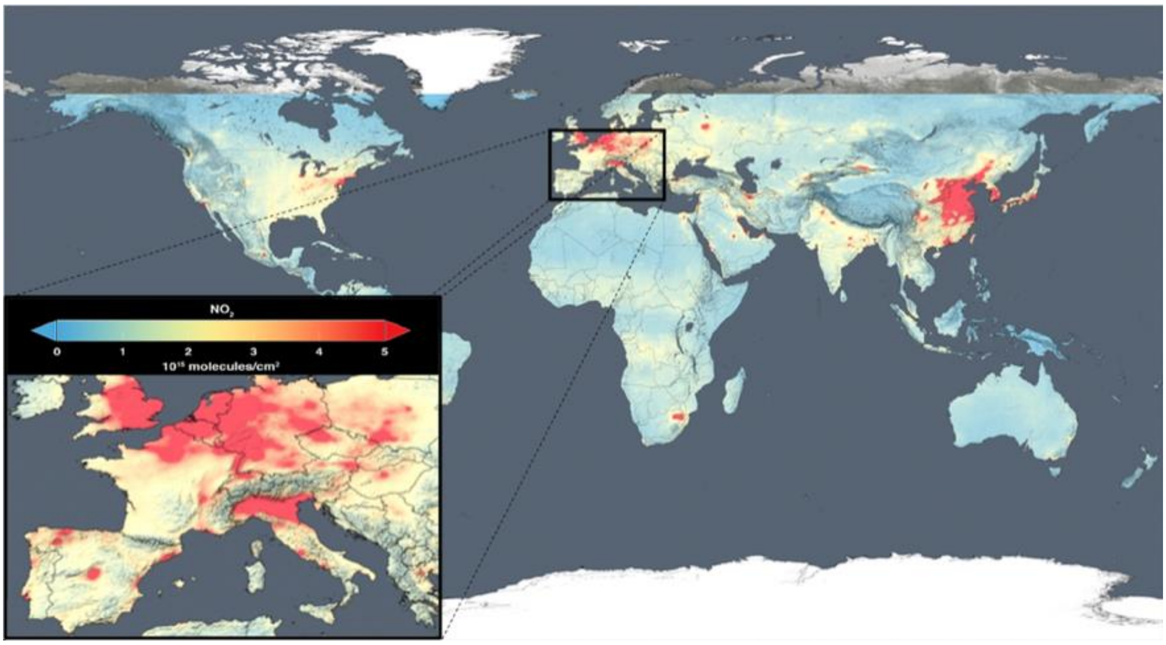

Figure 1.6: NO_2 level focused on Europe

Every day, the world hears about carbon footprints, and with good reason: carbon is everywhere, in the air, in our food, and even in our bodies, and it is the most common and basic ingredient for life on Earth. When it comes to emissions, the primary concern with CO_2, which is naturally released into the atmosphere in a variety of ways, including from the oceans to the atmosphere, from animals and plants, and nature tends to balance the emissions through natural processes such as photosynthesis and ocean absorption. However, people extract, refine, transport, and shape fossil fuels, resulting in additional emissions. It also includes cutting trees, reducing the natural CO_2 absorption process. There are also some reasons that are related to a country's population, for example, a country like China emits pollution because there are many needs that are necessary to fulfil the demand, so the more transportation that is required for people's mobility, the more vehicles that are required for travel. This might also be a contributing factor to the increase in emissions. Figure 1.7 below depicts thousand metric tons of carbon emitted by each country [17] in 2014.

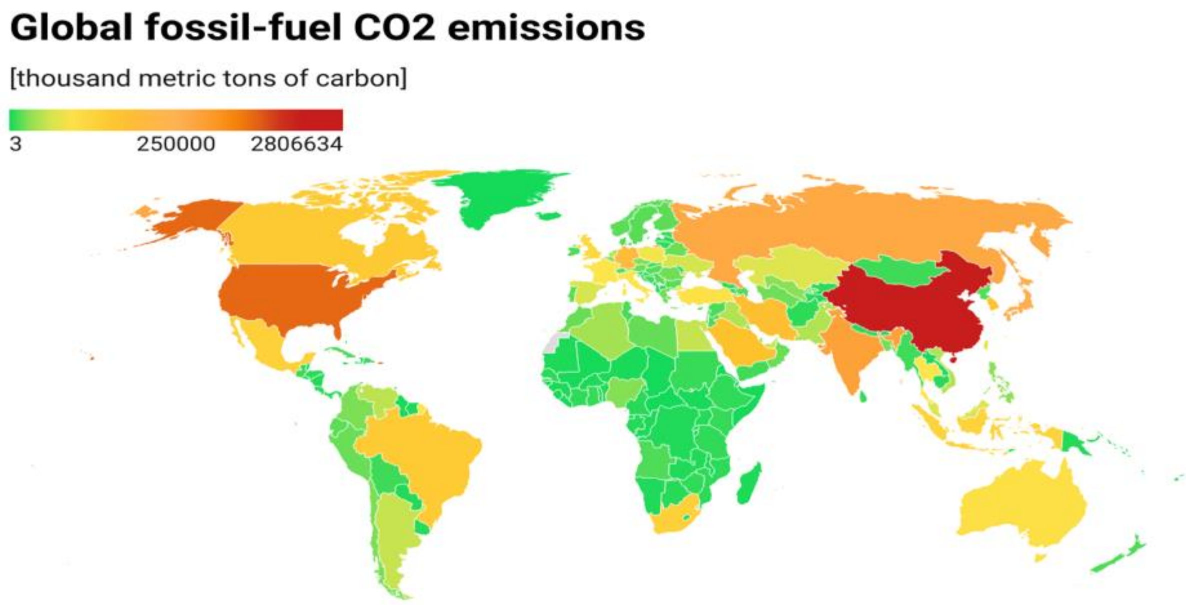

Figure 1.7: Global fossil fuel emission

Transport accounts for more or less one-fifth of the global CO_2 [18] and according to IEA road transport is responsible for almost three quarters of the total emissions, which means around 15% of the total. The majority of this is due to passenger vehicles (cars and buses), which account for 45% of the total transport emissions. The remaining 29% is accounted for by freight vehicles. While aviation receives the greatest attention in conversations about climate change action, it accounts for just 11% of total transport emissions.

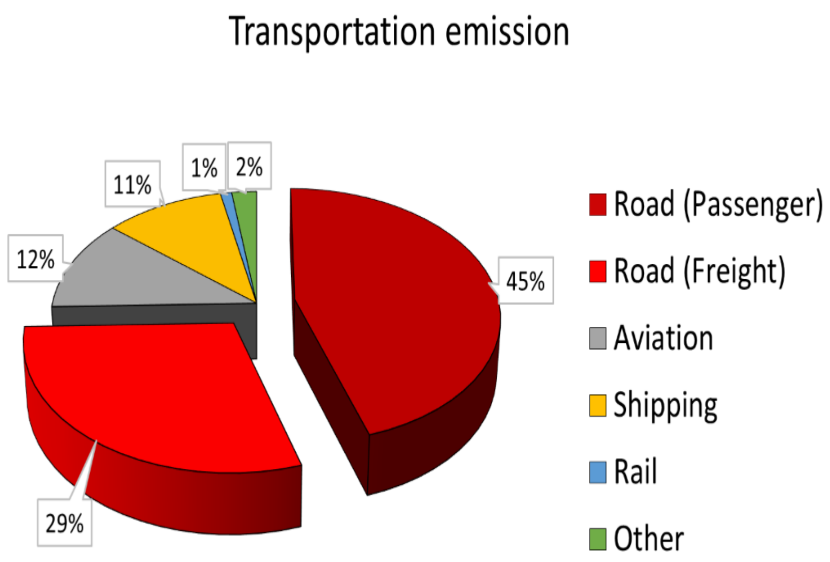

Figure 1.8: Transportation emission

The transport sector's contribution to fossil fuel emissions is illustrated in the figure below, as it can be seen, numerous sectors are engaged in the contribution to emission levels. Some sectors that were developed in the late 1990s appear to have lowered the amount of emission, such as the railway sector, but it can be seen that some industries, such as international aviation, road transport are increasing, that may bring significant environmental issues in the future [14].

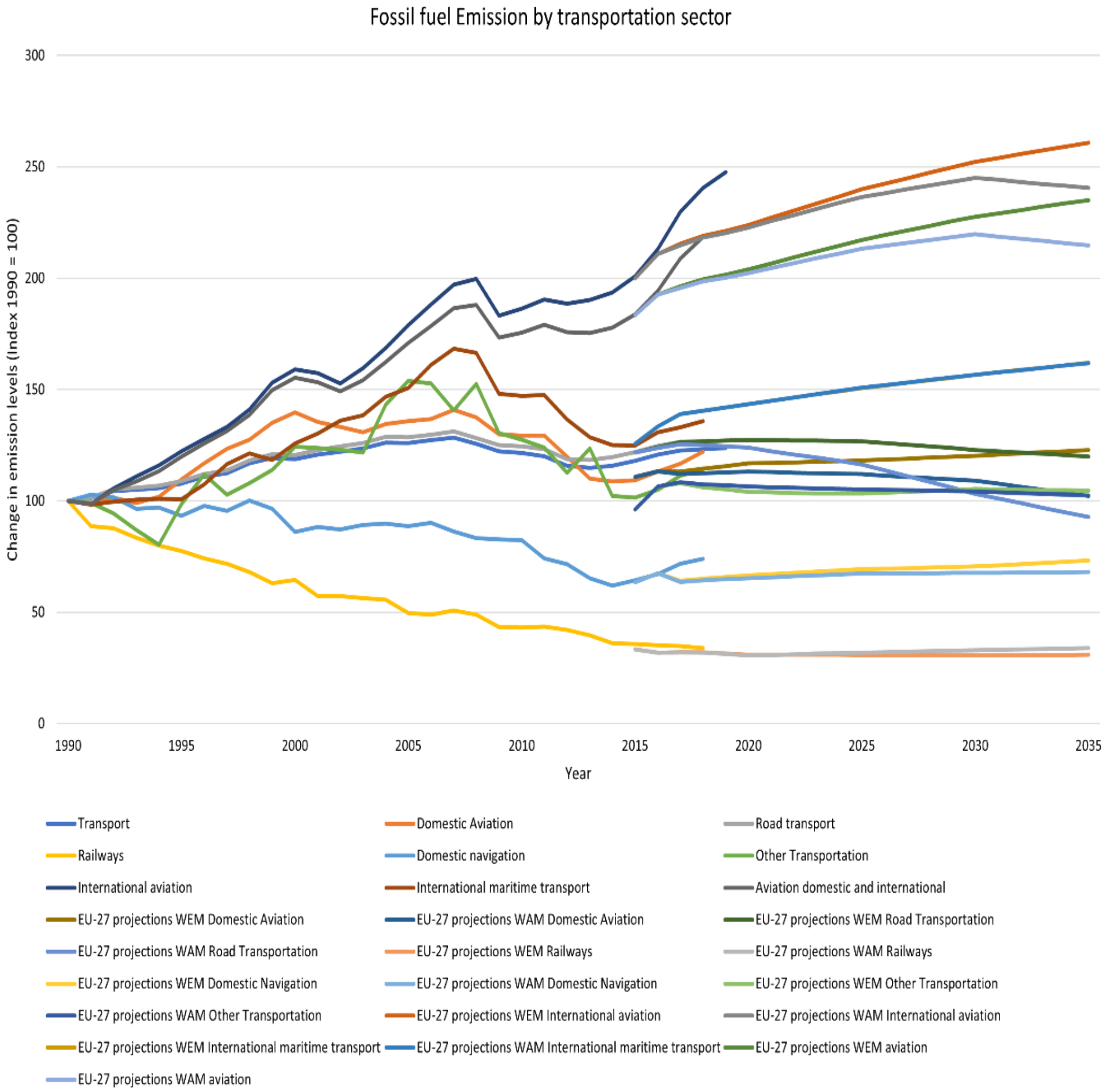

Figure 1.9: Fossil fuel emission by transportation sector

1.1.4 Alternative vehicles according to future trends

On some day in future the non-renewable resources get exhausted, and it is required to look for some alternatives that can sustain the future of mobility and automotive sector, such as:

- Hybrid electric vehicle (HEV and PHEV)
- Battery electric vehicle (BEV)
- Hydrogen fuel cell vehicle (FCEV)

From the graph below, [19] future trend of alternatives to ICE can be seen. The cost of the alternative energy-based vehicles is costlier before, are then reduced to a certain rate that can cope up with the ICE engine vehicle.

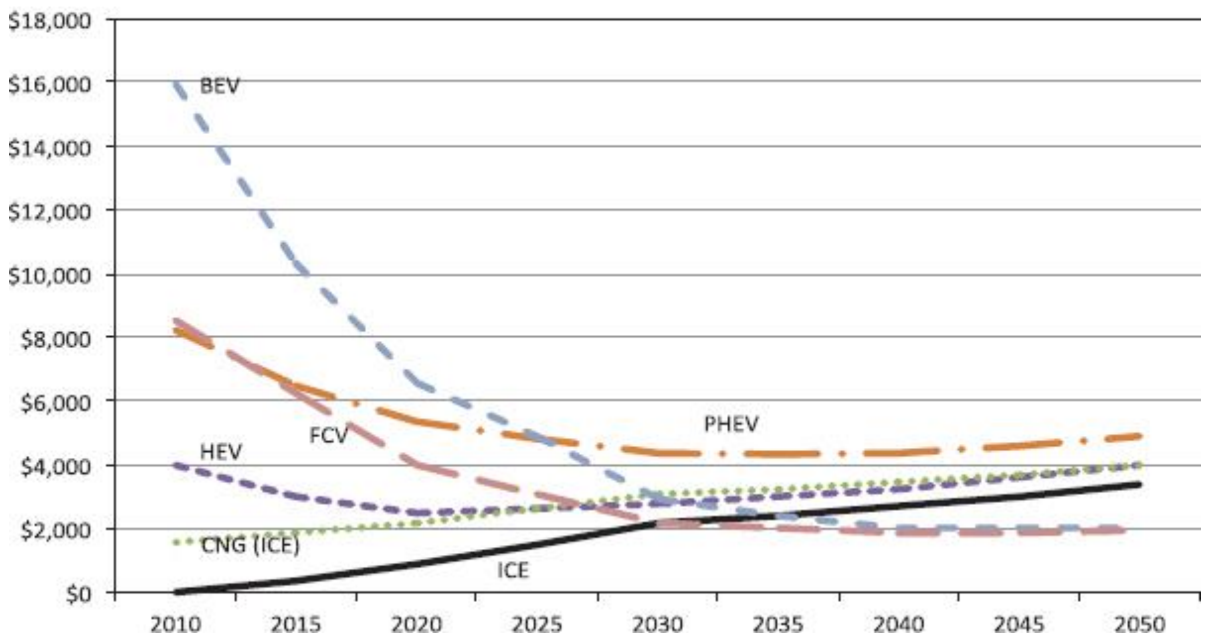

Figure 1.10: Trend cost per type of vehicle

1.2 Hybrid electric vehicles

Hybrid electric vehicles are useful for people transitioning from ICE to different options because they can reduce the CO_2 emission and dependency of petrol as they can use batteries for charging and electrification purpose to run the vehicle. These users also use the ICE for fuelling if they do not have the time to charge the battery. They can also learn about charging technologies and their benefits while driving hybrid vehicles.

1.2.1 Hybrid Electric Vehicle

HEV consist of both internal combustion engine and electric motor from which this vehicle can be fuelled with gasoline also charged with the help of connected charges. This car cannot be charged by a connection; instead, it must be charged using the regenerative braking system or the engine.

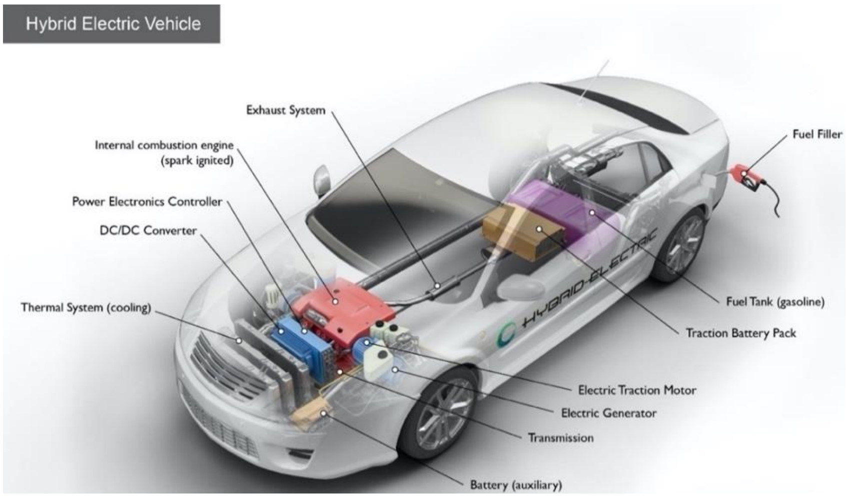

Figure 1.11: Hybrid Electric Vehicle (HEV)

1.2.2 Plugin Hybrid Electric Vehicle

PHEVs' batteries may be charged using charging equipment and regenerative braking along with the usage of internal combustion engine. This car is like a hybrid electric vehicle; the only difference is that it can charge the battery via a connection.

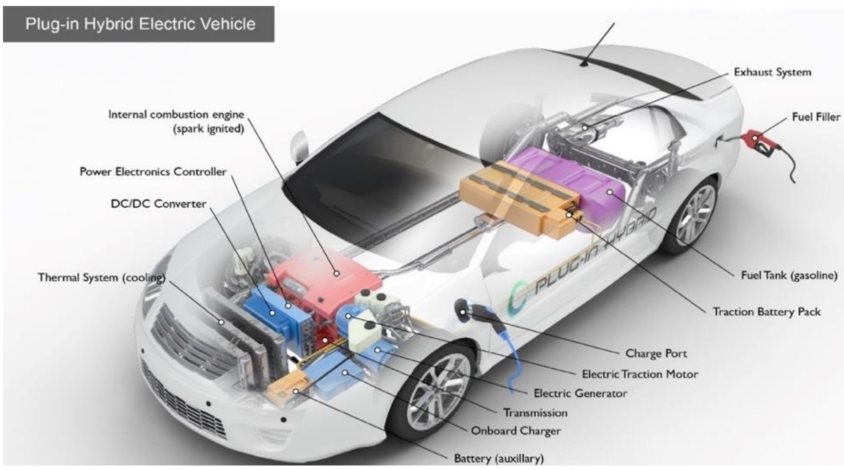

Figure 1.12: Plug-in Hybrid Electric Vehicle (PHEV)

1.3 Battery electric vehicle

A battery pack is used in battery electric cars to store electrical energy that may be used to power the motor. That may be used to power the motor. By connecting the car into an electric power source, EV batteries are charged. Although the generation of energy contributes to air pollution, those vehicles are known as zero-emission because they produce no direct exhaust.

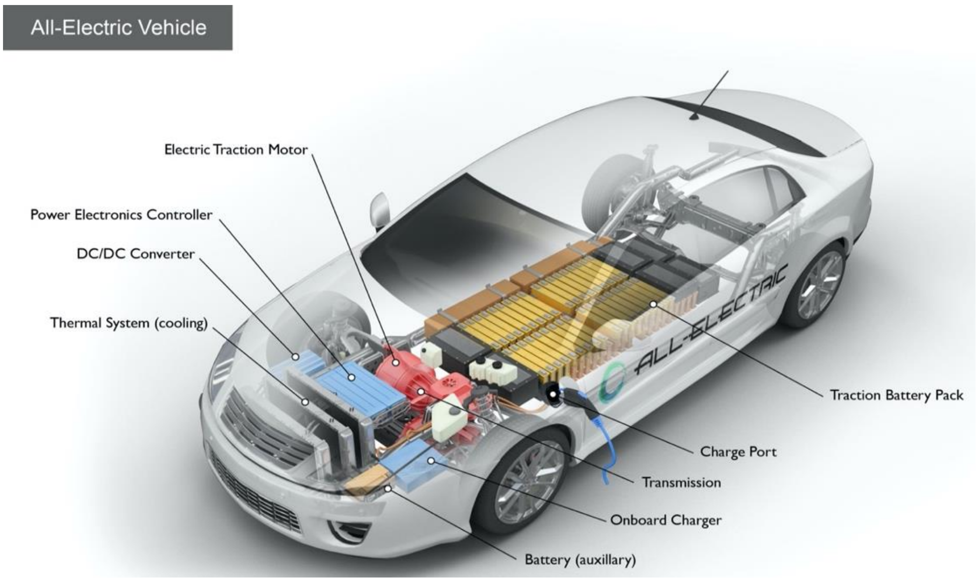

Figure 1.13: Battery Electric Vehicle (BEV)

Commercially available EVs include both heavy-duty and light-duty models. EVs are normally more expensive than comparable conventional vehicles, however, part of the cost might be offset by fuel savings or state incentives. In general, today's EVs have a lesser range (per charge) than equivalent conventional cars (per tank of petrol). However, the growing number of new models on the market, as well as the ongoing development of high-powered charging equipment, are closing the gap. The efficiency and driving range of EVs vary depending on driving circumstances. Extreme low temperatures tend to restrict range since more energy is required to heat or cool the cabin. EVs are more efficient in cities than on highways. City driving circumstances necessitate more frequent stops, which maximizes the advantages of regenerative braking, but highway travel necessitates more energy to overcome the greater drag at higher speeds. Carrying big items or driving up slopes, e.g., hills or mountains, can significantly affect range.

1.3.1 Transmission of electricity from power plant to charging stations

Distribution systems have always functioned in a radial fashion due to their ease of operation and overall economy. When possible, regulatory obligations to raise reliability indices have introduced technology such as loop systems to assist the continuous delivery of energy to the load. From inception through life-cycle support, the expanding distribution system landscape brings several contemporary issues in policy, operation, maintenance, protection, and management. Microgrid development has also provided new opportunities to the distribution system, such as contributions to capacity, reliability, and power quality enhancement. The Figure 1.14 depicts the main steps from production to consumers [20].

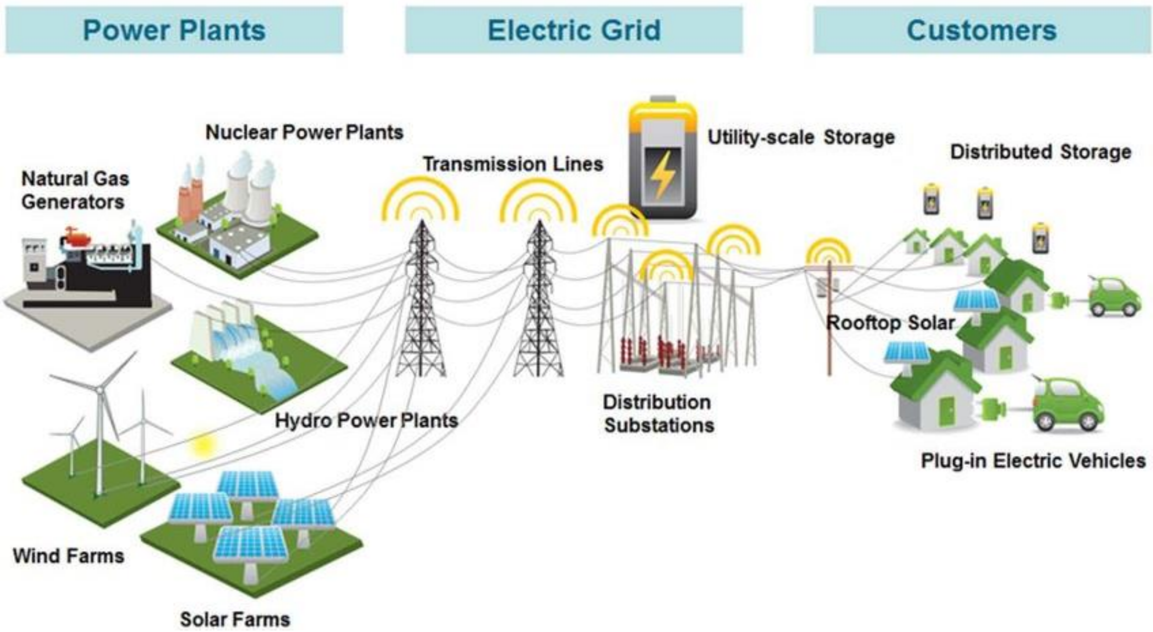

Figure 1.14: Transmission of electricity from power plant to charging stations

The use of CCS plugs allows for DC fast charging, and they are intended to charge EVs quickly in public environments. In the Figure 1.15 [21] the presence of CCS in Europe is shown, it can be noted that, a denser presence of availability in the northern part. The Figure 1.16 [22] displays the absolute number of public charging stations in Europe, which include both AC and DC connections.

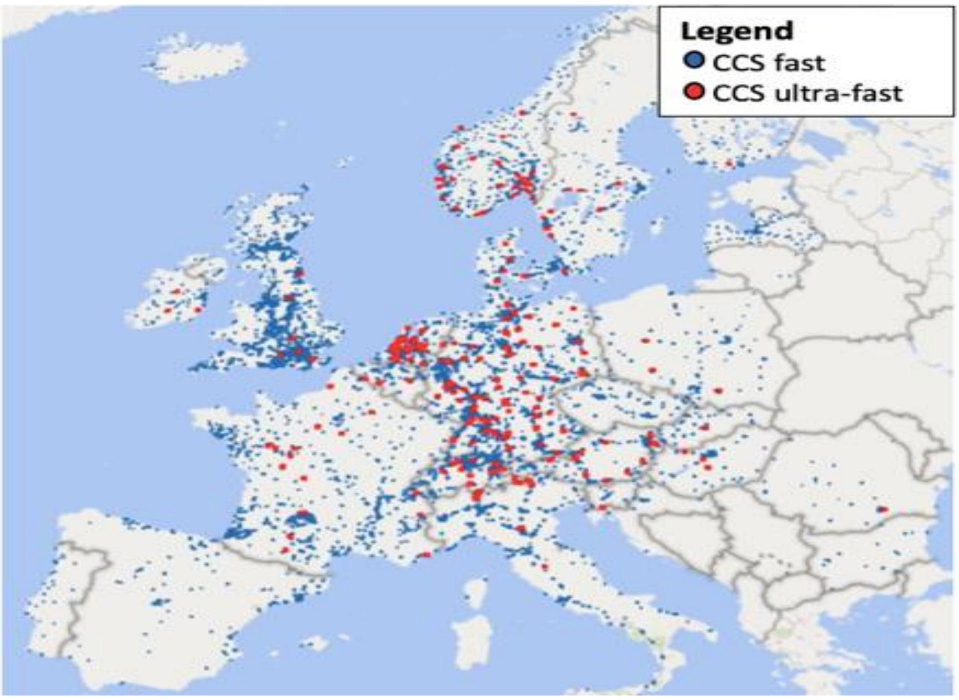

Figure 1.15: Distribution of CCS fast and CCS ultra-fast public fast charge points

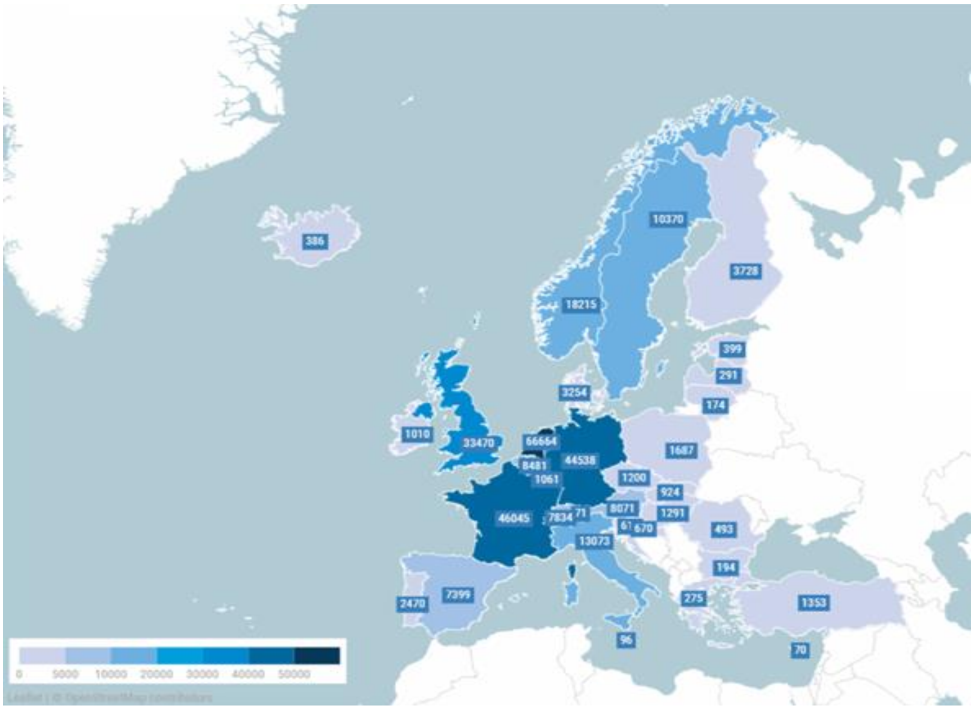

Figure 1.16: Public charging stations in Europe

1.4 Fuel cell electric vehicle

FCEVs run on hydrogen. They are more efficient than conventional internal combustion engine vehicles and emit no tailpipe emissions, which means only water vapor and warm air. FCEVs and the hydrogen infrastructure are still in the initial stages of development. FCEVs are powered by genuine hydrogen gas stored in the vehicle's tank. Comparable to internal combustion engines, they can fuel in less than 4 minutes and have a driving range over 450 km [21]. FCEVs are outfitted with regenerative braking systems, which harvest and store braking energy in a battery.

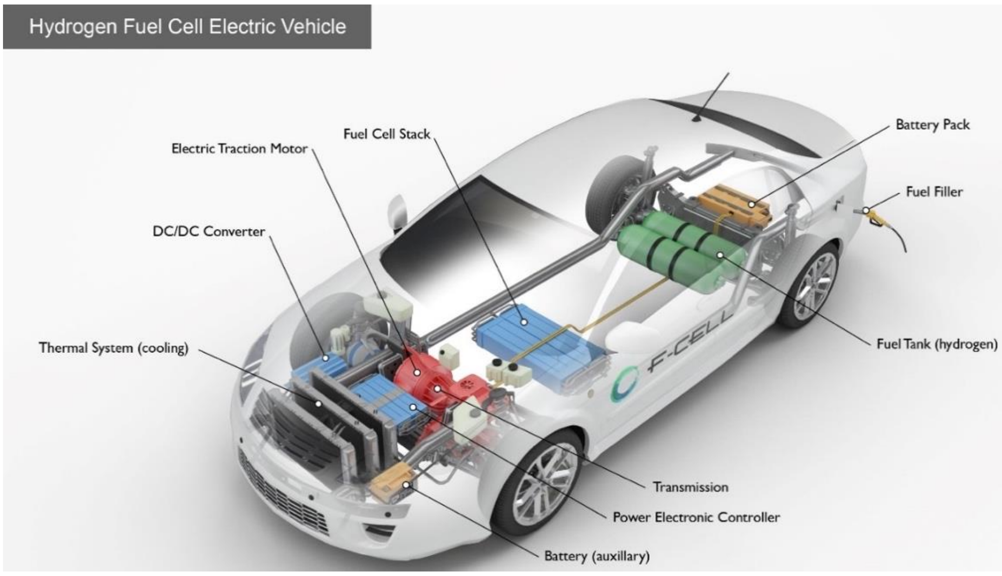

Figure 1.17: Hydrogen fuel cell-based vehicle

The linkage of the electricity and mobility sectors is enabled by producing hydrogen via electrolysis with high renewable energy generation for eventual usage in fuel cell electric vehicles. SMR is now the most cost-effective method of producing H_2 [23]. Molecular form, for example cryogenic tanks for liquid hydrogen, pressure vessels, or underground storage units, [24] or bonded form (e.g., liquid organic hydrogen carriers or transition metal hydrides) in conventional containers at atmospheric pressure, are the main ways in which hydrogen can be stored. The current state of the art in hydrogen storage is molecular hydrogen storage. Even though it takes very less time to refill the empty tank, it costs extremely high for the infrastructure implementation as the process is tedious as it requires large equipment and storage facilities. The Figure 1.18 shows the infrastructure behind the refuelling station, which includes different modes of transportation to reach the destination.

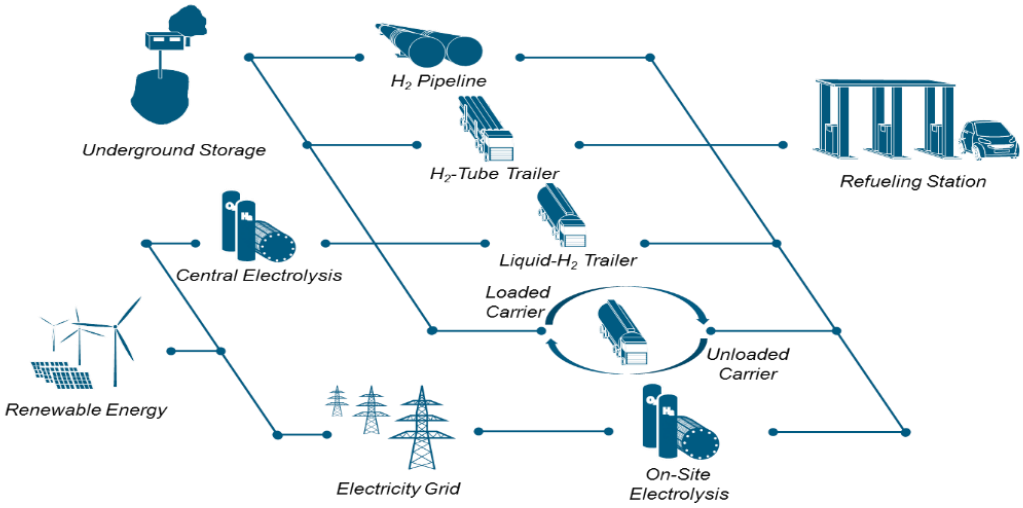

Figure 1.18: Transportation of hydrogen from refinery to hydrogen fuelling stations

The Figure 1.19 below depicts the number of hydrogen fuelling stations in Europe [15]. It can be observed from the data that there are very few hydrogen-based fuelling facilities. The explanation might be because the transportation, production of hydrogen fuel is extremely expensive and the vehicles sold currently are not that high, therefore the demand is not as strong as that of other fuels. Europe focuses more on the manufacture of clean hydrogen technologies and is well positioned to benefit the worldwide growth of clean hydrogen as an energy carrier [25].

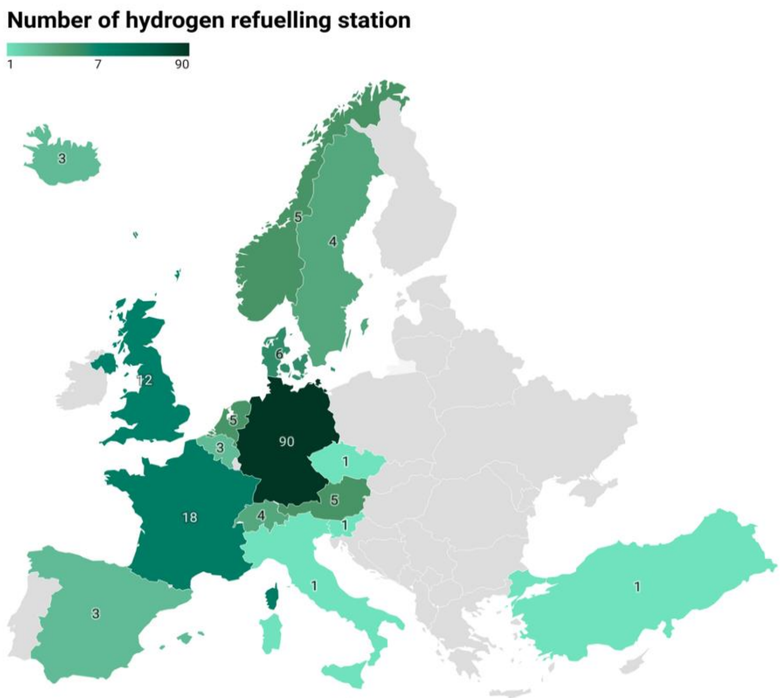

Figure 1.19: Hydrogen fuelling stations in Europe

1.5 Energy infrastructure archetypes

The Table 1.1 summarizes the different infrastructures for each type of vehicles, highlighting the availability of stations across Europe.

	PETROL	ELECTRIC	HYDROGEN
	 **Petrol station**	 **Charging station**	 **H_2 fuelling station**
Suitable powertrains	▪ ICE ▪ HEV ▪ PHEV	▪ PHEV ▪ BEV	▪ FCEV
Availability in Europe	Widely available	Limited	Very limited

Table 1.1: Energy infrastructures archetypes

1.6 Incentives to switch from ICE to zero and low emissions vehicles

Having realized that oil will run out eventually and that conventional cars are responsible for an interesting fraction of CO_2 emissions, it is needed to invest in innovative technologies. To speed up this process, some governments are encouraging people to buy cars that pollute less and use a sustainable alternative to petrol, for example electric cars, giving some incentives. In recent years, the average CO_2 emissions of new passenger automobiles in the EU have progressively reduced, decreasing with a 2% yearly reduction rate. There is a significant difference across nations in terms of average CO_2 emissions and the pace of reduction witnessed over time. There is a significant difference across nations in terms of average CO_2 emissions and the pace of reduction witnessed over time. In 2016, Portugal had the lowest average CO_2 emissions among the EU-28 nations, at 105 g/km, followed by the Netherlands, Denmark, and Greece, with Estonia having the highest amount, followed by Lithuania. In terms of EEA member nations, Norway had the lowest average CO_2 emissions of new automobiles [14] (93 g/km), while Switzerland had the highest average CO_2 emissions (134 g/km). Taxes and incentives under consideration include those based on CO_2 emissions (or a related criterion such as engine power) of cars, as well as those aimed expressly towards zero- and low-emission technology (including fuel cell, electric and hybrid vehicles).

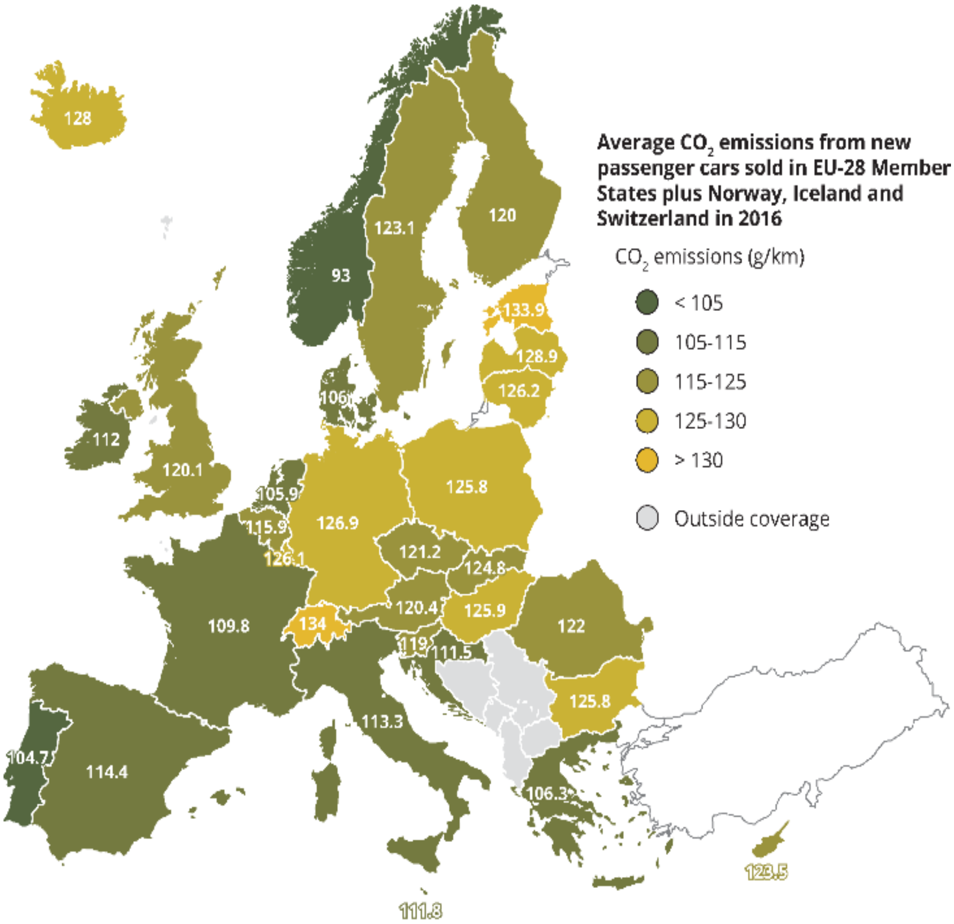

Figure 1.20: Average CO_2 emissions in Europe

Among them, four types of taxes and incentives have been identified:

- **Acquisition**: registration taxes, purchase subsidies, bonus/malus schemes in which low-emitting cars receive a tax break (bonus) while polluting cars above a certain threshold are heavily taxed (malus) or scrappage-for-replacement schemes.
- **Recurring**: Yearly cycle taxation, road tax, traffic or limited zone costs, free parking, or preferred channel use are all examples of fees.
- **Company**: as benefit-in-kind taxation of employees using a company car privately, proportional to CO_2 emissions
- **Infrastructure**: government grants for the establishment of low-emission vehicle refuelling and charging stations for low-emission automobiles.

Every one of the 32 nations introduced at least one sort of tax or incentive to encourage the use of low-emission passenger vehicles as shown in the table down below.

Country	CO_2 and proxy based incentives				Incentives for zero- and low-emission vehicles				
	Acquisition	Recurring	Company	Total number*	Acquisition	Recurring	Infrastructure	Company	Total number*
Austria	✓	✓	✓	3	✓	✓	✓	✓	8
Belgium	✓	✓	✓	4	✓	✓		✓	4
Bulgaria		✓		1		✓			1
Croatia	✓	✓		2			✓		1
Cyprus	✓	✓		2		✓			2
Czech Republic		✓		1		✓			1
Denmark	✓	✓	✓	3	✓	✓	✓		6
Estonia				0		✓			2
Finland	✓	✓		3	✓				1
France	✓	✓	✓	8	✓		✓	✓	5
Germany		✓		1	✓	✓		✓	5
Greece	✓	✓		3	✓	✓			4
Hungary	✓	✓	✓	4	✓	✓		✓	7
Iceland	✓	✓		2	✓	✓	✓		5
Ireland	✓	✓	✓	3	✓	✓	✓		6
Italy	✓	✓		2	✓	✓			3
Latvia	✓	✓	✓	3	✓	✓		✓	5
Liechtenstein		✓		1	✓	✓			2
Lithuania				0		✓			2
Luxembourg		✓		1		✓		✓	2
Malta	✓	✓		2	✓	✓			5
Netherlands	✓	✓	✓	3	✓	✓	✓	✓	6
Norway	✓			1	✓	✓	✓	✓	10
Poland	✓			1					0
Portugal	✓	✓		2	✓	✓		✓	6
Romania	✓	✓		2	✓	✓	✓		4
Slovakia	✓	✓		2		✓			2
Slovenia	✓	✓		2	✓	✓			2
Spain	✓	✓	✓	3		✓	✓	✓	8
Sweden		✓		1	✓	✓	✓	✓	7
Switzerland		✓		1	✓	✓			2
United Kingdom	✓	✓	✓	7	✓	✓	✓	✓	5
Total	23	28	10	30	22	28	12	13	32

Figure 1.21: Incentives in Europe

1.7 The reaction of the automotive market sector

The world has now begun to explore for ways to limit emissions, and, as an initiative, the automobile industry began looking for industrial revolution, which leads to the search for alternatives and consumers began to exhibit interest in electric and hydrogen automobiles. The corporation began to adapt in response to client desires and environmental concerns. In the Figure 1.22 [26], it is seen that numerous firms started producing various models of alternative fuels, and they are being upgraded with new features and benefits every year.

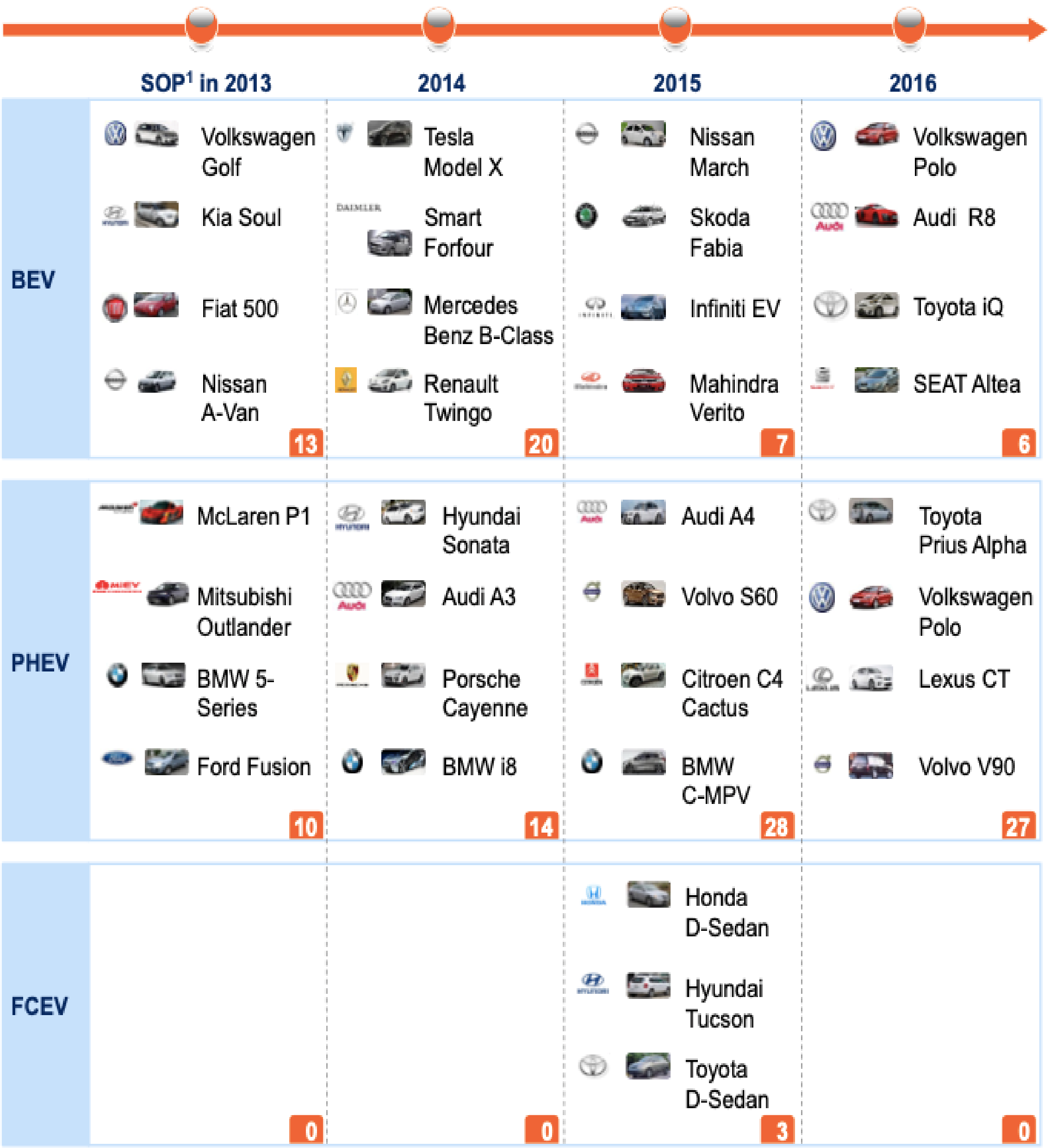

Figure 1.22: Alternate fuel vehicles manufactured by different companies

1.8 Connected and Autonomous cars

Some of the most enticing automotive technologies are connected and autonomous car technologies, which are constantly evolving and acquiring new features. It is widely regarded as a technology with significant potential to improve transportation safety, traffic functional ability, dependability, and urban sustainability.

1.8.1 Connected cars

Connected cars used to be the linkage between phone and the automobile system, however things have evolved, and connected cars now connect one car to another, allowing various vehicles to communicate with each other. In an emergency, for example, an ambulance may utilize this sort of linked car technology to change the light from red to green, allowing patients within the ambulance to reach the hospital quicker. Infrastructure should also be developed, such as the establishment of smart cities, which can aid in the synchronization of all systems such as signals, tolls, and so on, and may be employed as needed.

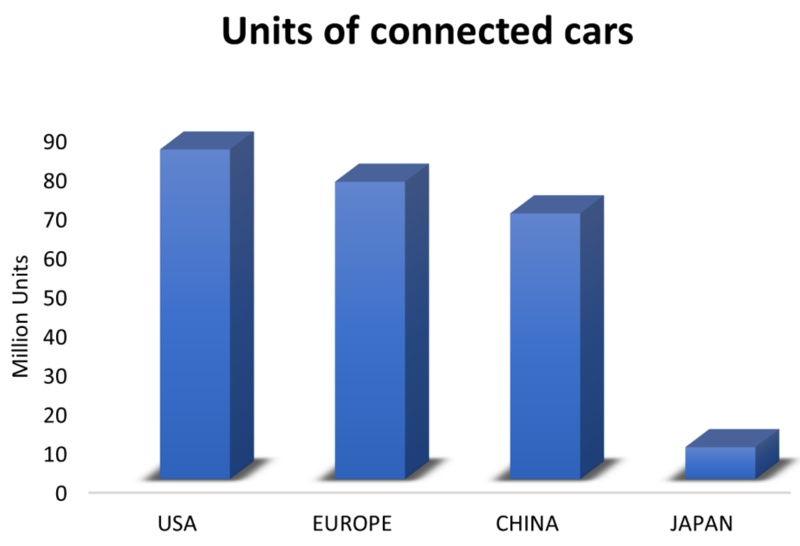

Figure 1.23: Connected cars sold in 2021

From the figure above [15] it shows four regions, in which connected cars are sold to a greater extent, are developing in the field of connected cars, for example the United States of America appears to be at the top of the table, alongside Europe in second place. Based on this graph, it is anticipated that the number of connected cars will increase in the coming years. In future, other regions also develop as these are gaining the popularity and it can also be very much useful if the smart cities are developed, this will attract most of the future consumers.

Figure 1.24: WiFi vs. 5G in connected cars

The usage of WiFi or 5G in the connected cars is always a debate [27]. Different companies have their own choices. Twenty-one EU nations [28] voted against a European Commission plan that would have restricted 5G cellular vehicle connectivity in favour of short-range WiFi, paving the way for 5G-connected cars in Europe but not precluding WiFi use. Their dispute stretched on long enough that the primary claim in support of WiFi, that it was ready to deploy in 2016, but 5G was not, has been called into question by both international deployments of various 5G networks and delays in launching linked vehicles.

1.8.2 Autonomous vehicles

Autonomous cars drive themselves from a starting point to a predefined destination using a variety of technologies and sensors such as adaptive cruise control, active steering, anti-lock brake systems, GPS, lasers, and radars. A self-driving automobile observes by monitoring its surroundings using sensors. The sensors provide data to the computer, which combines the sensor data with high-definition map data to pinpoint the vehicle's location. Sensors and computer identify and categorize things, calculate their position, and offer information about their speed and direction. They also create a three-dimensional picture of the world in which relevant things are tracked. The Figure 1.25 [29] below displays a brief description of the technologies used in the autonomous car.

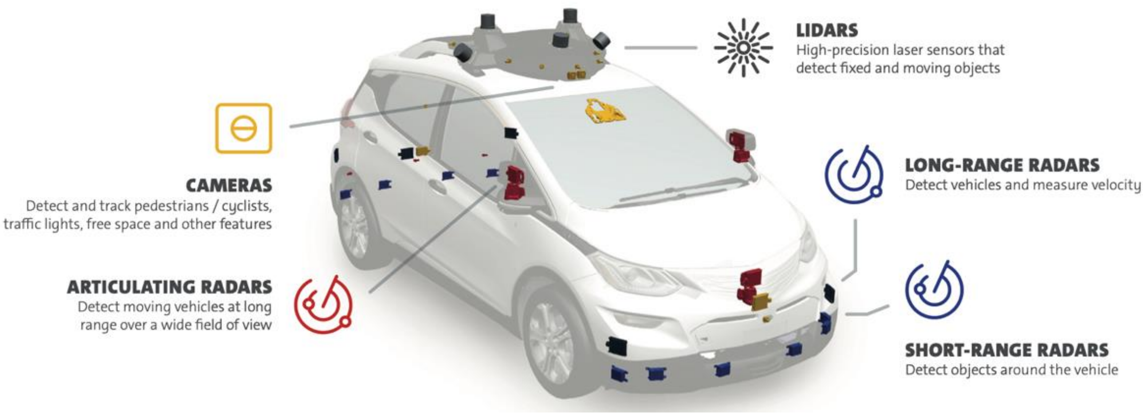

Figure 1.25: Technologies on autonomous car

Uber is testing different technologies and the Figure 1.26 [30] shows how they created different configurations among self-driving vehicles, for instance Ford Fusion has greater number of lidar and cameras than Volvo XC90.

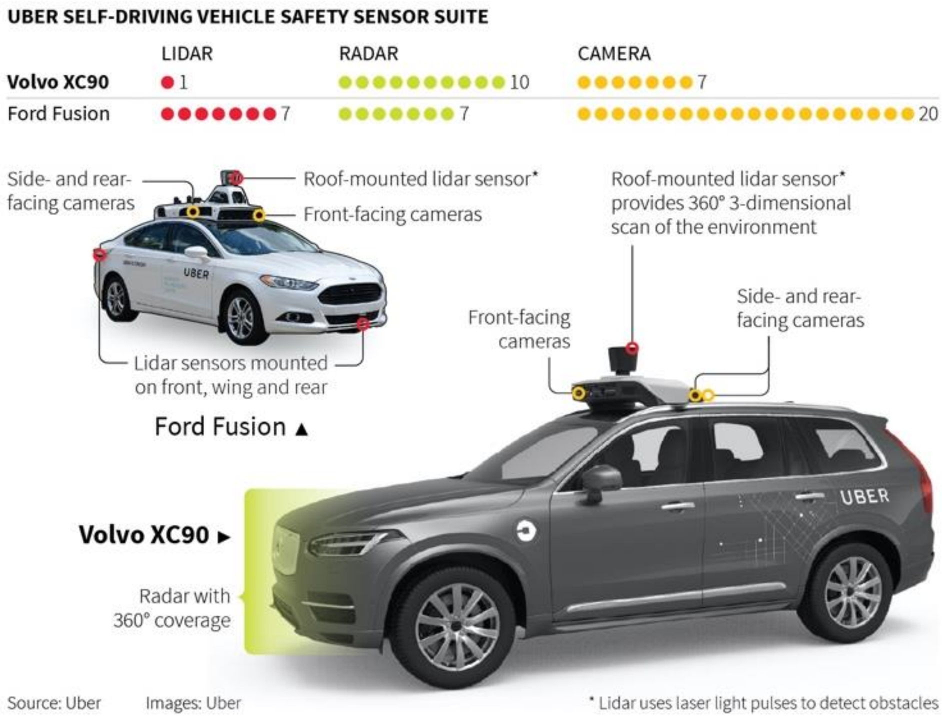

Figure 1.26: Self-driving car used by Uber

With the growth of self-driving vehicles and technologies produced by high-profile corporations, transportation as we know it is beginning to change. This is becoming increasingly apparent as new testing locations on public roads and closed courses spring up throughout the world monthly. With more than a half-dozen locations now operational, the United States has been in the vanguard of the autonomous-vehicle live trial movement. Europe began with controlled environment testing and is now concentrating on public transit initiatives. There are three testing locations throughout Asia, with intentions to expand. The first Canadian testing of self-driving automobiles began in Ontario late in 2016. The Figure 1.27 [31] depicts the current locations of self-driving car testing and deployment throughout the world.

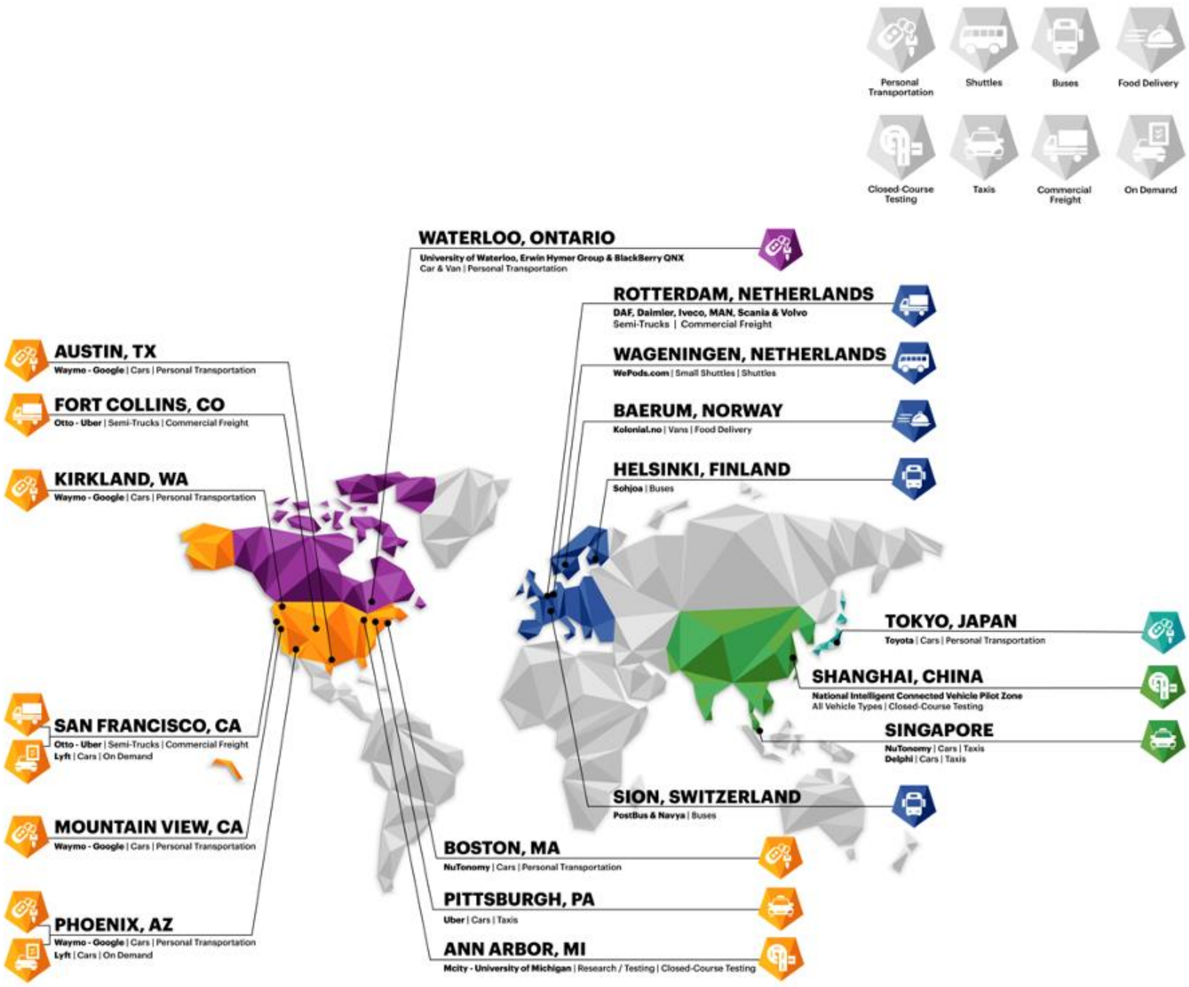

Figure 1.27: Deployment of self-driving cars in the world

Autonomous vehicles can happen only if the cars are well and safely connected with each other and with the infrastructure, which means that connecting car is the first step to go further in the development of autonomous vehicle. In this process it should be discussed and create the best policies to construct a new vision of the car and not just a mean of transportation to go from one to another location.

1.9 Shared mobility

Shared mobility refers to passengers using a vehicle collectively for transportation without owning it. The cars used in shared mobility may run on any sort of fuel and the goal is to limit the usage of private vehicles, which can cut emissions by a specific proportion and reduce traffic congestions. The emphasis in this thesis in the field of shared mobility is on car sharing, especially focusing on e-autos. The primary objectives are to minimize emissions and increase passenger comfort. From the Figure 1.28 [32] it is highlighted about positive trend from 2016 to 2019 with a marginally decrease in 2020 due to pandemic situation. Considering about car sharing, the number of trips is globally increasing, and new companies are getting involved in this movement investing time, effort, and money not to lose an important share in the market.

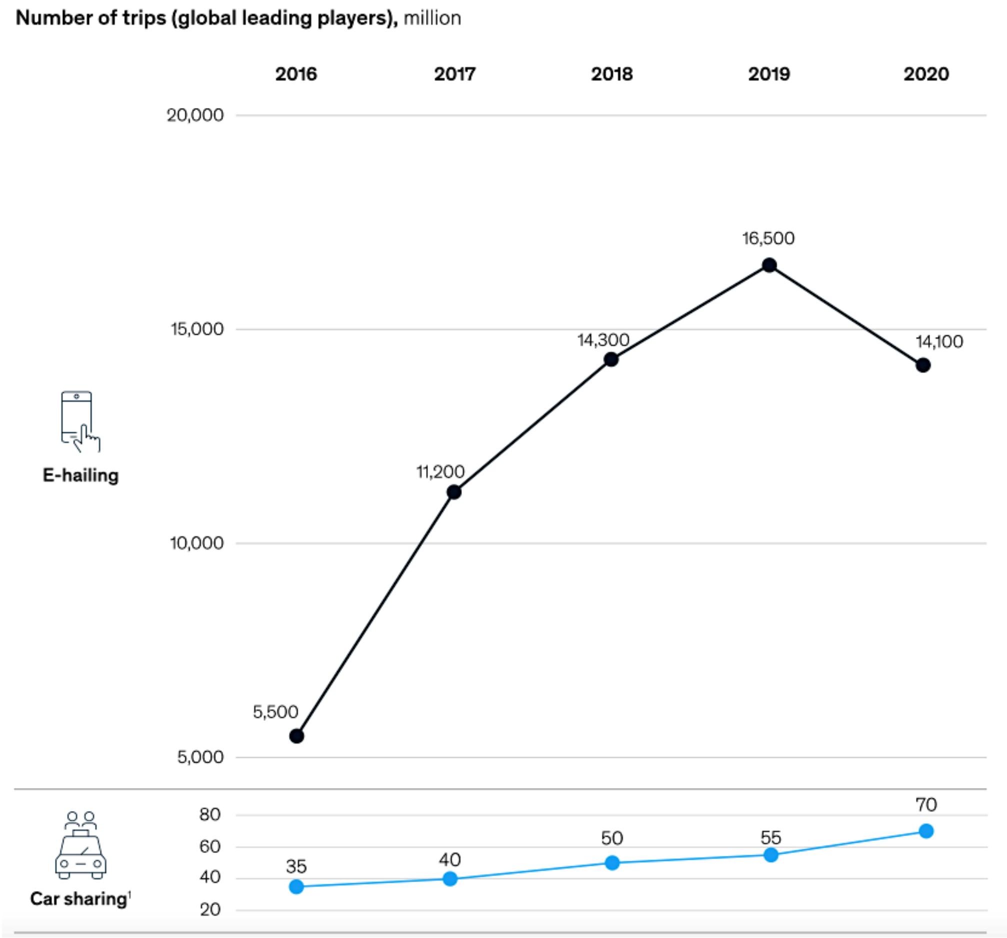

Figure 1.28: Number of global leading player trips

The Figure 1.29 [33] shows the European car sharing landscape focusing on different aspects related to a specific country, for example in UK parking permits is an obstacle for free floating providers, while in France all free-floating vehicles should be hybrid or electric and they have easy access. In Italy Milan is the center for free floating with 80% of the market and bike sharing is very relevant. As you can see in the scheme below, Germany is the biggest car sharing market in Europe.

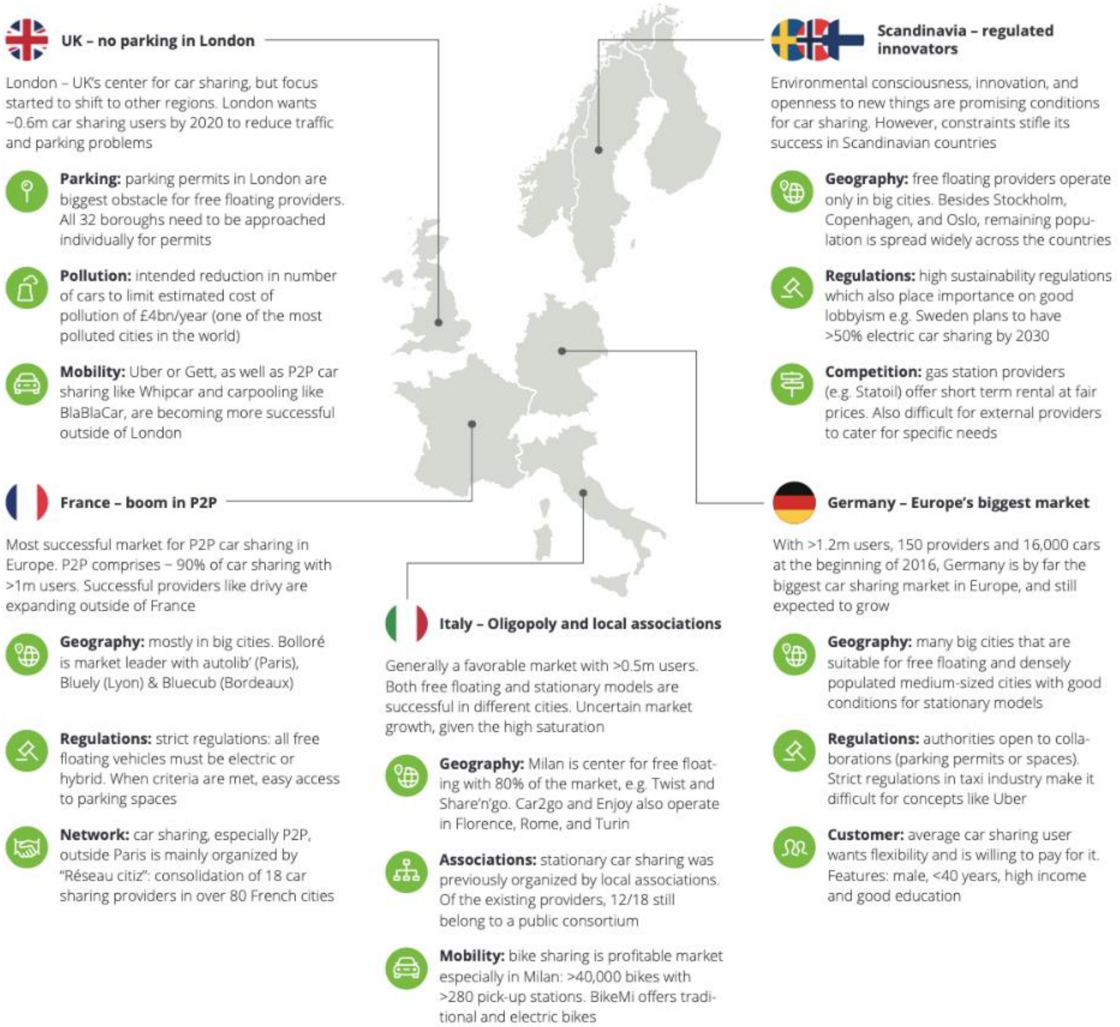

Figure 1.29: European car sharing landscape

The Figure 1.30 [15] depicts the number of cars sharing available in 2019 and it shows that there are more than eight thousand available cars in Italy, where Sharenow, Enjoy and Share'ngo occupy more than 70% share in the market.

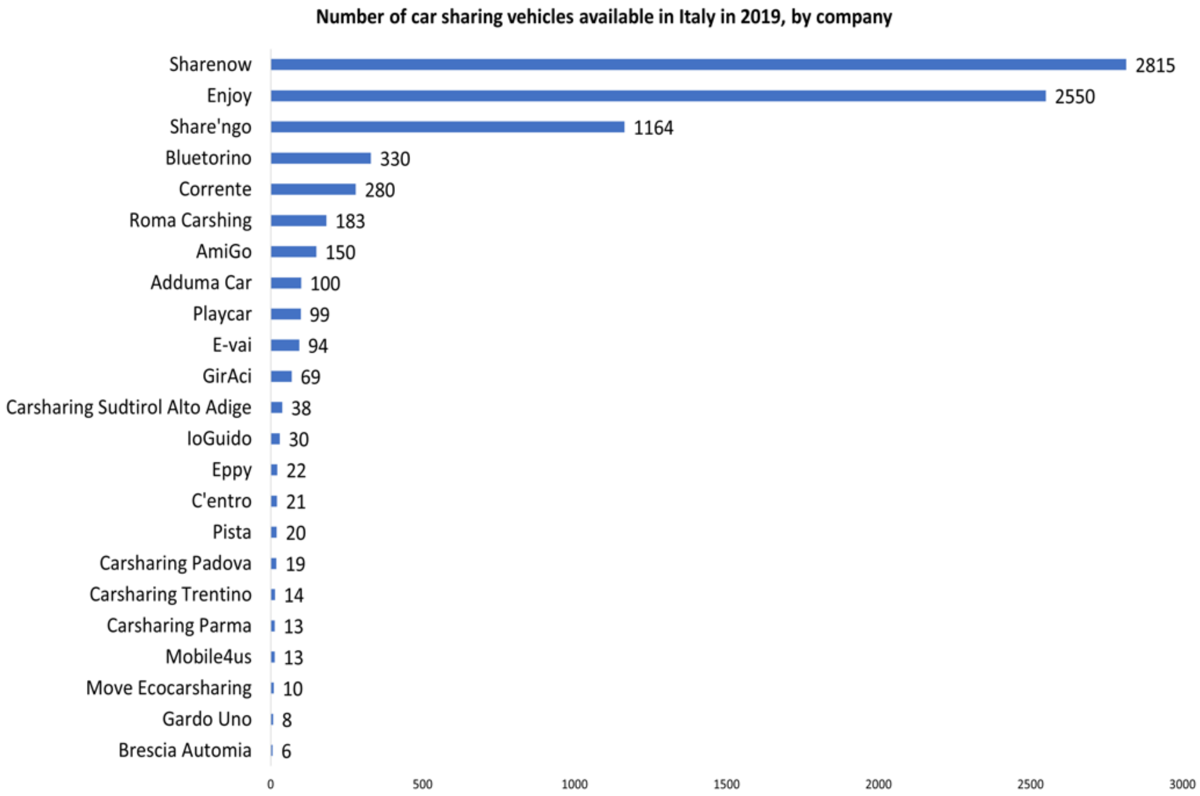

Figure 1.30: Number of car sharing vehicles available in Italy in 2019

2. The value chain in automotive sector

The value chain is a primary tool for understanding and interpreting the resources and capabilities in a structured manner by studying all a firm's operations and how they connect [34]. The value chain deconstructs a company into its strategically important operations to analyse cost behaviour and potential sources of differentiation. An organization has a competitive edge when it performs these systemically critical operations at a reduced or fairer expense than its peers. Firms' value chains differ among industries, reflecting their histories, strategies, and implementation success. Serving only one industry segment may enable a company to customize its value chain to that sector, resulting in cheaper costs or differentiation in serving that market as compared to competitors. In every company a set of activities are conducted to design, manufacture, sell, distribute, and support its product or service. The value chain represents overall value, and it is made up of value activities and margin. Value activities are the physically and technologically separate operations conducted by a company, these are the building elements that a company uses to develop a product that is valued to its customers. The margin is the difference between the overall value and the whole cost of conducting the value activities. In this chapter, it is focused on value chain in the automotive sector and how each element can shape the value chain from an infrastructure perspective by understanding the role of infrastructures in the future mobility value chain and relating with different trends.

2.1 Actors

2.1.1 Manufacturers

Manufacturing steps are almost similar in all the trends that are considered, first the inbound logistics which include the following: material handling, warehousing, inventory control, vehicle scheduling, and returns to suppliers are all examples of activities related with receiving, storing, and dispersing product inputs. Automotive logistics refers to the storing and shipping of produced vehicles, as well as their assemblies, throughout the automotive value chain. The global automotive logistics market size was estimated around 141.8 billion USD in 2019 [35]. The logistics process starts receiving the raw materials that include steel, plastic, aluminium, rubber, glass, and others. According to the International Organization of Motor Vehicle Manufacturers [36], approximately 78 million vehicles were produced in 2020 and 92 in 2019. The decrease is related to the pandemic crisis started in 2020. On average 60% of today's vehicles body structures are made by steel, they use AHSS optimizing the design, safety, and fuel efficiency. Based on total vehicle curb mass, the steel in a vehicle is distributed like this: 40% in the body structure, panels, doors and trunk closures to protect in case of car crash and guarantee a good thermal insulation, 23% in the drive train consisting of cast iron for the engine block and machinable carbon steel for the wear resistant gears, 12% in the suspension and the remainder in the wheels, tires, fuel tank, steering and breaking system [37]. According to American Chemistry Council, in 2016 the typical car included 151 kg of plastics and composites. This accounts for around 8% of the average car's weight and 50% of the volume of materials contained within the vehicle [38]. Nowadays this percentage is around 10%, however it differs among the different companies. Cars have been increasing in weight since the 1970s and aluminium accounts for around 10%, mostly used in engines, cylinder heads, gear housings, brackets, and pump bodies. Aluminium car bodies are confined to luxury cars [39]. The Figure 2.1 shows the materials used in a car with the percentage per each type of them and it can be easily noticed that steel, plastic, and aluminium build around 80% of the vehicle and others refer to rubber, glass, iron, copper, and all other materials that are part of the car body. These percentages can vary depending upon the manufacturer.

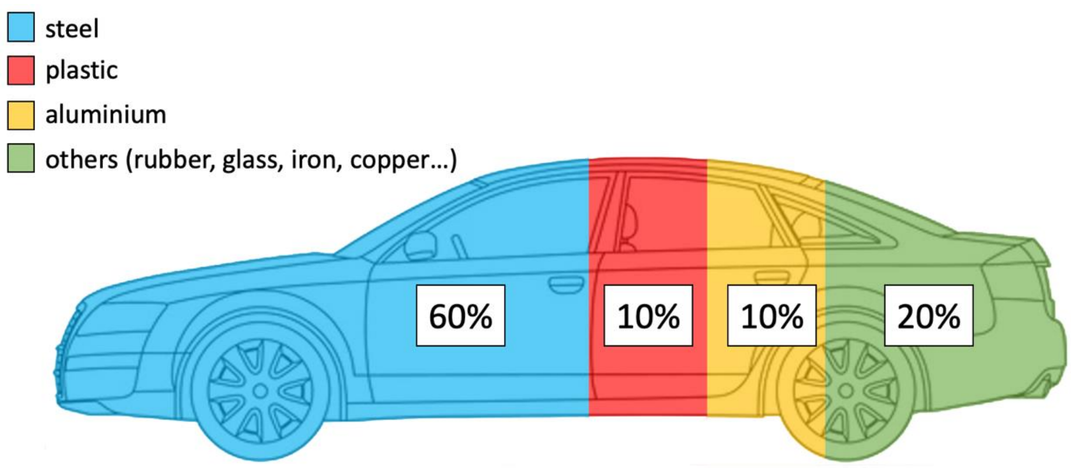

Figure 2.1: Distribution of raw materials in a car

After sourcing and processing the raw materials, it is delivered to a storage facility and manufacture them, as it is showed in Figure 2.2. Transportation refers to the movement of goods from one site to another as they make their way from the start of a supply chain to the customer. To plan the best way to transport, it is important to analyse the relative infrastructure and the mode of transportation.

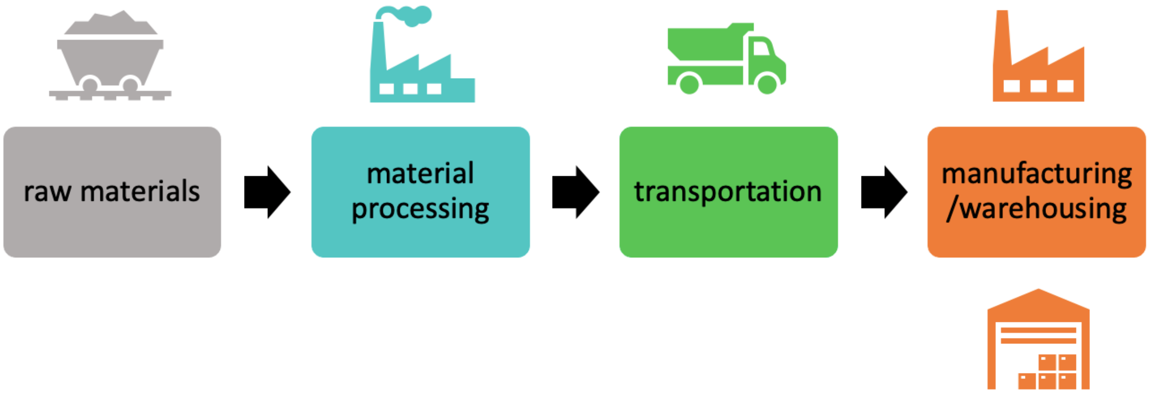

Figure 2.2: From raw materials to warehousing and manufacturing

There are various kinds of cargo and freight transportation, each with its own set of advantages and applications. The appropriate form of transportation is critical to profitability, while the wrong decision may cost time, money, and a lot of extra aggravation that might have been avoided. Transportation modes have variable cost functions based on the distance served [40]. Road, rail, and sea transportation have C1, C2, and C3 cost functions based on a basic linear distance effect. While road transportation is less expensive over short distances, it is more expensive than rail and ocean transportation when distance increases. Rail transport becomes more economical than road transport at distance D1, and marine transport becomes more advantageous at distance D2. The Figure 2.3 shows the general behaviour of the different modes.

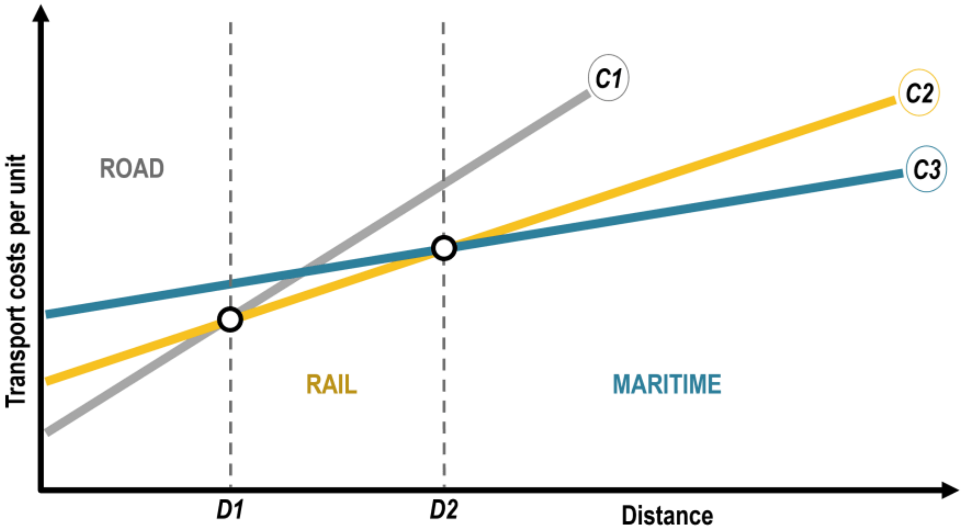

Figure 2.3: Distance, modal choice, and transport cost

The last step considered in inbound logistics is warehousing, which is the practice of holding physical items or inventory in a warehouse or storage facility until they are sold or dispersed. Storage facilities preserve items in a systematic and secure way, making it simpler to identify a product's position, when it arrives, how long it has been there, and the quantities. Warehousing has an impact on any firm and choosing the best storage solution may help save money, satisfy consumer demand, and increase efficiency. The modern automobile production lines are notable in that they have not changed all that much from the basic Ford system from so long ago [41]. Robots are increasingly performing some of the jobs that human autoworkers used to do. Even though production line labour requires repeated actions, it is simple, and safer, for a robot to take over a function of a person.

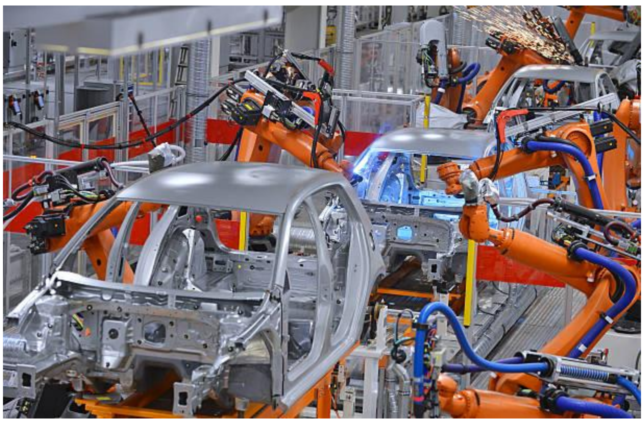

Figure 2.4: Assembly line

Defective items that would normally be discarded are recycled. Vehicle production comprises the fabrication and assembly of the final product from a range of metallic, plastic, and electrical components. There are numerous techniques available, such as finishing procedures include metal cutting, pressing, and other operations such as polishing, grinding, welding, plating, and painting. Many parts are created by the vehicle industry, while others are purchased. Engines are often constructed with aluminium or steel iron, which is then further processed at engine factories. Vehicle bodies are frequently made of sheet metal. Despite a trend toward more plastic, vehicle components composed of reinforced fiberglass and aluminium bodywork are used. Automotive testing involves putting complete cars, components, and systems through a range of laboratory, virtual, and "real world" [42] tests to verify that they are safe, dependable, and compatible with safety laws. Automobile testing is a prerequisite for producers to get access to global automotive markets, and they must demonstrate that their product has been thoroughly evaluated. From individual component analysis to emission testing, testing covers a wide spectrum of vehicle aspects. Some most important tests that are being conducted:

- **Global new car assessment test (NCAP)**: each automobile in the NCAP programme is given a maximum of 5-star rating; the greater the star rating, the safer the car. The rating is based on the crash test results for adult occupant protection and child occupant protection. These rankings are mostly based on crash-test dummy readings, however additional points may be granted for the availability of specific safety measures. These tests are common for all alternative fuel vehicles that are considered.
- **Noise, Vibration and Harshness test (NVH)**: in the automobile sector, NVH testing is frequently utilized for the reduction, design, and quality assurance of interior and external vehicle noise or vibration. NVH can be tonal, like engine noise, or wideband, like road or wind noise. It can be whatever that car user or travellers may listen to and feel from a car while running, such as breeze noise, road noise, suspension bumps, or engine throbs.
- **General braking test**: automotive brake performance testing entails determining stopping time, distance, and deceleration level. The braking performance of a car must be assured for a variety of surfaces such as dry, wet, concrete, mud, so on, as well as for extended usage. Various brake testing standards are used across the world to ensure the safety of vehicles and pedestrians.
- **Regenerative braking test**: two tests were done for vehicles to describe the hybrid braking systems and acquire data to be used as a reference during the validation tests to be undertaken in control system dbDyno [43]. The tests that were used include pedal feeling and blending characterization tests. The

fundamental idea behind the sensation test is to measure the pedal reaction to a linearly rising deceleration during brake applications, whereas the goal of the blending test is to measure the contribution of each braking system to varied deceleration conditions. Brake pedal feel is an essential issue in hybrid braking tuning because difficulties can develop if the system is not correctly built or tuned, particularly in the transition zones from regenerative to friction-based braking and vice versa, depending on the regeneration approach used. Blending characterization studies are conducted on cars equipped with regenerative braking systems to determine the contribution of each braking system (friction-based and regenerative) under various deceleration circumstances.

- **Lithium-Ion battery testing**: EV, PHEV, BEV, and FCEV all require lithium-ion battery testing and certification. Altitude, submersion, salt spray, humidity, highly accelerated life testing, thermal vacuum, dust, fungus, vibration, shock, drop, external short circuit, impact, seismic, penetration, and overcharge are some of the lithium battery test categories [44].
- **EMI/EMC testing**: electronic components are found in all modern automobiles, as well as older ones. As a result, EMI and EMC are crucial for ensuring that a vehicle’s electronic systems and sub-systems work properly in a digitally linked environment.
- **Environmental and climatic simulations**: the environment has a significant impact on the lifespan of automobiles and their components and replicate every type of environment on the planet. Therefore, parts are evaluated in a variety of environments to evaluate how long they would endure in hot, cold, dry, and rainy temperatures, as well as UV exposure combined with salt, fog, dust, and humidity. Excessive moisture in the air in many locales, such as coastal or tropical climates, can cause rusting of automobile coatings, paint wear, and electrical component degradation. Because temperature and humidity grow in lockstep, frequently assess both at the same time. The Figure 2.5 [45] summarizes the main tests.

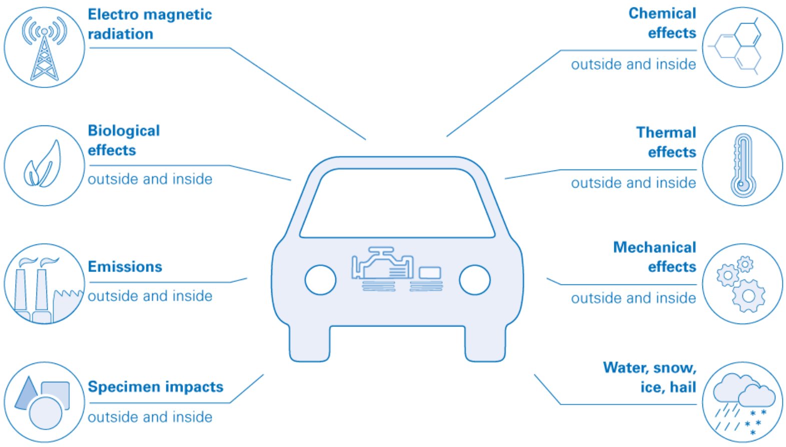

Figure 2.5: Vehicle testing

The weight of a vehicle is one of its technical factors. Vehicle weight and distribution on axles can have an impact on performance factors such as fuel economy and acceleration dynamics. An examination of historical patterns in vehicle weight change reveals that automakers used the designs of enormous vehicles between the 1950s and 1970s, rather than attempting to reduce vehicle weight [46]. Later, from the 1970s until the mid-1980s, the use of lightweight materials became fashionable, and steel was substituted in vehicle design by lightweight composite materials (plastics). As a result, the average weight of the same class of cars fell by 15–20 percent. However, a significant reduction in vehicle weight resulted in decreased passenger safety and design durability. Vehicles began to be equipped with different safety technologies, such as safety airbags, the ABS, and stability control systems, to improve passenger safety in the 1980s and 1990s. A variety of passive safety measures were also created. The development of new safety systems and their installation on vehicles resulted in increased vehicle weight, as shown towards the end of the twentieth century. EV have remarkably high energy capacity per unit battery weight, ranging from 60 to 96 Wh/kg. If a vehicle is outfitted with 20 kWh lithium batteries, its weight may exceed 200 kg. It is recommended to pick a custom-made pack of EV batteries to lower vehicle costs, as carrying the extra weight of the batteries is economically wasteful. If an electric vehicle is outfitted with contemporary lithium-ion batteries, current technologies allow for a travel range of 40 to 480 km per battery charge. These batteries are not only hefty, but they also take up a lot of space 450 to 600 litres inside the automobile. The occupied space might be cut in half by adopting fuel cell technology. Electric cars now use lithium-ion batteries, although slower-moving electric vehicles still use lead batteries. When compared to other types of batteries, lead batteries add the most weight to an electric car. Increasing the capacity of the battery pack can extend the trip range. The Figure 2.6 [47] depicts the impact of vehicle weight due to battery type.

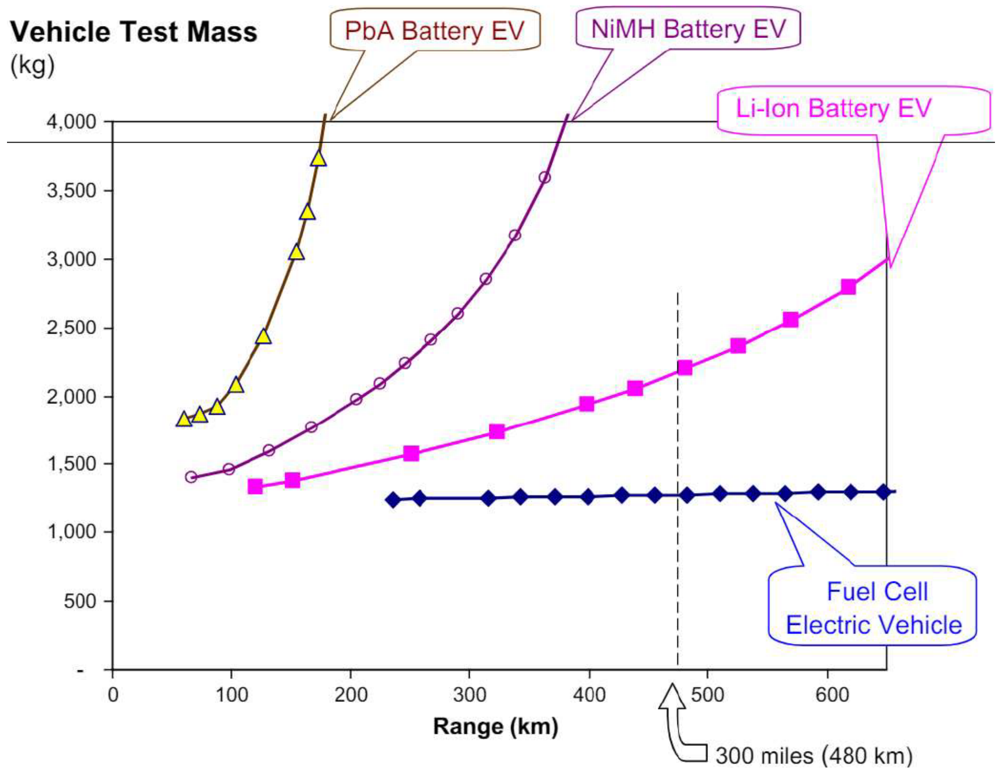

Figure 2.6: Impact of vehicle weight due to battery

2.1.2 Suppliers

Organizations that manufacture components utilised in the manufacturing phase of an automotive sector or become a part of an automotive value chain, supplying these products explicitly or implicitly to an automotive company, are referred to as OEM. Some important components are listed below.

2.1.2.1 Battery

A battery is a portable storage device that typically consists of numerous electrochemical cells capable of converting stored chemical energy into electrical energy with high efficiency and no gaseous emissions during operation. Over the last few decades, several battery chemistries have been created. All types of batteries contain two electrodes, an anode and a cathode as shown in Figure 2.7. Among the existing technologies, Li-ion chemistry now dominates the market in a wide variety of applications. These batteries come in four different shapes: small and large cylindrical, prismatic, and pouch.

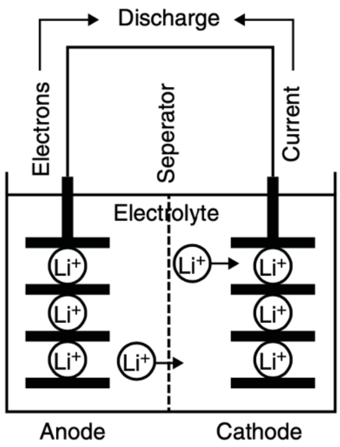

Figure 2.7: Battery

The battery capacity (which is proportional to the maximum discharge current) is measured in Ah, the energy stored in the battery (capacity x average voltage during discharge) is measured in kWh, and the power (voltage x current) is measured in kW. The maximum discharge current (typically represented by the index of C) indicates how quickly the battery may be drained and is influenced by the chemical processes and heat created by the battery. Another essential parameter in batteries is the SOC, which shows the percentage of available charge in the battery. Batteries are currently the most widely used technology for EVs and HEVs due to their ability to deliver peak and average power at excellent efficiencies, but they have inherently low specific energy, energy density, and refuelling/charging rates (compared to fossil fuels), which limits their range, increases their size, and cost, preventing widespread adoption. For example, current technology requires around 150 kg of Li-ion cell (or more than 500 kg lead acid cells) to go 200 km in a non-demanding driving cycle for an ordinary passenger automobile. To increase this range, the power, weight, and cost must be nearly doubled, posing significant limits. Currently, some of the most prevalent technological demands for batteries include high discharge power, high battery capacity and cycle capabilities, good recharging capability, and high-power capacity for electric vehicle applications. To make excellent commercial and economic sense, EV batteries must have high energy densities for extended driving ranges and high-power densities for quick acceleration, as well as be durable and affordable. A variety of battery technologies are currently available for electric vehicle applications, each with its own set of benefits and drawbacks, and alternative chemistries are also being researched to have a comparable technology and ease the transition between conventional and electric vehicles by improving performance, lowering costs, and reducing environmental impact. Rapid technological breakthroughs in improved chemistries are predicted to result in the manufacturing of cost-effective and long-lasting batteries. Today, only a few battery technologies are commonly used in electric and hybrid electric vehicles, such as lead-acid (used in original versions of EV1 and RAVEV), nickel cadmium (used in Peugeot 106, Citroen AX, Renault Clio, and Ford Think), nickel metal hydride (used in Toyota Prius and Highlander, Ford Escape, Honda Insight, and Saturn Vue), and lithium-ion (used in Toyota Prius and Highlander, Ford Escape (used in Tesla Roadster, Chevrolet Volt, BMW i3, i8 and majority of the vehicles developed after 2013). As seen in the Figure 2.8 [48] CATL, LG and Panasonic make up almost 70% of the EV manufacturing market, where Central Europe is on its way to become the EU's battery supplier [49].

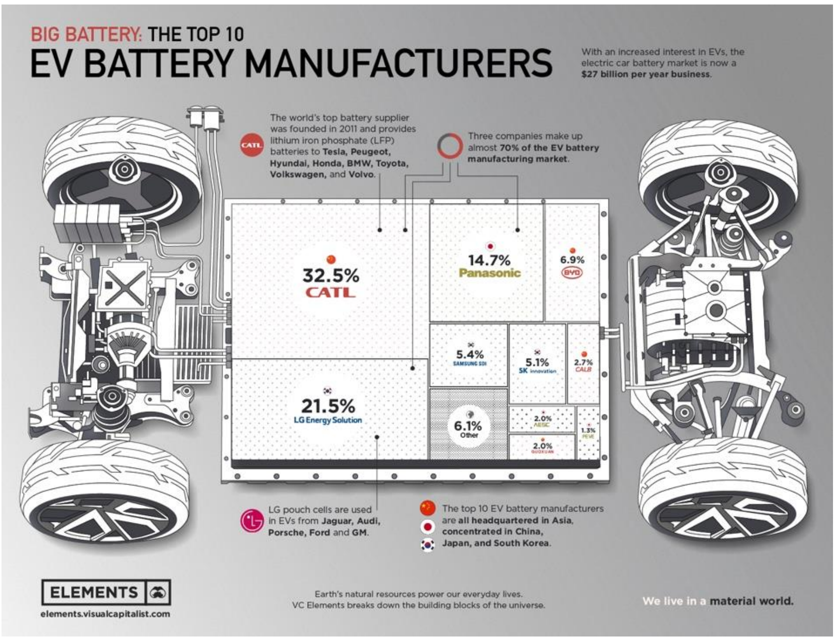

Figure 2.8: EV battery manufacturers

2.1.2.2 Fuel cell

Fuel cell technology has several applications. Currently, extensive research on the fuel cell is being undertaken in attempt to develop a low-cost car powered by a fuel cell. FCEVs, or fuel cell electric vehicles, use clean fuels and are thus more environmentally benign than internal combustion engine-powered automobiles. In many remote locations, fuel cells are also employed as primary or backup sources of electricity. There are several types of fuel cell which include polymer electrolyte membrane fuel cells, Alkaline fuel cell, Phosphoric acid fuel cell, molten carbonate, solid oxide. Here, mostly the polymer electrolyte membrane fuel cell is used. The use of solid electrolytes lowers corrosion and electrolytic management issues and can perform at low temperature. The area has seen an increase in the implementation of fuel cell-based systems in the transportation industry, including light motor vehicles, trucks, and heavy-duty vehicles. The European Union's ongoing efforts to reduce carbon emissions mobility in the area are the most major stimulus for such a change. According to Eurostat, the percentage of renewables in overall energy utilization in the transport industry was about 10% in 2020, which was a success for the EU, as they had established the very same aim. They have now proposed a new goal of increasing the figure to 14 percent by 2030. As a result, various projects are presently underway to accelerate the expansion of green-hydrogen technology in the transportation industry. The fuel cell market in Europe is fragmented those include Plug Power Inc, Ballard Power System Inc, Toshiba Corp, Nuvera Fuel Cell LLC [50] are few protruding corporations in this commerce. Germany is also planning to expand its fuel cell manufacturing capabilities by constructing additional production sites in the nation. Cummins Inc., for instance, began construction in April 2021 on a fuel cell system manufacturing site in Herten, Germany. The planned factory is expected to begin with assembly activities before expanding to fuel cell stack repair. The yearly capacity is projected to be 10 MW.

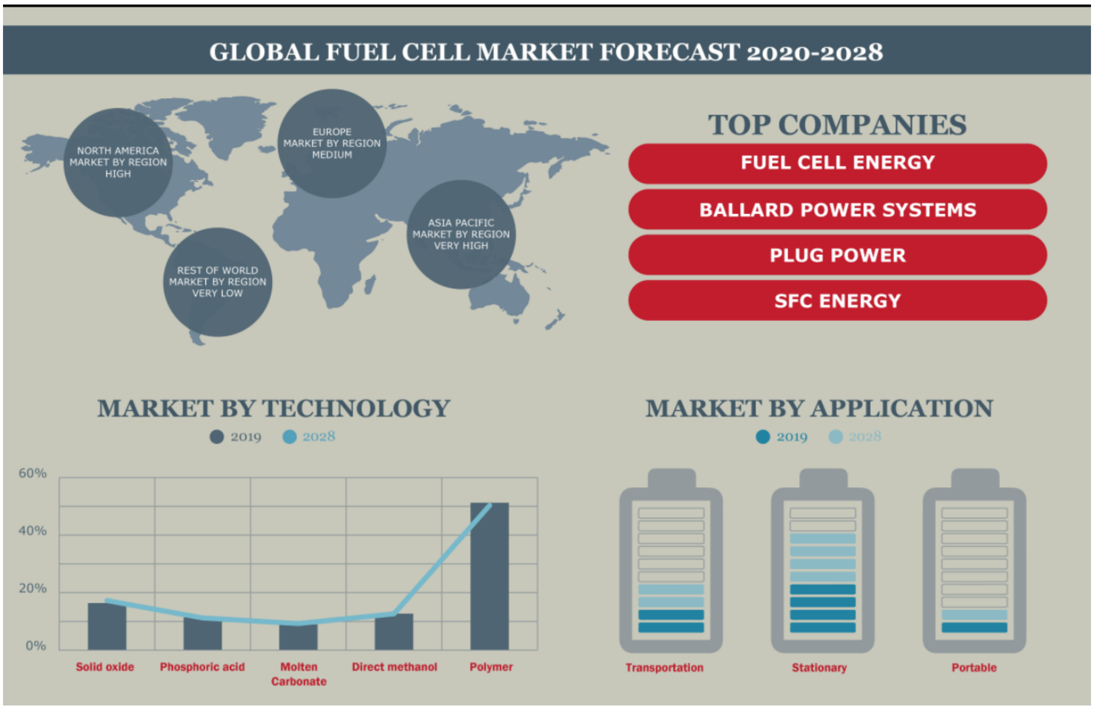

Figure 2.9: Global fuel cell market

2.1.2.3 Drivetrain

The powertrain market is being driven by the desire to lower automobile carbon footprints through cost-effective, efficiency-enhancing advancements. Concrete approaches include engine downsizing, enhancing fuel injection precision, and increasing after-treatment efficiency. On the transmission front, automakers are attempting to optimize both gear ratio and gear changing. Other tasks that improve efficiency include decreasing friction and hydraulic losses. In a broader sense, the desire for greater environmental stewardship on the road is driving the shift toward car electrification and hybridization. The primary subject in powertrain category is electrification, which allows for locally emission-free transportation and driving enjoyment. If just the electric motor is utilized for propulsion, a long driving range necessitates a lot of energy. A battery stores and delivers the required energy and high motor efficiency in the drive train extends range or decreases the demand for battery capacity. To improve battery lifespan and handle critical conditions during operation, BMS monitor and regulate all battery-related operations such as charging and discharging, SoH, and cell balancing to ensure the battery's safe operation and extended lifetime. Brake energy may be converted to and stored as electrical energy. Purely electric propulsion provides maximum torque from the beginning. The electrified powertrain lies at the heart of all these electric car technologies. Semiconductors can help to improve energy efficiency at all stages of the energy supply chain. They are critical components for enabling electromobility and they improve the overall performance of hybrid and electric cars by reducing power losses and boosting power savings. The Figure 2.10 highlights the most important components in the EV drivetrain. The traction inverter is one of the most crucial systems in an electric car and it manages the electric motor and is an important component in electric vehicles since it dictates driving behaviour, much as the EMS in combustion vehicles. Semiconductors in the traction inverter convert the direct current from the battery into the alternating current that operates the motor [51]. Less energy is lost in this manner, resulting in a longer range. The energy for the electric powertrain is mostly supplied by lithium-ion battery systems. This process must be monitored to safeguard the battery from early aging and to guarantee that the battery's capacity is fully utilized. The BMS can monitor the SoH, SoC, and DoD; it can also aid to prevent unauthorized manipulation of both the system and battery packs. An electric vehicle's battery, which all electric system rely on, is worthless without an on-board charger.

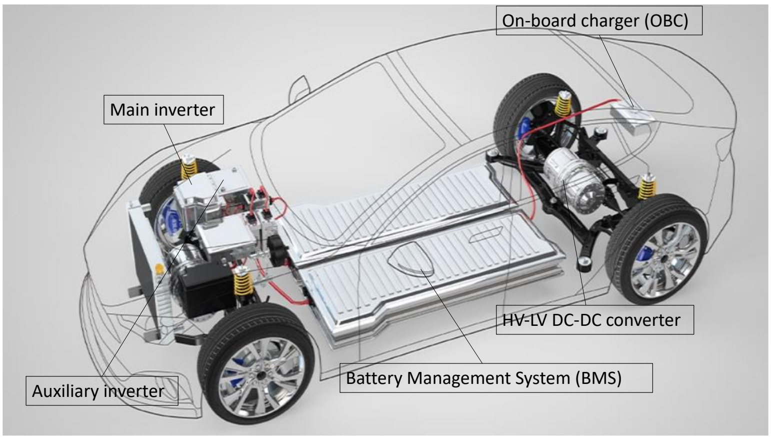

Figure 2.10: Components in EV drivetrain

Electric cars will be the key to future mobility with such energy-efficient technologies, making them a strategic priority for the automotive sector in the next years. The major suppliers in the EV powertrain are shown in the Figure 2.11 below.

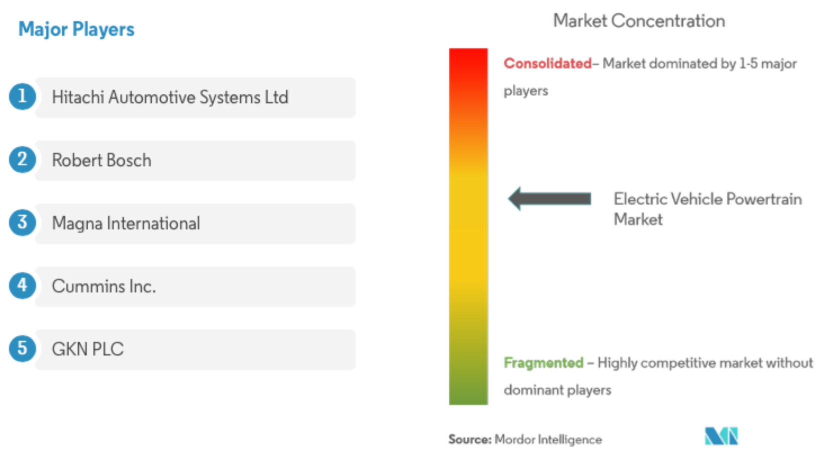

Figure 2.11: Major players in drivetrain

2.1.2.4 Sensors

Sensor technology is a major driving force in the advancement of ADAS. The sensors' role is to deliver a constant stream of information about the area surrounding the car to ADAS and autonomous driving features. The sensor must detect not just what the driver can see, but also what the driver cannot or has not seen. There are currently a variety of sensor types in use, each with its own set of pros and disadvantages in terms of capabilities, cost, and it is becoming more common to employ more than one type of sensor for each ADAS function. Because each type of sensor has known strengths and limitations, it is possible to improve ADAS functionalities by integrating diverse technologies. This fusion of sensor technologies is increasingly becoming the norm; the problem then becomes to interpret the stream of data from various sources reliably and promptly. Another thing to consider is the sensor's resilience and endurance. While some sensors may be mounted within the vehicle's interior, many need placement outside the vehicle, in susceptible regions such as bumper corners and behind the grille, which can be unfriendly conditions for high-tech equipment. The car insurance and repair industries have also expressed worry about the high cost of sensor replacement or recalibration in the event of an accident. The increasing adoption of ADAS and the continued development of self-driving vehicles are propelling sensor technology forward at a rapid pace. Many existing systems are still working at a basic level in terms of object recognition and categorization, and there is a long way to go before ADAS capabilities can make the leap to completely autonomous applications. Current algorithms, for example, may fail to recognize pedestrians beyond a precise shape. They may fail to recognize a person if they are dressed in attire that dramatically modifies their form, if they are carrying a bulky object, or if they are shorter than a specific height. However, as technology advances, these restrictions will surely be solved. Radar, ultrasonic, lidar, and cameras are the four primary types of ADAS sensor technologies available [52]. As can be noticed in the Figure 2.12 [53], the main suppliers of ADAS registered a large increase in their revenues that is driven by the increase of level of automation in this sector.

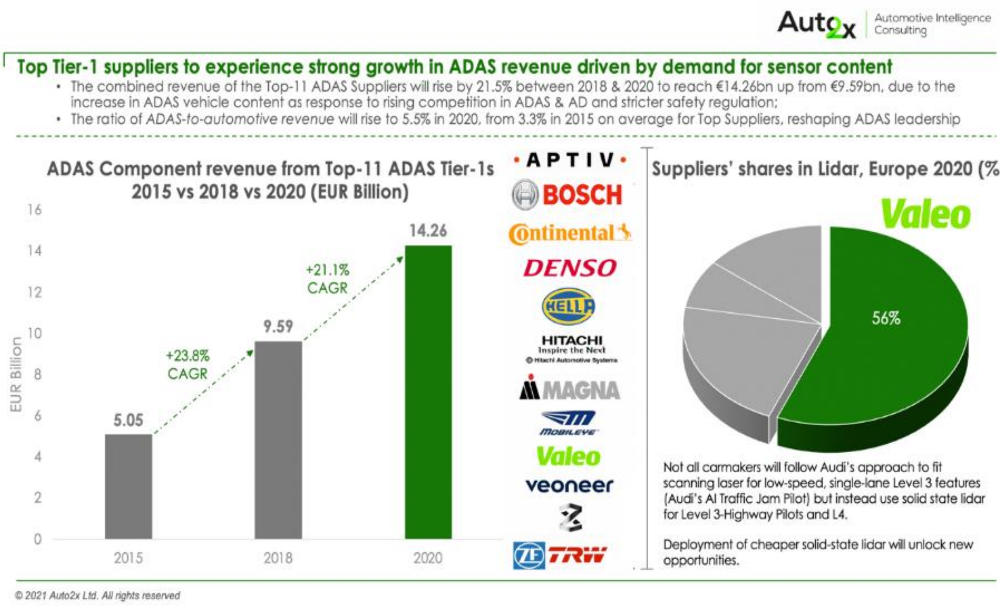

Figure 2.12: Suppliers for sensor components

2.1.2.5 Infotainment and communications

Infotainment provides both useful information and fun. It is the name of the device that sits in the place formerly held by the AM radio for automakers. Global IT companies such as Apple, Google, and Samsung Electronics are boosting collaboration with conventional automobile manufacturers to obtain a competitive advantage in the developing smart car sector. Apple recently launched CarPlay, a car infotainment operating system that incorporates iPhone services such as phone calls, texting, and navigation while driving.

Figure 2.13: CarPlay

Figure 2.14 depicts the growing trend in global automotive infotainment operating system, which means the market is going to increase to better connect the user to car experience.

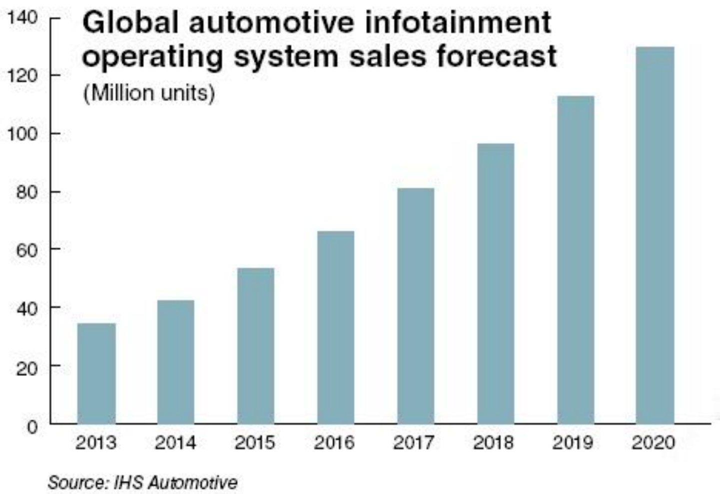

Figure 2.14: Global automotive infotainment operating system

2.1.2.6 Engine

The internal combustion engine industry is predicted to rise significantly throughout the forecast timeframe, as manufacturers focus on innovative technologies such as engine control unit replacement to increase vehicle average life, thus increasing engine lifespan. At some point in the estimated cycle, the emerging requirement for fuel-efficient and lightweight vehicles is anticipated to engender worthwhile expectations for market accomplices. Considerations such as rigid fuel efficiency, regulatory standards, and increased need for technologically superior propelled engines for improved performance parameters are likely to boost global market. Leading engine manufacturers and suppliers in Europe is the Volkswagen group. The Figure 2.15 [54] shows the main features of the automotive engine market.

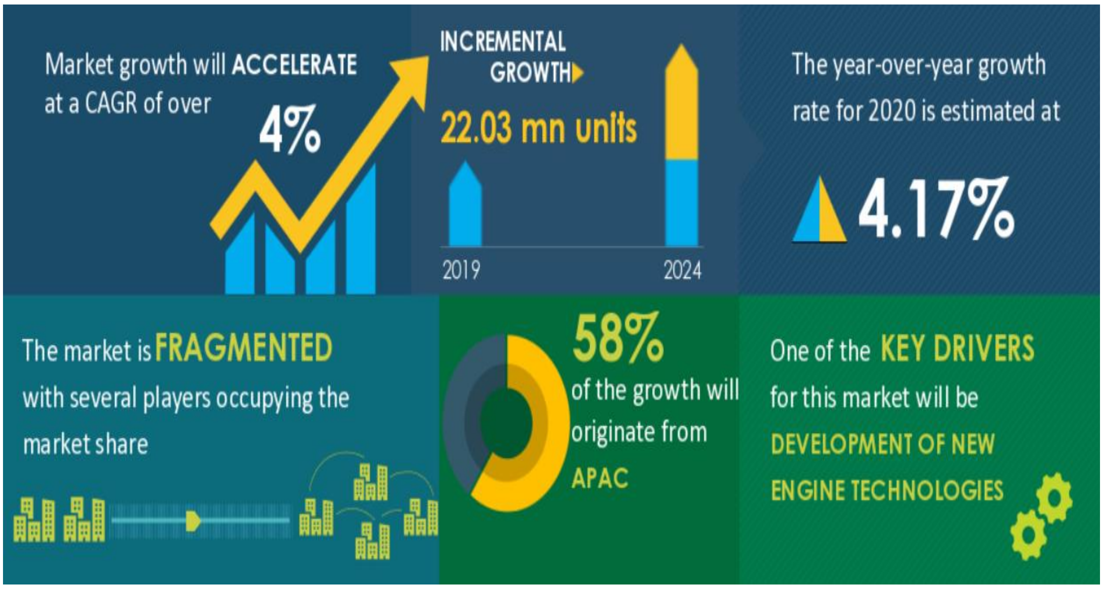

Figure 2.15: Automotive engine market

2.1.2.7 Brakes

The worldwide economy for brakes and brake parts has expanded in recent years. The prediction is similarly encouraging; the worldwide brake market is expected to rise at a CAGR of 4.7 percent from 2016, owing in part to an increase in vehicle production. Europe exports parts like brakes and brake linings, with an aggregate trade estimate of €23.0 billion in 2015 [55]. Because of this, the EU is a great market for developing-country producers of materials and components. The vendors are grouped into two broad categories: system control and foundation brake component makers. While Bosch sold their foundation break component business and is now a provider of solely process control, rivals such as Continental and ZF TRW also provide systems and components [56]. Suppliers of brake control systems have systems integration experience with the brakes and steering innovations that are at the heart of the safety devices used in the constantly increasing area of creating sophisticated technologies. All these system providers wield considerable power in the worldwide market. Leading suppliers in Europe include Robert Bosch, Continental AG, ZF TRW automotive holdings Corp, Brembo S.p.A.. The automobile rising performance braking system market research study includes a complete analysis of the main industry vendors to assist businesses in strengthening their market presence. The research also provides industry executives with information on the competition environment as well as perspectives into the diverse value propositions provided by multiple organisations. The Figure 2.16 [57] displays the automotive brake system market, while the Figure 2.17 [58] depicts the supplier component trend dividing them in three clusters.

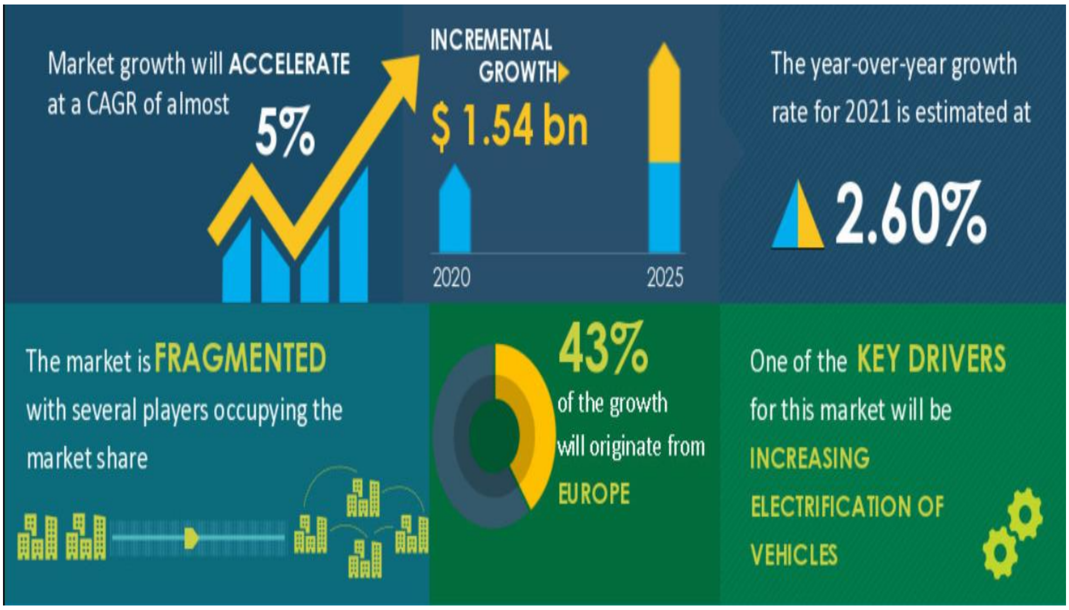

Figure 2.16: Automotive brake system market

Vehicle component cluster (GER, NAFTA, CHN)	Total Volume 2016 in € bn	Volume Development 2016–2025 S1	Volume Development 2016–2025 S2	Volume Development 2016–2025 S3	Volume Development 2016–2025 S4	Average Develop. 2016–2025 in %	Average Volume 2025 in € bn
HV Battery/Fuel Cell	5.5	+1,359%	+892%	+925%	+1,380%	+1,139%	68.1
Electric Drivetrain	1.3	+1,116%	+670%	+666%	+1,231%	+921%	13.2
ADAS & Sensors	6.4	+995%	-6%	+458%	+989%	+609%	45.4
Electronics	50.3	+48%	+6%	-6%	+40%	+22%	61.2
Interior	71.5	-2%	+1%	-8%	-3%	-3%	69.3
Seats	39.3	-3%	+1%	-9%	-3%	-4%	37.9
Infotainment & Communications	46.9	+25%	-5%	-59%	8%	-8%	43.3
Body	114.9	-11%	-4%	-12%	-11%	-9%	104.2
Suspension	12.0	-11%	-4%	-13%	-11%	-10%	10.8
Steering	15.0	-11%	-4%	-13%	-11%	-10%	13.5
Wheels & Tires	22.2	-12%	-4%	-13%	-12%	-10%	19.9
Frame	22.3	-11%	-4%	-16%	-11%	-10%	19.9
Axles	20.7	-12%	-5%	-13%	-12%	-10%	18.5
Climate Control	12.1	-17%	-5%	-14%	-17%	-13%	10.5
Brakes	16.3	-20%	-4%	-13%	-20%	-14%	14.0
Fuel System	7.1	-28%	-5%	-19%	-29%	-20%	5.7
Exhaust System	21.8	-29%	-6%	-20%	-30%	-21%	17.1
ICE	107.1	-34%	-13%	-26%	-35%	-27%	78.5
Transmission	61.3	-35%	-16%	-28%	-36%	-29%	43.7

Likely winners (volume increases in more than one scenario) · Uncertain component clusters (volume increases in one scenario) · Likely losers

Figure 2.17: Supplier components trend

2.1.3 Automotive consumers

To analyse consumer or user behaviour, the automotive industry plays a major role in helping survive in the market by analysing customers' opinions, even after this helps the company to make the customer refer the product to another person. In the automotive industry, a separate team is involved in analysing consumer behaviour after and before sales. Each company will undergo some questionnaires, interviews, surveys, etc., asking the customers which ones satisfy them and upon which further development of the business strategies and investment of the company are carried out. The important question that is most concerning is the advanced technology for the upcoming cars. For example, a question may remain like, "Will the customer be willing to pay an extra amount for the advanced technology, or will they not be interested?" For instance, good quality with the latest upgrades in infotainment systems such as inbuilt GPS, a separate sim slot inside the system, etc., also there are some other questions like customer requirements while making a purchase and sharing their experience with the company so that in future they can avoid some complications that they faced earlier and with the help of customer reviews, they can overcome these obstacles. Suppose the company has branches in many countries, they take a survey in each country and look for answers to the survey conducted about the interest of the customer, whether they are fully satisfied or not, and find out which lags for the dissatisfaction of the user and what all the other requirements are needed if the same car is being upgraded in the next year. For example, some customers may opt for an infotainment system that is comparatively small and that can fit inside the cabin quite nicely without any distraction while driving, or some may suggest a bigger screen for a larger view for the passengers inside the car, also for the driver to look onto the screen while reverse with a 360 degree camera as an additional upgrade, which is used and monitored in front of the screen placed inside the cabin. Some other factors like providing a completed report about the maintenance updates and vehicle health to the customer, and what are all the things that can be given as discounts in the future. Most people still prefer to buy a car from a reputable dealership. However, a sense of improved convenience and simplicity of use will certainly favour the further expansion of virtual transaction procedures. Every year, at the beginning or at the end of the year, they conduct this survey before manufacturing the new product. Customer reviews play a vital role in the industry.

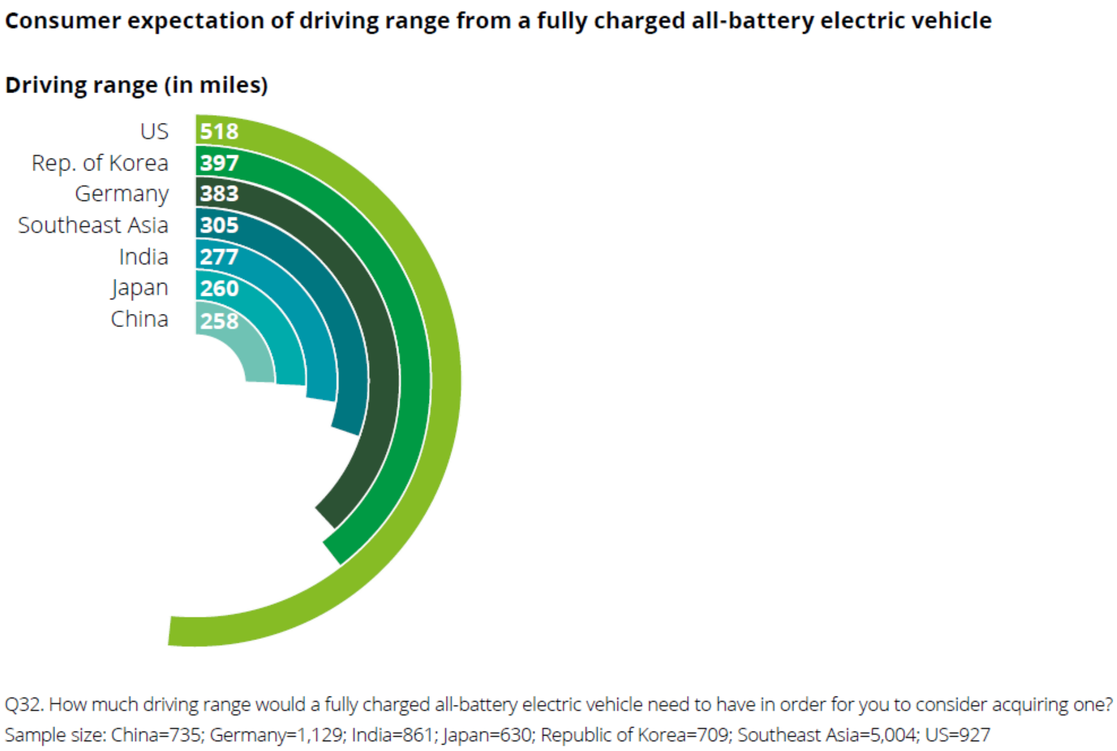

Figure 2.18: Consumer expectation of driving range from a BEV

Percentage of consumers that are unwilling to pay more than ~US$500[1] for a vehicle with advanced technologies (including people that would not pay any more)

Advanced technology category	US	Germany	Japan	Rep. of Korea	China	India	Southeast Asia[†]
Safety	56%	70%	66%	58%	31%	48%	59%
Connectivity	65%	77%	83%	72%	39%	48%	65%
Infotainment	69%	82%	86%	78%	39%	57%	72%
Autonomy	61%	69%	56%	42%	31%	37%	48%
Alternative engine solutions	53%	56%	57%	41%	31%	35%	46%
Unwilling to pay more than...	$500	€400	¥50,000	₩500,000	¥2,500	₹25,000	Local currencies[‡]

Note: Did not consider "don't know" responses.
[†] Southeast Asia region comprises Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam markets.
[‡] IDR 5 million/MYR 2,000/25,000 Php/SGD 500/15,000 Thai baht/10 million VND.
[1] Calculated for each country in local market currency (roughly equivalent to $US500).
Q3. How much more would you be willing to pay for a vehicle that had each of the technologies listed below?
Sample size: China=1,016; Germany=1,401; India=989; Japan=880; Republic of Korea=961; Southeast Asia=5,070; US=960

Figure 2.19: Advanced technologies

Factors that impact the decision to acquire an electrified vehicle

Factors	US	Germany	Japan	Rep. of Korea	China	India	Southeast Asia
Concern about climate change/ reduced emissions	2	1	2	2	1	1	2
Concern about personal health	6	4	5	7	3	4	5
Lower fuel costs	1	2	1	1	4	2	1
Less maintenance	4	7	7	3	6	5	4
Better driving experience	3	5	3	4	2	3	3
Government incentives/ stimulus programs	5	3	4	5	7	6	6
Potential for extra taxes/ levies applied to internal combustion vehicles	7	6	6	6	5	7	7

Top concern

Q26. Please rank the following factors in terms of their impact on your decision to acquire an electrified vehicle (highest to lowest).
Sample size: China=360; India=331; Germany=513; Japan=361; Republic of Korea=482; Southeast Asia=1,568; US=250

Figure 2.20: Factors that impact the decision to acquire an EV

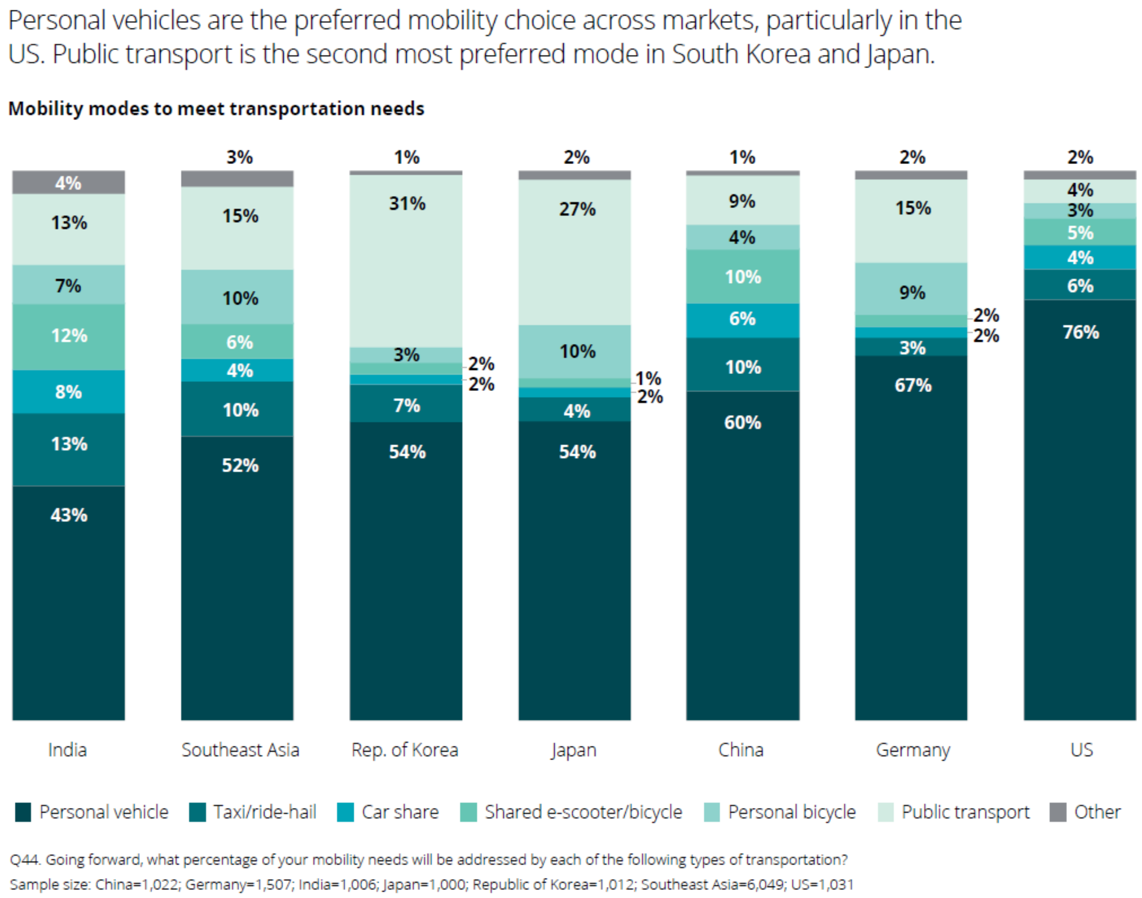

Figure 2.21: Mobility modes to meet transportation needs

2.1.4 Service providers

2.1.4.1 Car dealerships and repair

There is no doubt that client happiness is one of the most important goals of any business, not just for existence but also for sustainability [59]. Unfortunately, due to severe rivalry and consumer complexity, this is not easy to implement in practice. Customers have been pampered with so many alternatives, making it harder to match their expectations. Customer happiness cannot be achieved in the absence of quality enhancement elements that customers appreciate. If consumers do not express their appreciation for quality through service interactions and post-purchase reviews, customer pleasure will be a phantom especially in the case of the automobile industry. They have moved beyond a product's or service's features and performance to what will pleasure them. Service quality, while fundamental, has become an essential component of every service provider's product offering to its target market, and the car business is no different, as clients are more interested in superior after-sales services for value for money. It is true that after sales are one of the key factors to retain customers, this also helps them to recommend the company to their fellow mates. Most of the car dealerships, nowadays providing free services twice or thrice a year also negotiating cost due to repair of the damaged component. This can cut cost the customer's money spent on the maintenance of the product. Even after years of purchase, company provides, extended warranty to the car along with noteworthy discounts on the spare parts.

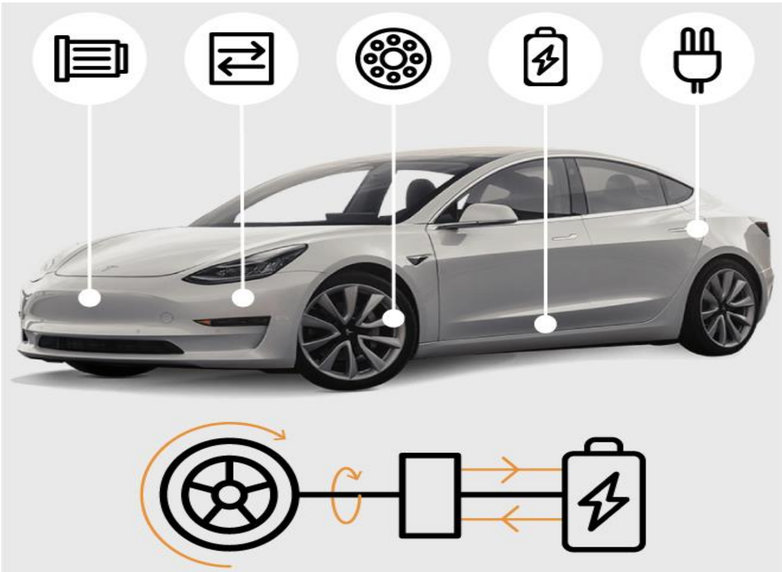

Figure 2.22: Service of a BEV

2.1.4.2 Car sharing providers

From the perspective of vehicle sharing providers, the service is distinct from that of automobile manufacturers. In the case of vehicle sharing companies, the firm allows customers to choose cars based on their journey. For example, an SUV type automobile may be offered to a large family, whereas hatchback cars might be offered to a small group. This option is available through the vehicle sharing mobility department's app, as showed in the Figure 2.23 [60]. People are also thinking about ways to decrease expenditures, including the money that will be paid to the shared mobility division. They provide discounts for the journey that consumers are entitled to take, and they are supplied to them based on the number of kilometres travelled. Furthermore, for each journey that they carry out, the car sharing services may give them with insurance for each voyage, so in this way they really help find served consumer contact.

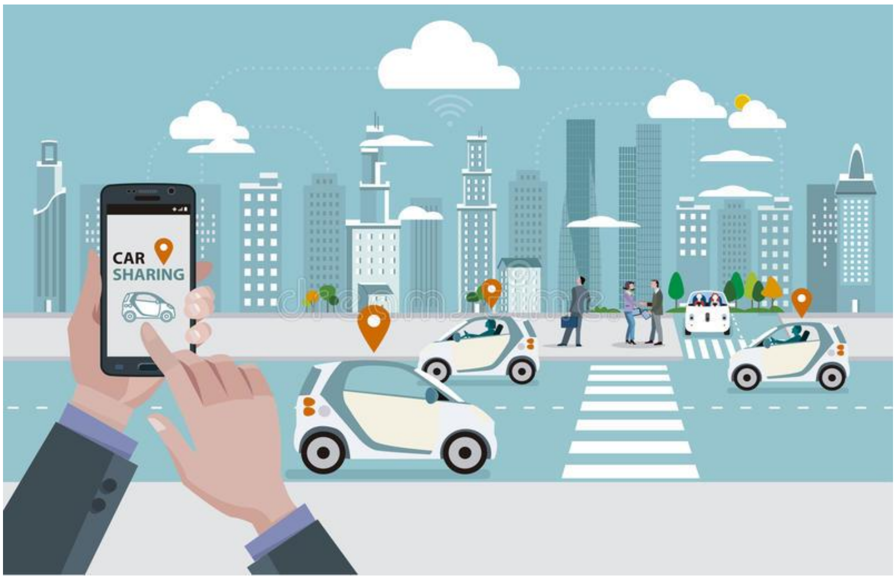

Figure 2.23: Car sharing

2.1.4.3 Energy providers

As known, there are several types of energy that may be delivered to the vehicle to propel it. Fossil fuel is one of the most well-known types of energy and companies that operate based on fossil fuels can offer gasoline, diesel, and liquefied petroleum gas etc. So, from an infrastructure standpoint, for an energy provider, it means that to attract consumers, the infrastructure should be designed in such a manner that they may also be attracted. In the previous chapter, it is discussed also about alternatives that may be acceptable for vehicle motion apart from fossil fuel. Therefore, in the case of electric vehicles, the energy supplier would be an electricity provider from a charging station. Energy companies, for example, can now provide certain benefits like prepaid cards can be used to swipe for the charging cost and may accumulate points when people begin, so that for each charge they make at that specific station, they earn some points at the end, and these points may be redeemed for the vehicle to charge in the following days. This also applies to energy, such as hydrogen, so a similar approach is used here, with incentives and some discounts given to customers who use this energy provider's infrastructure for their vehicle, despite the fact as discussed in the previous chapter, the refuelling of hydrogen is short. As a result, in the case of energy infrastructure, service providers play an important role in the value chain. The Figure 2.24 [61] summarizes the alternative fuel vehicles trends and impact.

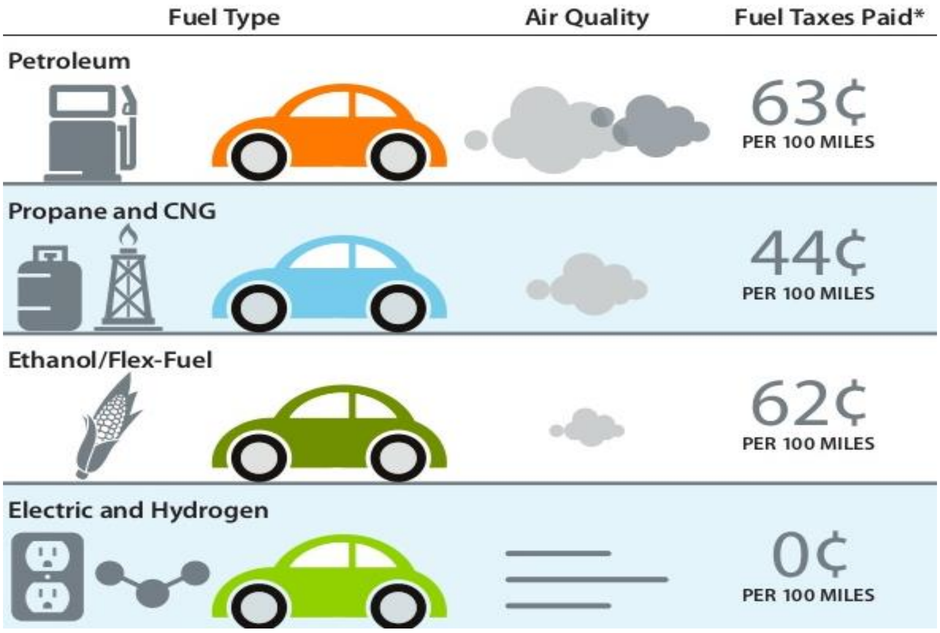

Figure 2.24: Energy source for vehicles

2.1.4.4 Network operators

In the realm of connected automobiles and autonomous vehicles, network operators play a significant role. For example, if an autonomous vehicle is considered, the role of the service providers is such that while driving to a location and the vehicle stops due to a problem with the sensors and processors inside, the service providers as the network operators, and with the help of an OTA update, they can fix it very quickly without taking the vehicle to the service centre, as usually done with alternate vehicles. So, in this case, network operators play a significant role in collecting data and usage of a vehicle in terms of the customer's behaviour inside the car, driving speed, and kilometres driven by the customers using WiFi and 5G technology, and storing this data in a cloud system that will be managed by the network operators. They protect each customer's privacy, which is one of the finest things for the customer's safety. The Figure 2.25 [62] represents an example of end to end encryption data.

Figure 2.25: End to end encryption

2.1.5 Government

The government establishes the regulatory framework and develops policies that can either encourage or impede the emergence of new trends. Policies continue to have a significant impact on the advancement of electric transportation. Typically, EV adoption begins with the formulation of a set of goals, followed by the acceptance of car and charging standards. Procurement programs are frequently included in an EV deployment strategy to drive demand for electric vehicles and enable the first roll-out of publicly accessible charging infrastructure. Fiscal incentives, which are especially important because EV purchase prices are higher than ICE vehicle purchase prices, are frequently combined with regulatory measures that enhance the value proposition of EVs (e.g., waivers to access restrictions, lower toll, or parking fees) or embedding incentives for vehicles with low tailpipe emissions (e.g., fuel economy standards) or establishing zero-emissions mandates. Minimum standards for EV readiness in new or rebuilt buildings and parking lots, as well as the rollout of publicly accessible chargers in cities and on highway networks, are policies to encourage the implementation of charging infrastructure. Standardization improves the interoperability of various forms of charging infrastructure. Policies and market frameworks must be developed to guarantee that electric mobility can actively contribute to enhancing the flexibility of power systems. Electric mobility, through offering flexibility services, can expand options for integrating variable renewable energy resources into the generating mix while also lowering costs associated with power system adaptation to higher EV uptake. Electricity markets should make it easier to provide ancillary services like grid balancing that are suited for EV participation, as well as enabling minor loads to participate through aggregators.

Aggregators should not suffer excessive transaction costs (including not only fees, but also any regulatory, administrative, or contractual impediments) to pool many minor loads to participate in demand response in the energy market. As seen in Figure 2.26 [63], leading nations such as those engaging in the electric vehicles initiative are already making progress from their earliest phases of EV policy implementation. Many of these nations have regulatory tools in place, and some mature markets, like as Norway, have begun to phase away some components of their EV support programs.

		Canada	China	European Union	India	Japan	United States
Regulations (vehicles)	ZEV mandate	✓*	✓				✓*
	Fuel economy standards	✓	✓	✓	✓	✓	✓
Incentives (vehicles)	Fiscal incentives	✓	✓	✓	✓		✓
Targets (vehicles)		✓	✓	✓	✓	✓	✓*
Industrial policies	Subsidy	✓	✓			✓	
Regulations (chargers)	Hardware standards**	✓	✓	✓	✓	✓	✓
	Building regulations	✓*	✓*	✓	✓		✓*
Incentives (chargers)	Fiscal incentives	✓	✓	✓		✓	✓*
Targets (chargers)		✓	✓	✓	✓	✓	✓*

Notes: * Indicates that the policy is only implemented at a state/province/local level. ** Standards for chargers are a fundamental prerequisite for the development of EV supply equipment. All regions listed here have developed standards for chargers. Some (China, European Union, India) are mandating specific standards as a minimum requirement; others (Canada, Japan, United States) are not. ZEV = zero-emissions vehicle. Check mark indicates that the policy is set at national level. Building regulations refer to an obligation to install chargers (or conduits to facilitate their future installation) in new and renovated buildings. Incentives for chargers include direct investment and purchase incentives for both public and private charging.

Figure 2.26: EV-related policies in the world

The private sector is responding to policy signals and technological changes in a proactive manner. A growing number of OEMs have stated their goal to electrify the models they sell, not only for vehicles, but also for other means of road transport. Battery manufacturing investment is increasing, particularly in China and Europe. Utilities, charging station operators, charging gear makers, and other power sector players are also expanding their investment in charging infrastructure rollout. This is taking place in an atmosphere that is becoming increasingly consolidated, with multiple acquisitions by utilities and big energy businesses. Government plays a fundamental role also in the regulation of autonomous and connected cars. Two major trends are defining the future of personal mobility: the first is a transition from human to machine vehicle control, and the second is a shift from individual to shared vehicle ownership [64]. Driverless or AVs have the potential to provide significant economic and societal advantages. It is widely assumed that driverless cars have the potential to save lives, reduce the financial cost of car accidents, improve urban mobility, reduce congestion, and negative environmental impacts, provide more inclusive modes of transportation for the elderly and people with special needs, and increase productivity. According to the European Parliament, the present legal EU framework for liability standards and insurance for connected and autonomous cars must be revised. Not only revision assure legal clarity and improved protection of consumer rights, but it would also certainly yield economic benefit.

2.1.6 Substitutes

Substitutes are currently one of the most advantageous things from the standpoint of the consumer. Different types of cars might be used based on the travel. If the route is within the city limits, an electric car is ideal due to its regenerative technology and excellent range within the city. If the car must be driven a long way, the same firm can provide a substitute. In this situation, a conventional car or plug-in hybrid electric vehicle with both a gasoline and an electric charging port can be utilised. Even if charging stations are not accessible for a long distance, traditional fossil fuel energy can be utilised as a replacement in this vehicle. This has the added benefit of lowering CO_2 emissions. There are also connected automobiles and self-driving vehicles that can be employed, particularly at a location such as a company's headquarters for a trail if the company needs some improvement before officially announcing its arrival on road. This technology can be initiated by the corporation on campus. For example, if an employee working in that organisation must move from one building to another within the campus, they can utilise connected car or autonomous vehicle technology to get there. Because they are inside the range, and even if a problem arises, the provider may begin the repair fast. Substitutes are alternatives that can be used without giving much problem for the customers travel.

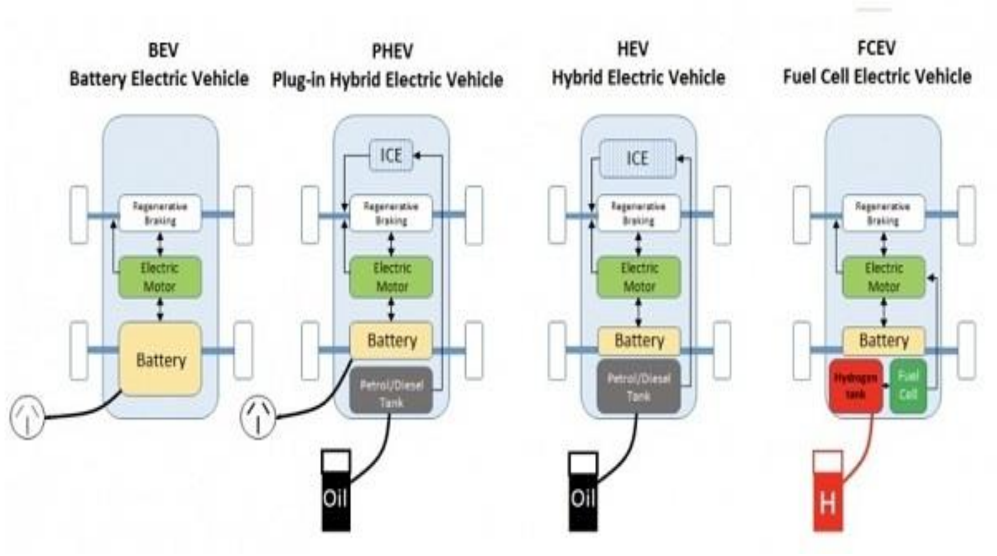

Figure 2.27: Substitute vehicles

2.2 Technologies

Every value activity incorporates technology, whether it be know-how, methods, or technology embedded in process equipment. Most businesses use a wide range of technologies, from those needed to prepare paperwork and convey items to those embedded in the product itself. Furthermore, most value operations employ a technology that incorporates several distinct sub technologies combining several scientific disciplines. Technology development encompasses a wide variety of actions that may be classified as attempts to enhance the product and process. The engineering department or the development group is typically linked with technology development. It does not just refer to technologies that are related to the product; instead, technology development may take numerous forms, ranging from fundamental research and product design to media research, process equipment design, and service methods.

2.2.1 Adding filters for an ICE vehicles

Nowadays, the world is more concern about the pollution, as discussed in the previous chapter, percentage of emission is more in the automotive sector. The European Union upgrading the terms to Euro 7 which means adding some filters to remove fossil fuel emission. Gasoline particulate filter are used to get rid of particulate matter from the discharge air of a gasoline direct injection engine. GDI cars are becoming increasingly popular because of CO_2 emission rules, with Euro 6.2 [65] being at the forefront. A GDI engine, on the other hand, generates more particulate matter than a gasoline engine with port fuel injection. By trapping particulate matter, GPF decreases particle emissions, resulting in cleaner autos for the environment. GPF filters are extremely efficient, collecting more than 90% of airborne particles that would otherwise be discharged into the environment. While the GPF and DPF technologies are linked, there are certain changes in the filter configuration, operation, and control approach due to variances in operating circumstances, as well as particle emission rates and composition between gasoline and diesel engines. The Figure 2.28 [66] is a typical example of fuel emission filter.

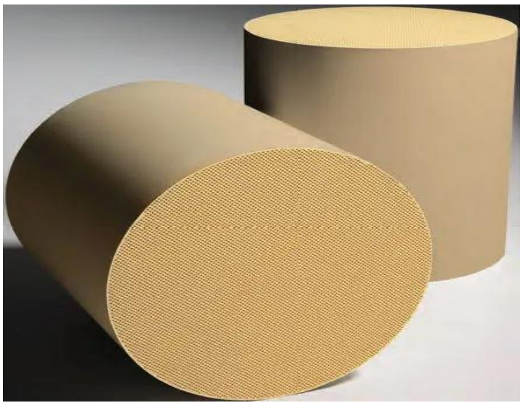

Figure 2.28: Fuel emission filter

2.2.2 Technology research on next generation battery

Scientists have created a biologically inspired membrane that has the potential to triple or quadruple the charge capacity of electric car batteries, significantly improving their range. Lithium-sulphur batteries can hold up to five times the amount of charge as normal lithium-ion batteries [67]. The expected lifespan of 1,000 cycles means that the ordinary automobile battery would need to be changed every 10 years, even though the materials used are significantly more available and less ecologically destructive than those used in lithium-ion batteries. Graphite is used in the anodes of today's lithium-ion batteries. Researchers have settled on sand or, more accurately, silicon as a replacement for graphite. In the same batteries, silicon anodes perform three times better than graphite anodes. Unlike many of the other major advancements on this list, switching from graphite to silicon is a simple move that manufacturers can incorporate into their existing operations [68]. Gold Nanowire Gel Electrolyte Batteries in which instead of using liquid electrolytes, researchers coated gold nanowires with a layer of manganese dioxide and then covered them with electrolyte gel.

2.2.3 Ultracapacitor

Ultracapacitors are a form of energy storage technology. They are also known as supercapacitors, double-layer capacitors, or electrochemical capacitors. Ultracapacitors, like capacitors, feature a dielectric separator that separates the electrolyte. However, unlike batteries, ultracapacitors store energy electrostatically (like a capacitor would) rather than chemically (as a battery would) [69]. Ultracapacitors, on the other hand, store less energy than a comparable-sized battery. However, because the discharge is not based on a chemical process, they may release their energy more quickly. Another significant advantage of ultracapacitors is that they can be recharged indefinitely with little or no deterioration. The ultracapacitor can be substitute for a battery, it also has drawbacks that must be considered, like as the charge being depleted much more quickly than batteries. Instead of depending the ultracapacitor only on all electric vehicle, they may also be used in hybrid vehicles in place of batteries when the power demand is less than the power capability of the electric motor; when the vehicle power demand exceeds the power capability of the electric motor, the engine is activated to meet the vehicle power demand as well as to provide power to recharge the supercapacitor unit, as showed in Figure 2.29 [70].

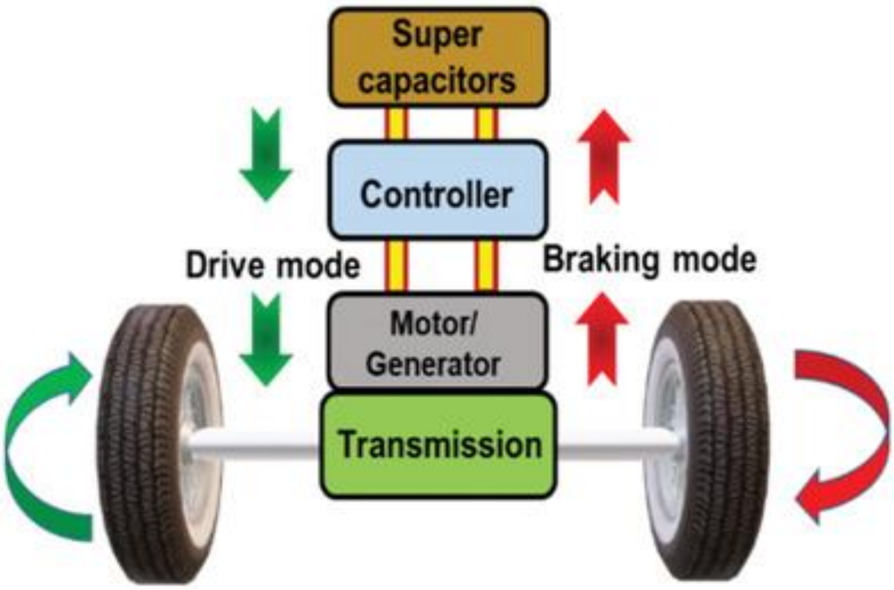

Figure 2.29: Supercapacitor based transmission

2.2.4 Charging sockets

Manufacturers are squabbling about connection types and standards in the EV sector. The shapes of connectors change from one maker to the other. In the case of CCS connector these plugs allow for fast DC charging and are intended to charge EV rapidly at the charging stations. When required a quick charge at a highway rest stop, it requires to take the tethered Combo 2 plug from the charging machine and insert it into car's power outlet. The bottom DC socket will allow for quick charging; however, the above Type 2 piece will not be engaged in charging at this time. For quick DC charging, CHAdeMO competes with the CCS standard. In Europe, the CHAdeMO system is now losing against CCS in the connection battles. CCS is being preferred by an increasing number of new EVs. CHAdeMO, on the other hand, has one significant technological edge: it is a bi-directional charger. This implies that power may travel not just from the charger to the vehicle, but also from the vehicle to the chargers and to the household or grid. Similarly, Tesla connection uses level 1, 2, and DC rapid charging. It is a Tesla connection that receives any voltage, thus see no need for a separate socket for DC fast charging, as other regulations demand. Tesla vehicles are the only ones that can utilise their DC fast chargers, known as Superchargers. Tesla established and governed these outlets, which are only available to Tesla owners. Even with an adaptor connection, charging a non-Tesla EV at a Tesla Supercharger station would be impossible. This is due to an access control mechanism that confirms the car is a Tesla before providing access to the electricity. The Figure 2.30 [71] recaps the main connectors.

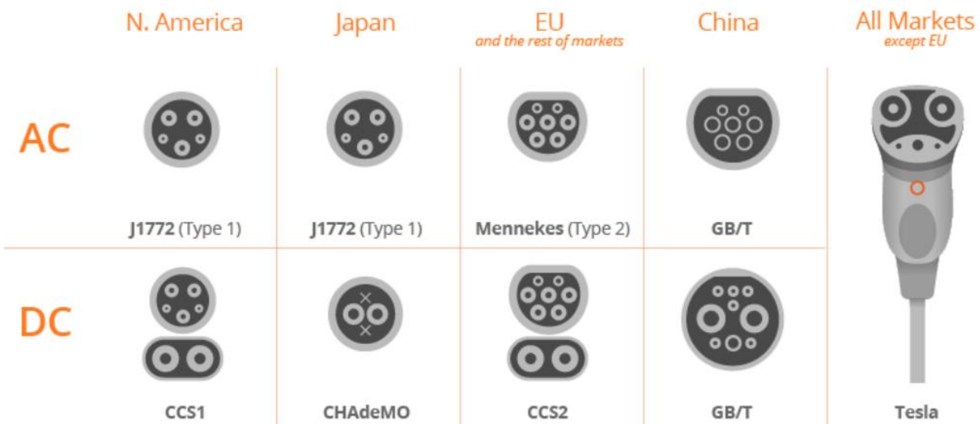

Figure 2.30: Connectors

2.2.5 Lidar, radar, and cameras

Radar is the most well-known of the ADAS sensor systems now in use. Radar detects objects measuring the time of radio waves to go and return to the source. Radar was initially developed concurrently by numerous nations for military use in the run-up to World War II, but it now has diverse uses on land, sea, air, and space. Radar has been used in automobile systems for some years, thus the hardware is well established and inexpensive, making it appealing to automakers. Radar is classified into three types: short-range radar (SRR), mid-range radar (MMR), and long-range radar (LRR). SRR systems have typically employed microwaves in the 24 GHz range. SRRs have a practical range of 10 meters but can extend to 30 meters, making them appropriate for blind spot detection, lane-change assist, park assist, and cross-traffic monitoring systems. The 77 GHz frequency is already used by MRR and LRR ADAS functionalities, which provides higher resolution and greater accuracy for speed and distance readings. MRR systems have a range of 30 to 80 meters, however LRR systems may reach up to 200 meters in some situations, making them appropriate for systems like as adaptive cruise control, front collision warning, and automated emergency braking. Because the measuring angle of LRR decreases with range, several systems, such as adaptive cruise control, incorporate data from both SRR and LRR sensors. Aside from being a tried-and-true technology, radar's other important advantages for ADAS application include its ability to perform well in adverse weather conditions like as rain, snow, and fog, as well as at night. Its limits, on the other hand, are widely recognized by the industry, particularly that radar does not provide adequate resolution to determine what an item is, simply that it exists. It also has a restricted field of vision in automotive applications, necessitating the use of many sensors on the vehicle to give enough coverage. Furthermore, SRR at 24 GHz has difficulty distinguishing between many targets. The Figure 2.31 [72] presents the different technologies related to the different ranges: short, medium, and long.

Figure 2.31: Radar technology

Lidar operates on the same basic principles as radar, but instead of electromagnetic waves, it uses lasers to build a high-resolution 3D picture of the surrounding environment. Lidar was initially created in the 1960s for meteorological, surveying, and mapping uses, but has lately been embraced for ADAS and autonomous vehicle research. There are two primary forms of Lidar, however they all use the same basic premise of monitoring reflected laser light. In the first case, a pulsed laser is directed against a spinning mirror, which scatters the laser beam in different directions. These systems are incredibly effective, with a range of 300 meters or more and a clear, 360° field of view if roof mounted. Their size, however, precludes their usage for ADAS functions in production vehicles, and they are also pricey. To radiate the laser beam, a more compact and ADAS-friendly variant of the same subject employs a revolving mirror based on MEMS technology. The second form is known as solid-state Lidar, and other varieties are being developed. One shoots a single laser via an optical phased array to aim the beam in many directions, and the other, known as flash Lidar, creates its picture with a single laser pulse, or flash. Each of the two major systems has advantages and downsides. Solid-state Lidar is preferred for automotive usage, not least because it is more durable – but in either instance, the emitted laser is reflected off any objects within range and is received by a sensitive photodetector, after which the information is transformed into a 3D representation of the local surroundings. The complexity and resolution of that 3D representation are what give Lidar the potential to be such a powerful instrument. With the right analytical techniques, a Lidar system [73] can identify objects, discriminate between them, and correctly track them in high-resolution 3D. Lidar also works effectively in rain and snow; however, it might be hampered by fog, and its effectiveness is impaired at night.

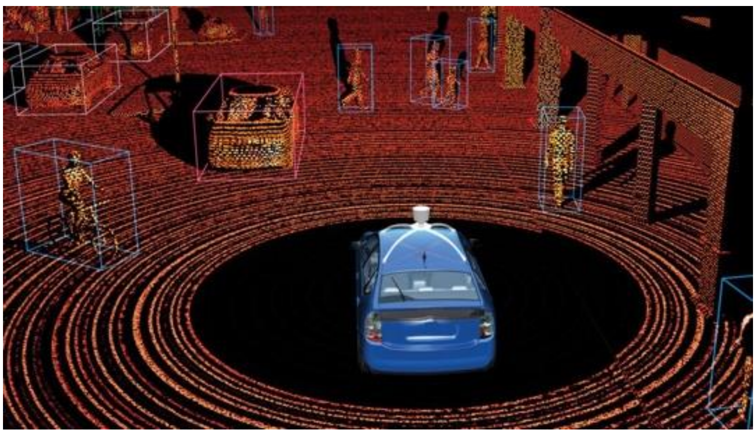

Figure 2.32: Lidar technology

Camera-based solutions have gained popularity as the preferred sensor technology among ADAS developers. They have limits, such as their sensitivity to poor performance in adverse weather and low or difficult light circumstances, but the technology, while still relatively young in comparison to radar or ultrasonic sensors, is already competent and adaptable. Cameras, unlike the other sensors in this category, can distinguish colour and contrast information, making them excellent for gathering road sign and road marking information, and they also have the resolution to categorize things such as walkers, cyclists, and motorcyclists. Cameras are also incredibly cost-effective, making them especially appealing to volume-selling car makers. Due to technological restrictions, data from camera sensors is increasingly being coupled with radar to give a more robust and dependable data stream over a wider range of situations. Cameras are employed in both monocular and, increasingly, binocular ADAS applications. Forward-facing monocular camera systems are used in medium- to long-range tasks such as lane-keeping assistance, cross-traffic warning, and traffic sign recognition systems. Rear-facing cameras have gained popularity as a reversing help for drivers. A dashboard-mounted screen displays a mirror-image picture of the region behind the car, which may be supplemented with positioning graphics relative to steering wheel movement to give parking advice. Forward-facing binocular or stereo cameras are a recent invention. A pair of cameras can display an 3D image that contains the information required to determine sophisticated depth information such as the distance to a moving object, making them appropriate for active cruise control and forward collision warning applications. Thermal imaging is another aspect of camera technology. Instead of utilizing visible light, or what little of it is available, thermal imaging cameras are great for spotting persons and animals, especially in low-light settings or at night, or simply in a busy and congested driving environment.

2.3 Infrastructure

The infrastructure of a corporation may be self-contained or divided between a business unit and the parent company, depending on how diverse it is. Many infrastructure services occur at both the business segment and type of economic. Infrastructure is especially important in the automotive business, without good infrastructure, it is extremely difficult for manufacturers to attract customers. For example, when a user gets an electric car, the infrastructure that is necessary for the buyer is the charging station. The infrastructure entices a client to buy a specific car. Here are some lists of infrastructure that are concerned.

2.3.1 Energy infrastructure

2.3.1.1 Gasoline stations

A gas station, often known as a petrol or gasoline station, is a business that sells gasoline, diesel, and automotive lubricants. Three main categories of service are done at gas stations: full service, minimum service, or self-service. A full-service gas station hires employees who run the pumps, frequently clean the windshield, and occasionally check the vehicle's oil level and tire pressure, whereas a minimal service gas station employs attendants who operate the pumps. The products and services that are made by gas stations to customers are:

- Retailing automotive fuels, like gasoline and diesel fuels;
- Automotive repair and maintenance services, e.g., wheel alignment and wheel assistances;
- External services, for example car washes and groceries.

Each company (Car Wash, Gas Station, and Supermarket) is usually owned and operated by a separate person [74]. However, all three have agreed to give their services in a specific location where potential clients are likely to be present. This provides a fantastic symbiotic relationship since a consumer who come to buy groceries may also recharge with gasoline and wash and wax their vehicle and vice versa, as showed in Figure 2.33 [75].

Figure 2.33: Relationship between gas station, car wash and supermarket

2.3.1.2 Public charging stations

Consumers for battery electric vehicles as well as plug-in electric car customers are drawn to public charging facilities. This is because the plug-in hybrid electric vehicle includes both gasoline fuel and charging outlets, allowing the user to charge his vehicle at a public charging station during his spare time. This has the potential to lower the quantity of fuel consumed by plug-in hybrid electric cars. Level two or DC rapid charging is used for public charging. DC fast charging is often employed when an automobile must be charged quickly, and the consumer is ready to spend extra money for the quick charge. Fast charging outlets for direct current are usually commercial operations owned and maintained by a charging network provider. DC fast charging necessitates the development of specialized power grid throughout the planning and execution stages. DC fast charging stations, at a minimum level, need the deployment of specialised three phase power supply equipment that requires more electrical output than AC charging solutions. In store outlets, cafes, and offices, AC charging stations with power outputs of approximately 10 kW per charging connection are widespread. These are often used more throughout the day and in the evening. As utilisation rises, the everyday pattern tends to stabilise as more customers charge in the mornings and evenings. Surges often emerge in the late evening hours when commercial business is at its highest. Users who are unable to charge their vehicles at home can use public fast charging stations to charge their vehicles at a quicker rate. People whose everyday commutes take them through cities would benefit from the installation of rapid charging stations. Roadside charging in densely populated metropolitan areas where cars are already parked have been included in charging rollout schemes across the world. Long-distance travellers are the primary consumers of highway public rapid charging stations because of the big depots, more charging power outlets, or charging guns, may be put in a single charging station. The management involved in the establishment of public charging infrastructure that want to recoup expenses or create money from their charging stations may require payment for the usage of their recharging stations. Charges can be paid at the power outlet, with a credit or debit card, over the phone, or at a local institution. Many recharging channels will enable the transaction for users who would like to earn revenue at the power supply unit. Through mobile apps, or in-person transactions, site operators can additionally cost for the usage of non-networked charging equipment such as paying to the parking in charge person in that area. Pricing models that are commonly used include by kWh, per cycle, by duration of time, or via a membership. Arrangements based on sessions and duration are typical in areas where non-utilities are forbidden from selling power. Diverse recharging network operators have different price strategies, including as cost for subscribers vs non-members, consumer payment for instance, proving complimentary charging for only certain car users, and for others pricing depends on amount of consumption.

Figure 2.34: Public charging station

2.3.1.3 Home charging

Electric vehicle owners prefer home charging to charge their vehicle overnight using AC level 1 or level 2 charging sockets. Most of the users, who have a separate garage, usually prefer this home charging as a safe mode of charging their vehicle even in harsh weather conditions. Slow AC charging is the most basic method of charging and simply refers to putting a vehicle into a conventional three-pin 5A or 15A wall socket with no information output to the EV's on-board charger. These basic modes of charging do not provide controlled charging and provide less range for a short charge time and takes more hours to charge the vehicle depending on socket and automobile types. Some plug-in hybrid electric car owners use this home charging strategy to charge the vehicle overnight to extend their driving range at no additional cost, and the only thing that counts is the setup of the residential charger. Some electric car providers now offer incentives and other benefits if a person prefers to use or build home charging stations. This can be beneficial for persons who do not prefer to spend more money on DC fast charging at public charging stations. Household charging should be compatible with all electric vehicles. However, there are a few things to consider. The compatibility of an EV with a given residential charging point is determined by the vehicle's plug, the recharging cable connection for instance, CHAdeMO or CCS. It is also possible to charge Tesla with any Level 2 charging outlet if there is correct charging point connection. Connecting the household EV charging station to a charge management solution might help to save money on charging. Smart functionalities of charge management platforms, which securely regulates energy use between a charging point and other equipment. The initial investment of a household charging point for electric vehicles, like the price of any physical item, varies based on location, needs, and whether any additional support installing the charging system. A well-known fact is higher the power output of a charging station, overpriced it will be for the installation. The capabilities provided by the charging station are what distinguishes inexpensive home charging from conventional home charging that puts out of cash. Factors like as scheduled charging, drawing electricity from the grid or using solar arrays, and optimising charging session would assist to low-cost charging. The Figure 2.35 [76] shows an example of home charging.

Figure 2.35: Home charging

2.3.1.4 Gigafactories

The anticipated rise of the energy storage industry, particularly electric mobility in the next years is compelling nations to take positions across the whole value chain of this manufacturing industry, including companies that manufacture battery packs. Beyond all else, taking into consideration the maintaining financial surrounding the mobility sector, the European Union and its member states see this business as a critical trigger to kick-start the economy in upcoming years and fulfil the EU's transition to renewables and environmental goals. Together with Northvolt, among the most popular European initiatives in this era has been Tesla's proposed venture in Deutschland. The business, founded by Elon Musk, plans to establish European Gigafactory, with the goal of eventually reaching a capacity of 40 GWh. The

American firm's prospective in Europe are so promising that it is already revealed intentions to begin work on a new project on the mainland. However, Northvolt and Tesla are only the commencement [77]. More than twenty battery pack plant proposals have been launched in Europe for the upcoming decades. With most of them, a yearly expectancy value of six hundred GWh is predicted, that is only half of the EU industry's expected base need for 2040. Because of the future demand and the need for several nations to adopt roles in this civilization to enhance the auto sector, new disclosures and infrastructure improvements are predicted from various agents in the following months, notably considering the possible financial support that these developments might obtain from the European Legislature recovery program. Indeed, several of the initiatives revealed in recent times have already stated their desire to seek for these funding in partnership with various national authorities, with the goal of accelerating their start-up and planning cycle. Some of these CEOs have already notified the European Union of their ambitions to establish and engage in Gigafactories under their respective jurisdictions. Europe has decided to take a significant role in the global manufacturing of batteries for the automobile industry, and the European network of Gigafactories will evolve over the next several years, as showed in the figure [78] down below.

Figure 2.36: Gigafactories in Europe

2.3.1.5 Battery swapping

As electric cars gain popularity, numerous stakeholders are seeking for ways to make them more inexpensive, simple to recharge, and cost-effective to run. Battery switching is one such solution that provides all these advantages to fleet operators. A switching unit is built in a prime location, with numerous batteries regularly recharged. An electric vehicle user may find a swapping depot, exchange the depleted battery with a fully charged one, and travel to work. This growth has brought enormous opportunity for fleet operators who would like to take their cars operating without having to worry about battery recharging time [79]. Battery swapping facilities combine the features of both slow charging and quick charge, notably gently refilling EV batteries during off-peak hours while swiftly recharging EVs. The entire battery switching operation may be completed in a matter of minutes using unmanned gear, which is exactly equivalent to the present refuelling technique for traditional automobiles. There are several barriers to effectively adopting battery switching. Beginning with the basic cost of establishing, this battery swapping system is quite high, requiring sophisticated automation to change the battery as well as a substantial number of costly batteries for essential operation. The time it takes to replace out the battery might be as little as around five minutes. As a result, it is as fast and easy as refilling up a petrol tank. The energy administrator can recharge the batteries as quickly before another client requires it [80] and this helps cut down on delaying. The entire price of establishing a battery swapping station might vary based on overall capacity of the batteries, the locality, and the intricacy of the replacement procedure. The Figure 2.37 [81] is a typical example of this process.

Figure 2.37: Battery swapping

2.3.1.6 Dynamic charging

Induction technology underpins dynamic wireless charging which is based on underground coils attached to electric lines. The coils produce an electromagnetic field, which is taken up by vehicles travelling over them and transformed into power by a mechanism incorporated inside the vehicles. The dynamic electric car charging technology being evaluated presently can recharge an electric vehicle on the go by providing a charge of twenty kilowatt which speeds of up to hundred kilometres per hour. The device comprises of a receiver equipment put beneath the car and a transmitter embedded in the pavement surface, avoiding damage. There are two primary approaches to what is a true vehicle power source, continuous transmission lines and the sequential execution of the static recharging devices. In regarding safety, wireless power transmission offers a step forward beyond conventional transmission systems since it eliminates the risk of shock in the event of connection. It does, however, provide a significant problem of electromagnetic emissions since it generates a high frequency electromagnetic field between the two connected coils. This field, which is the fundamental basis of the entire system, cannot be insulated and is not properly connected owing to the spacing present, leading to a high scattered field [82]. As a result, it must be evaluated for each unique system whether the isolated field complies with the multiple nations' safety requirements. The metal components provide both internal and instantaneous protection in which metal pieces are required for composite materials like carbon fibre. Car detection is an important responsibility for this technology, since it should not be engaged when there is no vehicle present for safety purposes. After recognition, the program will communicate with the pricing structure, which is shown onboard, the possible interconnection with alternative energy sources like solar or wind reduces necessity of supplementary energy storage systems and allows for a fairer allocation of power requirements daytime.

Figure 2.38: Dynamic charging road lane

2.3.1.7 Smart grid

The smart grid provides a once-in-a-lifetime chance to guide the energy sector into a new phase of dependability, accessibility, and effectiveness that will benefit both our financial and environmental health. During the transitional phase, it will be necessary to conduct experimentation, technical advancements, consumer awareness, policy and regulatory implementation, and data exchange among schemes to guarantee that the advantages that foresee from the smart grid become real. The term "vehicle to grid" refers to a technique that allows transfer of energy back to the electrical grid from an electric vehicle's battery. A battery pack may be recharged and drained using electric vehicle-to-grid innovation, also known as car-to-grid new tech, depending on multiple indicators such as energy output or by usage. When this comes to implementing V2G, the most crucial thing is to ensure that electric vehicle users have enough charge in their battery packs whenever they require it. When they go for work the next morning, the vehicle battery must be charged sufficiently to get them to the destination and return if necessary [83]. This is the fundamental need of V2G and any other recharging future technologies, the EV user must be informed about the battery percentage remaining also the time still pending for the completion of the charge. The smart grid cycle includes decentralisation, which considers consumers as the basis system or an aspect that requires substantial coordination. Solar cells, distributed storage, and microgrids are examples of technology that might be incorporated. Digitalization is a real-time protection for open automated communication and operation of the system. The Figure 2.39 [84] represents the steps involved in the smart gird.

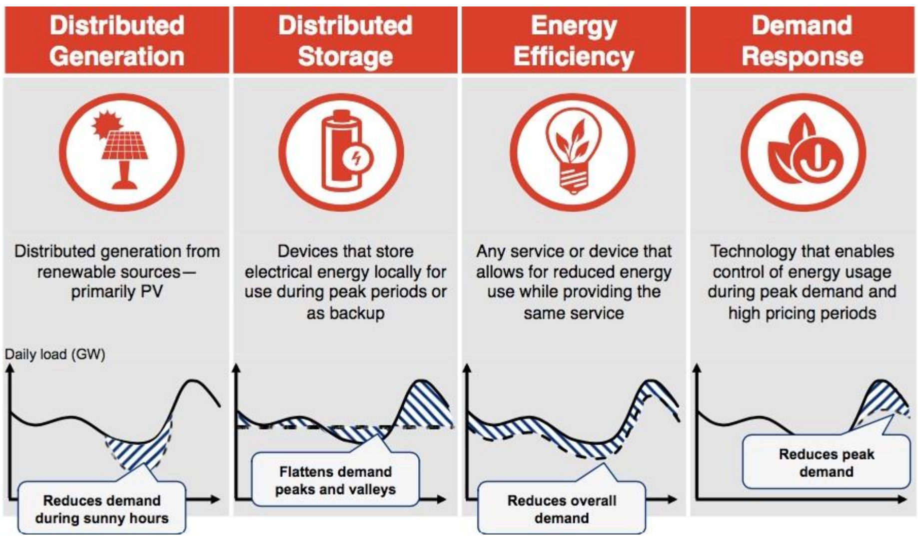

Figure 2.39: Smart grid

2.3.1.8 Hydrogen refuelling stations

Hydrogen is the lightest and most common element available in nature and it can be produced from various sources in different processes. Nowadays, a big part of the H_2 produced from natural gas steam reforming, however, in the future it will increase the focus on green hydrogen. There are three main types of hydrogen: grey, which is produced from fossil sources releasing CO_2 in the atmosphere; blue, which is produced storing CO_2 underground; green, which is created from green electricity and water. The Figure 2.40 [85] shows the colours of hydrogen and how they are processed.

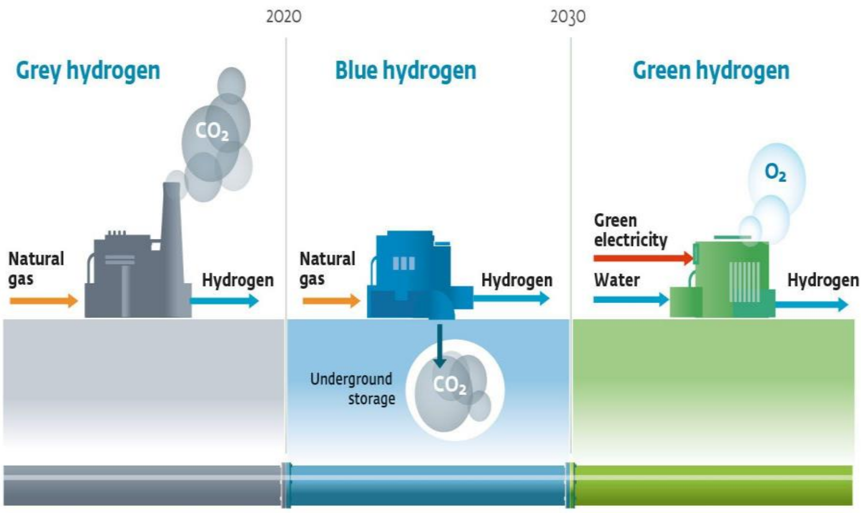

Figure 2.40: Colours of hydrogen

According to the gas company SNAM, hydrogen can have a very crucial role in Italy. It can be used to decarbonize the most pollutant sectors. Hydrogen can represent a solution in heavy duty tracks, trains, ships, airplanes, feedstock for fertilizer, heating buildings, etc. Hydrogen can be used to convert surplus electricity for use in other sectors, for cost-effective mid and long-term storage of energy and for cost-effective transport leveraging existing gas infrastructure. The greatest promise is in transportation, buildings, and industrial applications, where some players are already using grey hydrogen (e.g., refining, high-heat processes). This lowers the costs of incorporating additional renewables into Italy's electricity grid and increases their effectiveness in lowering emissions. Italy can become a European hydrogen hub and it has significant potential to use its solar and wind resources for the low-cost production of hydrogen [86]. Hydrogen could play a key role in the Italian energy system of the future providing almost one quarter of all energy. A typical infrastructure of green hydrogen is made by many components, as shown in the Figure 2.41 [87].

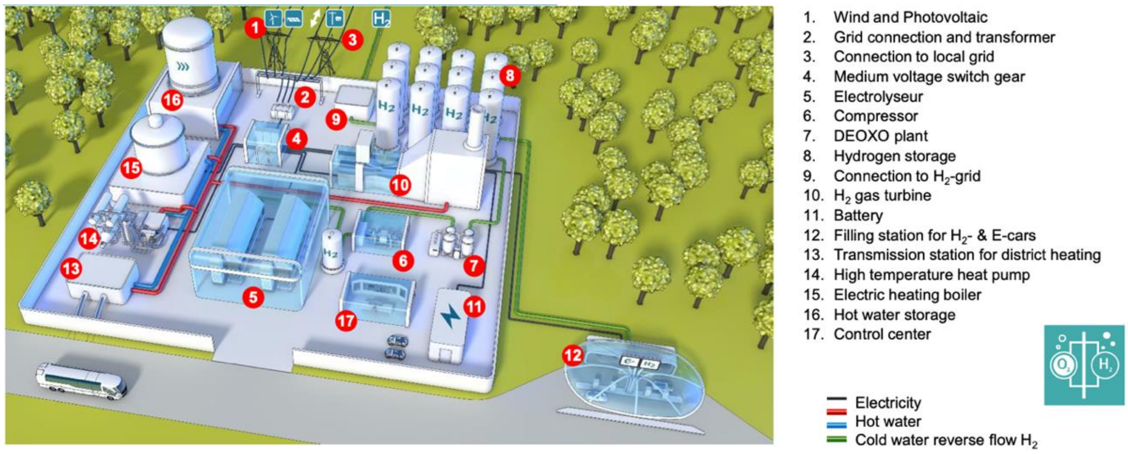

Figure 2.41: Green hydrogen infrastructure

Today, hydrogen is mostly employed in oil refining and fertilizer manufacture. To make a meaningful contribution to sustainable energy transitions, it must also be embraced in sectors where it is now entirely absent, such as transportation, buildings, and power generation. In transportation, the competitiveness of hydrogen fuel cell automobiles is determined by fuel cell prices and refuelling stations, whereas the aim for trucks is to lower the supplied price of hydrogen. Hydrogen stations typically include a hydrogen storage system, a cooling system, and a dispenser with a nozzle that connects to a fuel cell vehicle. The process of refilling hydrogen with a hydrogen pump is like refuelling with gasoline at a regular petrol station. The hydrogen refuelling station is innovative technology and it features a tank that may be above or below ground. Present hydrogen stations can refill up to 60 passenger vehicles with hydrogen, depending on the size of the hydrogen storage. Compressors are used to decrease the amount of gaseous hydrogen because hydrogen refilling demands high pressure. It is intended to provide high-pressure hydrogen to the nozzle to refill the vehicle at up to 700 bar or, in certain situations, 350 bar, the expansion of hydrogen causes it to warm up. Coolers reduce the temperature of the hydrogen to around -40° Celsius before it reaches the nozzle. The hydrogen refilling process is electronically always monitored. Refilling hydrogen fuel cell passenger car takes around three minutes if all the parameters are within the allowed requirements. The refuelling procedure ends when the pressure hits 700 bar (H70) or 350 bar (H35). If a malfunction occurs during the process, the hydrogen is released into the air in a regulated manner. The spread of this infrastructure depends on many factors, such as political decisions and cost, and it can really help to boost the decarbonization in the transportation sector. The Figure 2.42 [88] shows a design example of the H_2 station.

Figure 2.42: Hydrogen fuelling station

2.3.2 Communication infrastructure

2.3.2.1 Connected car ecosystem

The connected car trend is linked to society's ever-increasing urge to stay involved. Given recent global events, personal and commercial travel by vehicle is projected to increase as people feel more at ease and in charge of their own space. Consumers expect to be able to stream entertainment material, purchase online, navigate trips, and do business straight from their vehicles. A connected car employs many communication technologies, and here is where automotive and information technology collaborate. The following are the many types of connectivity technologies:

- **Vehicle to Infrastructure (V2I)**: This sort of connectivity is mostly employed for vehicle safety. The car connects with the road infrastructure, exchanging and receiving information such as traffic/road/weather conditions, speed restrictions, accidents, so on.
- **Vehicle to Vehicle (V2V)**: The vehicle-to-vehicle communication system enables the transmission of information between cars in real time. Vehicle-to-vehicle communication (V2V) is also utilized for vehicle safety.
- **Vehicle to Cloud (V2C)**: A V2C connection is created using a cellular LTE network and transfers data to the cloud. Car-to-cloud communication is mostly used for downloading over-the-air (OTA) vehicle updates, remote vehicle diagnostics, and connecting with IoT devices.

- **Vehicle to Pedestrian (V2P)**: The V2P system is one of the newest systems utilized in connected cars, and it is also employed for safety. Sensors in vehicles identify people and issue collision warnings.
- **Vehicle to Everything (V2X)**: V2X connection is the combining of all the above-mentioned forms of connectivity.

Connectivity is becoming increasingly important throughout the expanding mobility landscape, owing to the development of V2X infrastructure, which will improve the proliferating variety of mobility models and the creation of connected ecosystems. The automotive environment is experiencing considerable upheaval because of connection; V2X infrastructure is a vital component of this development, enabling new capabilities such as safety warnings, improved traffic management, and next-generation capabilities (e.g., autonomous) [89]. These connectivity-enabled services will support a growing number of future mobility models as well as continued evolution in connected ecosystems (e.g., connected car), which will necessitate communication standards to ensure data interoperability and security to maximize the benefits of V2X infrastructure. WiFi DSRC, cellular C-V2X, and 5G C-V2X standards have emerged as the leading candidates for V2X data transmission, and major industry stakeholders have differing perspectives on the best solution and the ultimate winning solution is likely to have a transformative influence across the ecosystem. As the industry grew, the connected car ecosystem saw fragmentation among application platforms and a profusion of apps and features, emphasizing the requirement for secure connectivity in-vehicle. The Figure 2.43 [90] shows the complexity, but also the possibility, of fresh players to become part of the automotive value chain.

Figure 2.43: Players in communication infrastructure

Wireless and fibre networks are the core of a connected community because they connect the layers of physical devices and systems, data, and sensing that allow for a linked community to exist. Remember that digital apps have latency, bandwidth, coverage, reliability, and security needs. As a result, communities must plan and build their infrastructure to interconnect and integrate with their physical assets, such as street lighting, cameras, utility systems, and associated apps, in an effective manner. Wireless technology is enabled by fibre optic networks ensuring that a community may grow into the future. Because high-speed internet, 5G, and wireless densification cannot be completely developed without deep fibre deployment, connected community innovation, and accompanying economic growth will be constrained. Cities will be unable to use IoT technology without these skills, and the digital gap in rural and underprivileged regions will increase. Fibre will also be used for fronthaul and backhaul from the network's edge to the core within the community network. As cities begin to adopt smart technology, fibre connectivity may be required to provide the intended functionalities and expected value. An IoT security camera, for example, cannot transfer collected pictures to the cloud for real-time facial recognition processing unless it has a strong internet connection, such as a direct fibre link or a wireless small cell connection, both of which are supported by fibre. WiFi, 4G LTE, and 5G networks connect mobile users and intelligent sensors to the community. Wi-Fi is an asset for tourists and residents, and it may be used to build connected community apps. Wi-Fi bridges the digital divide by enabling services in low to middle income and underserved communities since it provides last-mile connection. Many cities are upgrading to 4G LTE networks to offer better wireless internet speeds for real-time phone, data, video, and photo capabilities. Simultaneously, carriers have begun to roll out 5G, which will allow digital apps and solutions to expand at quicker rates than already observed. These two evolutions, however, will coexist to benefit both networks: 5G will share 4G's enormous coverage, accessible spectrum, and existing infrastructure, while 4G networks will employ 5G technology to give improved service. While it is fair for enterprises to continue operating existing 4G LTE systems until they achieve their return on investment, they must consider 5G when making 4G upgrades to safeguard investments and enable an effective transition to 5G. Community permission rules are critical to deploying the infrastructure required to extend 4G and roll out 5G. These networks need substantial labour including rights-of-way, poles, ducts, and communities to place antennas, tiny cells, and other densification technologies.

2.3.2.2 Smart roads

With increased demand on communities to build more efficient motorways and highways, smart infrastructure is critical for modernization. Smart roads based on IoT technology enable cities to gather and analyse data to enhance day-to-day traffic management and adapt to long-term transportation demands. Data from IoT sensors, cameras, and radar may be processed in near real time and used to enhance congested streets and streamline traffic flow. Data may also be transferred to the cloud for long-term study, offering important knowledge for initiatives such as lowering CO_2 emissions or improving road conditions. Smart roads include the physical roadways, smart lighting, smart traffic signs, and smart or autonomous vehicles that drive on them. Communications networks, IoT sensor networks, as well as big data and artificial intelligence technologies, are among the structures, systems, and applications that enable smart roadways. Smart road systems in smart cities necessitate large sensor networks that provide massive amounts of data on traffic flow and public transportation systems [91]. Thousands of traffic cameras, road detectors, traffic lights, parking meters, air quality and other sensors, mobility applications, and linked automobiles feed into these systems. This data may then be used to improve traffic flow, decrease congestion, and, eventually, assist city planners in addressing bottlenecks. Citizens also benefit from open data by having real-time access to traffic statistics, which allows them to better plan their trips and avoid traffic jams. Real-time navigation notifies drivers about delays and assists them in choosing the shortest route. Smart parking applications steer people to open places, saving time spent around city blocks. Emergency services benefit from real-time traffic monitoring systems, which allow accidents and disturbances to be addressed swiftly. Figure 2.44 [92] shows an example of a smart road.

Figure 2.44: Smart Road

2.3.2.3 Smart cities

If an emergency happens, smart city technologies will aid the ambulance in getting at the destination promptly and safely. The phrase "smart economy" typically refers to the world's prudent use of money and enough production and the end outcome was smart governance that preserved openness and open data sources gathered from citizens. The word "smart environment" refers to an environment that focuses on a green world that is eco-friendly and does not generate pollution or environmental damage. Smart cities often refer to the collecting of data by electronic or other sensors, which are then used as needed. The capability of a smart city is to develop a strong partnership between the government, including its administration and rules, and the private industry is crucial to project success. This partnership is vital since most of the labour required to establish and sustain a digital, data-driven society takes place far outside government [93]. Devices from one business, cams from another, and a database from still another might be used to monitor crowded streets. Private companies may also be adopted to analyse the data, which will then be submitted back to the local administration. This data might then contribute to the hiring of a software development team to find a solution to the difficulties discovered in the examined data. If the service needs continuous update and monitoring, this firm might become a component of the system. As a result, the sustainability of a smart city is more committed to developing beneficial connections than on finishing a particular task. Smart traffic management is used in mobility to track and evaluate movement of vehicles to optimise lighting and prevent highways from being excessively crowded depending on length of day or scramble schedules. Another aspect of smart cities is smart mass transit. Smart transport firms can integrate operations and meet the demands of users of the service, increasing efficiency and user experience. In a smart city, car sharing are also popular options.

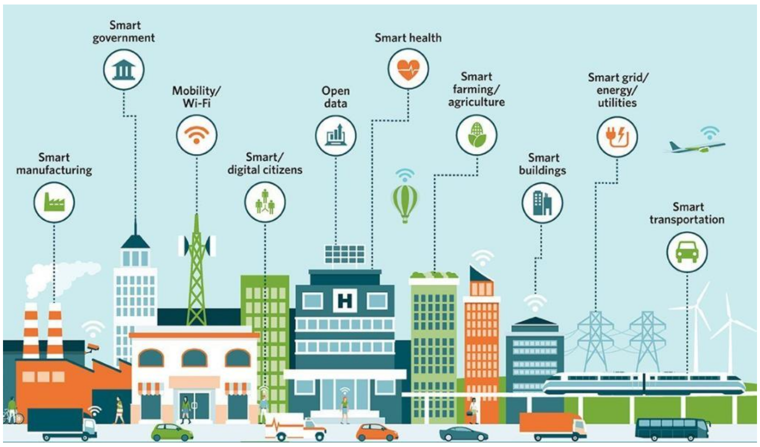

Figure 2.45: Smart city

2.3.3 Shared mobility

Providers and integrators with online platforms connect to the right combination of different modes of transport to offer an embedded, multi-modal door-to-door mobility solution using a mobility platform by leveraging technological expertise, operational excellence, infrastructure investment progressions, B2C suppliers, and API providers are a few examples. There are several major kinds of mobility applications, each defined by the app's principal function. Mobility applications, smart parking apps, car connectivity apps, courier network services, and supplementary apps. Aggregator provides mobility solutions as a main company, as self-providers, or through collaborations. They offer digital and physical platforms such as ticketing systems and parking areas to become the mobility hub for any mode of transportation, allowing a single direct payment for multi-modal transit. In Germany, Moovel provides access to a variety of travel solutions in a single app, where you can plan, book, and pay. This is known as MaaS, or Mobility as a Service Apps: Whim (MaaS app), Uber (ride hailing), and Share Now (car2go & DriveNow). MAAS is a novel idea for mobility connectivity that offers a new mindset about and administering transportation services. It employs a smart mobility aggregator to generate a unique hub which can be used to book and pay, supplying a digital business strategy in which it allows to pay for a contract plan, such as a smartphone or streaming services, seamlessly solely on a single platform. This latest model is completely different from the earlier one. This travel model promotes the use of public transportation, considered as the easiest method to travel. This includes not just city transportation, but also long-distance transport. The desire for shared transportation services, as well as the opportunity to minimize personal car ownership in return for simple access to automobiles, are driving the shared mobility trend. Each user's vehicle experience must be tailored to their own demands. Eventually, each shared car will be able to be configured for the driver or rider. Whether it is a livery service or a car-sharing vehicle leasing, easy access to mobility applications (apps) and cloud data makes it all possible.

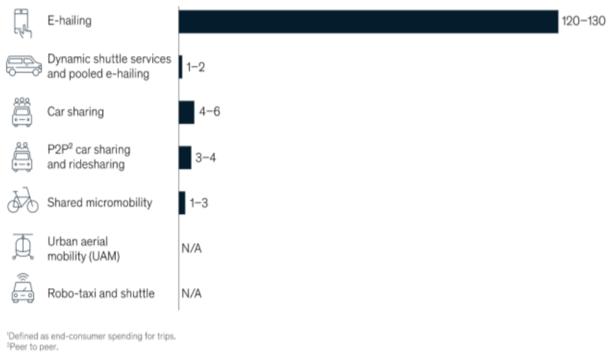

Figure 2.46: Trends in shared mobility investment ($ billion)

In the Figure 2.46 [94], riders use a virtual gadget to schedule a car to pick them up in e-hailing, also known as ride-hailing. The driver, who does not need a business license in some areas, picks up the passenger and drives to the indicated place. Riders use their mobile device to book auto service and share trips with other passengers. The driver picks up passengers at itinerary-based locations and takes them to their drop-off places in an itinerary-optimized order. Customers utilize company-provided automobiles for shorter periods of time than rental, and they often stay within a geographically confined area. Sharing models can be free-floating or station-based. Car owners in P2P car sharing enable other drivers to make use of their vehicles for a fee. Private-car owners transport paying passengers to their destinations, which are usually great distances, in P2P ridesharing.

2.4 Correlation between actors, infrastructures and technologies

Infrastructure, actors, and technologies have a relationship with each other in the field of automobile value chain. The elements listed cannot work independently without connectivity together with the other constituents. To run a profitable organization, these elements must rely on one another to meet the demands of the consumer. There are some examples listed below.

- **Customer (actor) – Electric (infrastructure) – Batteries (technology)**
  An organisation cannot function properly unless their customers are satisfied. As it can be seen, people looking to purchase electric vehicles will prefer the availability of infrastructure in the locality where they usually travel or live not to be worried about the remaining state of charge. Customers also look for suitable batteries according to their driving behaviour. Even though there are several types of batteries, as previously said, the client seeks an appropriate battery that is safe and delivers a longer driving range also charges quickly with a DC fast charging connection at public charging stations. Here, the actor, technology and infrastructure are linked to entice customers to buy this specific vehicle.
- **Service provider (actor) – Connected (infrastructure) – lidar/radar and cameras (technology)**
  In this case, network operators are regarded as actors, as they are one of the service providers. As previously stated, network operators may gather essential information from customers using Wi-Fi and 5G technologies, and this information can be kept in a data cloud management system. Infrastructure must be one of the requirements for conducting the procedures.

In the case of a connected car, infrastructure focuses on smart cities and telecommunications. With the help of proper city maintenance along with the Internet of things that are used in a connected world, smart city can ensure the safety and security of the driver also the people who live within it. Supporting the infrastructure, technologies such as lidar, radar, cameras, and other sensors can be installed to observe vehicle and the surroundings. As a result, these three elements must be interconnected in such a way that, they can supply the entire cycle for environmental wellbeing.

- **Government (actor) – Sharing mobility (infrastructure) – Filters and Charging socket (technology)**
  In this example government is the actor who cares about the living conditions of the population. Increasing the usage of sharing mobility, which is addressed as the infrastructure, government cannot only decrease the number of cars inside the cities, but also try to enhance the concept of sustainable mobility and reduce the pollution. A key element to support this process is the adoption of the right technology, such as filters to abate the exhaust from ICE vehicle while in the case of electric vehicles, a universal charging socket that can be used to charge the vehicle at almost all the charging stations to spread the shared electric mobility development. The result of pushing this trend connecting all the three elements can help to alleviate traffic congestion, cut CO_2 emissions, and free up public space.

It is important to underline that all the trends are connected among each other, and they can be pushed or discouraged by societal change and technology, however, the customer demand can also create interesting outcomes. Some tools to analyse the future mobility trends are creating scenarios with right methodology to find out the strategic decisions to support a particular trend. The Figure 2.47 [95] shows the interconnection between the different trends.

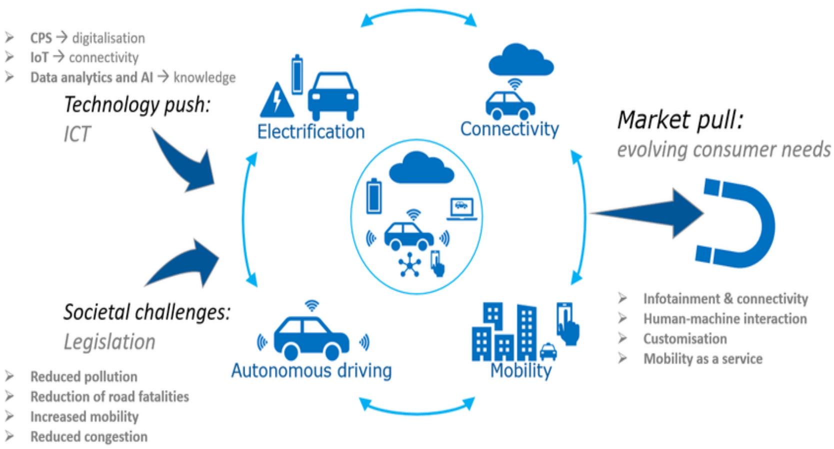

Figure 2.47: Correlation between the trends

3. Qualitative Analysis

Forecast studies based on vehicle types and infrastructures, projects including connected and autonomous automobiles, socio-economic analyses, SWOT analyses, and finally some hypothetic scenarios are developed in this chapter to better comprehend the major essential elements in the automotive sector.

3.1 Forecast analysis

The forecast analysis gives an idea on how the trends are going and what they could be in the future. The analyses are performed using tools existing in Excel and give us some qualitative scenarios for the future. It is extremely hard to predict the future, especially when there are few data available and those automotive trends are quite new, so the level of uncertainty can be high if new regulations, political changes, or some disruptions happen. The data analysed are relative to infrastructures and vehicles, in particular passenger cars, located in Europe and Italy taking into consideration the path to 2050 to fight against climate change. The two models used to forecast are linear and exponential smoothing.

3.1.1 Linear forecast

The linear forecast calculates a future value based on present data. For a given x-value, the future value is a y-value. The historical data are known, and the others are forecasted using linear regression, which is a statistical method. For each data point, this linear regression indicator depicts the trendline value. The equation (3.1) of the forecasted value $\hat{y}$ is:

$$\hat{y} = a + mx \tag{3.1}$$

Where:

$$a = \bar{y} + m\bar{x} \tag{3.2}$$

And:

$$m = \frac{\sum_i^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_i^n (x_i - \bar{x})^2} \tag{3.3}$$

$\bar{x}$ and $\bar{y}$ are the averages of the historical values up to the last known value n and m represents the slope of the first equation, while a is the intercept.

3.1.2 Exponential smoothing forecast

A forecasting technique is an algorithm that generates a point forecast: a single value that predicts the value at a future time. A statistical model, on the other hand, provides a stochastic data generation process that may be utilised to generate a full probability distribution for a future time. The mean or median of the probability distribution may then be used to quickly produce a point forecast. A model may also be used to compute prediction intervals with a certain level of confidence [96]. Historically, exponential smoothing has been used to define a type of forecasting approach. The principle of exponential smoothing underpins some of the most successful forecasting approaches. The exponential smoothing family includes several approaches, each of which has the feature that predictions are weighted combinations of historical observations, with new observations given more weight than older observations. The term "exponential smoothing" refers to the fact that the weights of the observations fall exponentially as they age.

In business and economics, a time series is commonly thought of as a combination of many components such as the trend (T), cycle (C), seasonal (S), and irregular or error (E). These can be summed up as follows:

- Trend (T): the series' long-term orientation.
- Seasonal (S): a repeating pattern having a recognised frequency (e.g., 12 months per year, or 7 days per week).
- Cycle (C): a pattern that repeats with some regularity but with an undefined and fluctuating frequency (e.g., a business cycle).
- Irregular or error (E): the series' unpredictability.

It is concentrated exclusively on the three components T, S, and E.

These three components can be mixed in a variety of ways. A purely additive model, which is the one used in Excel, can be written as follows in (3.4):

$$y = T + S + E \tag{3.4}$$

Where y is the observed series.

The trend component is constituted by a level term (ℓ) and a growth term (b). Level and growth may be combined in a variety of ways to provide future trend types. Let T_h represent the forecast trend for the following h time periods. The only focus is on additive model, which is described in equation (3.5):

$$T_h = \ell + bh \tag{3.5}$$

When there is a trend in the time series, but the growth rate at the end of the historical data is unlikely to persist for more than a short period, the damped trend approach is acceptable. The damped trend equations accomplish exactly what the name implies: they damper the trend as the prediction horizon lengthens. This frequently increases prediction accuracy, especially with extended lead periods. After selecting a trend component, add a seasonal component either additively or multiplicatively. Finally, either additively or multiplicatively, incorporates an error. If the data show a linear trend, Holt's linear approach (or the damped method) should be used. However, if the data is seasonal, these approaches will fall short of the mark. Holt suggested a seasonal data approach. Winters studied his approach, and it is now known as the "Holt-Winters' method." Holt-Winters' approach is built on three smoothing equations: one for level, one for trend, and one for seasonality. It is like Holt's linear technique, but with one extra equation to account for seasonality. Depending on whether seasonality is treated additively or multiplicatively, there are two alternative Holt-Winters approaches. In this thesis, ETS (ExponenTial Smoothing) (A, A, A) that means that all components are treated as an additive model. Seasonal effects, represented by s_t can be added to the local trend model for time series that display seasonal trends. The structure of the seasonal pattern frequently changes throughout time because of changes in tastes and technology. Electricity consumption, for example, used to peak in the winter but now peaks in the summer in some areas due to the increasing use of air conditioning. As a result, the equations used to depict seasonal impacts should be flexible enough to accommodate shifting seasonal trends. The ETS (A, A, A) model is described by the equations (3.6), (3.7), (3.8), (3.9):

$$y_t = \ell_{t-1} + b_{t-1} + s_{t-k} + \varepsilon_t \tag{3.6}$$

$$\ell_t = \ell_{t-1} + b_{t-1} + \alpha\varepsilon_t \tag{3.7}$$

$$b_t = b_{t-1} + \beta\varepsilon_t \tag{3.8}$$

$$s_t = s_{t-k} + \gamma\varepsilon_t \tag{3.9}$$

Where y_t is the observed series, that is the combination of the level term ℓ_{t-1}, the growth term b_{t-1}, the seasonal term s_{t-k} (k is the number of seasons in a year, that in this case it is not considered since it has a yearly time series) and ε_t is the forecast error at time t. The other elements in the equations are parameters. If $\gamma = 0$ the model is Holt's Linear Trend Model and if $\beta = 0$ and $\gamma = 0$ the model is the Simple Exponential Smoothing Model. In this case, the ETS (A, A, A) model can be considered a Holt's Linear Model since there is no seasonality. It is explicated recursively in the equations (3.10), (3.11), (3.12) to de-seasonalize in the trend equation, and (3.13):

$$\ell_t = \alpha y_t + (1-\alpha)(\ell_{t-1} + b_{t-1}) \tag{3.10}$$

$$b_t = \beta^*(\ell_t - \ell_{t-1}) + (1-\beta^*)b_{t-1} \tag{3.11}$$

$$\beta^* = \frac{\beta}{\alpha} \tag{3.12}$$

$$\hat{y}_{t+h|t} = \ell_t + hb_t \tag{3.13}$$

ℓ_t denotes the series level at time t, b_t denotes the slope at time t; α and β^* are constants with values between 0 and 1; $\hat{y}_{t+h|t}$ is the forecast based on weighted moving average of all past observations with the weights decreasing exponentially in the time period h.

3.1.3 European and Italian infrastructures forecast

The first infrastructure described is the European charging stations and then the Italian charging stations. The Table 3.1 shows the historical data [97] about the number of charging stations in Europe. The year over year growth rate has always been positive in the timeframe considered and the lowest value is 13% referred as 2018.

Year	Cumulative number of charging stations in EU	N° of charging stations per year	Year-Over-Year (YOY) growth rate
2010	400	400	N/A
2011	2392	1992	498%
2012	10507	8115	339%
2013	17850	7343	70%
2014	26536	8686	49%
2015	49363	22827	86%
2016	77038	27675	56%
2017	109896	32858	43%
2018	123727	13831	13%
2019	167900	44173	36%
2020	215616	47716	28%
2021	306864	91248	42%

Table 3.1: Number of charging stations in Europe EU-27

The availability of the charging points distribution across Europe is unbalanced, as it can be seen in Figure 3.1 [98], with 70% of the total located in just 3 countries, which are Germany, France, and Netherlands. Italy and Sweden are among the top 5 countries for the total number of charging stations.

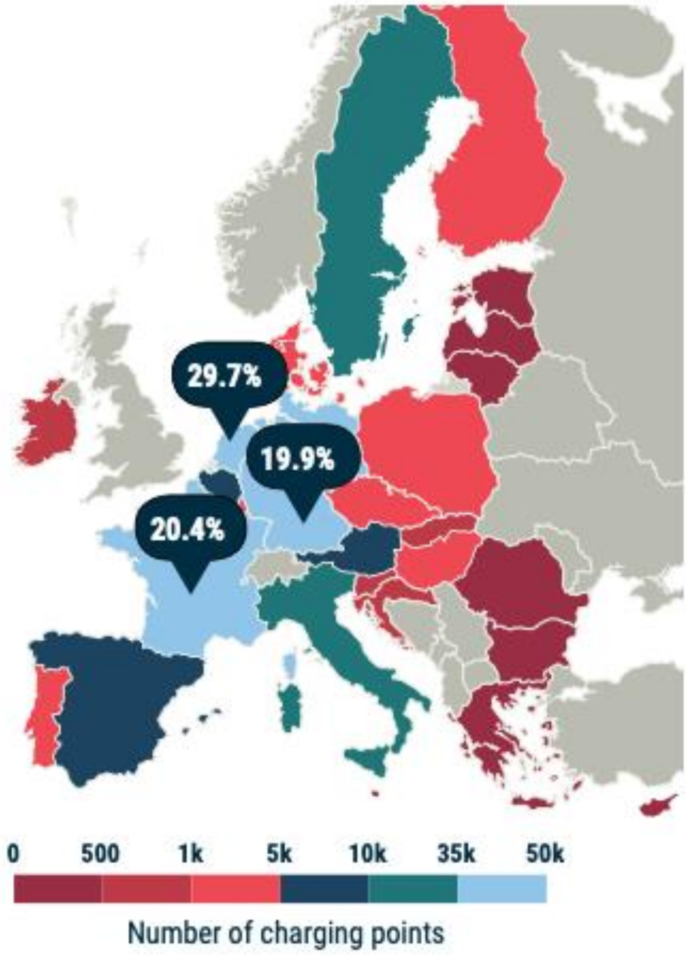

Figure 3.1: Distribution of charging points across Europe

Figure 3.2 depicts the forecasted number of charging stations in Europe according to historical data and considering 2035 as a reference year to understand the development of the infrastructure. In case of linear growth, the forecasted values are around 1.8 million in 2035 and almost 5 million in 2050. In case of exponential smoothing the worst cases illustrate around 1.5 millions of charging points in 2035 and almost 4 million in 2050, while the best cases are their double with 2.9 million in 2035 and 7.5 million forecasted in 2050.

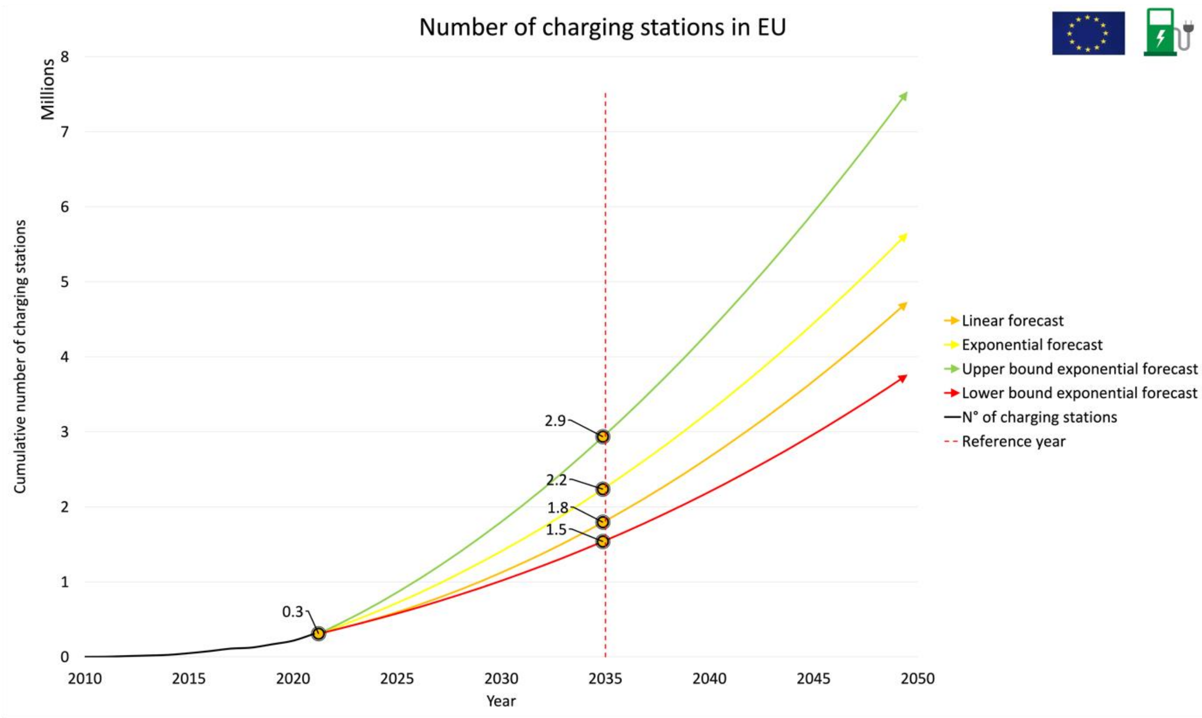

Figure 3.2: Forecasted number of charging stations in Europe EU-27

Focusing on Italy, Table 3.2 shows a hesitant growth in the first years followed by a stable uptrend in the following ones registering the highest growth of the infrastructure in 2019.

Year	Cumulative number of charging stations in Italy	N° of charging stations per year	Year-Over-Year (YOY) growth rate
2010	N/A	N/A	N/A
2011	N/A	N/A	N/A
2012	1351	1351	N/A
2013	1356	5	0%
2014	1363	7	1%
2015	1749	386	28%

Year	Cumulative number of charging stations in Italy	N° of charging stations per year	Year-Over-Year (YOY) growth rate
2016	2071	322	18%
2017	2885	814	39%
2018	3562	677	23%
2019	9370	5808	163%
2020	13302	3932	42%
2021	23543	10241	77%

Table 3.2: Number of charging stations in Italy

Figure 3.3 [99] illustrates the distribution of charging points per region in the Italian scenario. The presence of charging infrastructure in the northern part is higher compared to the southern part of Italy.

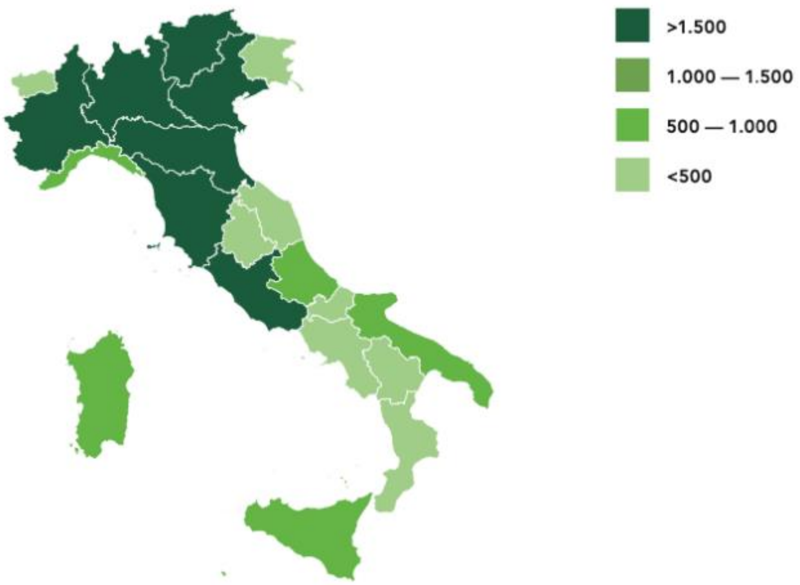

Figure 3.3: Distribution of charging points per region

Figure 3.4 illustrates the forecasted number of charging stations in Italy according to historical data [97] and considering 2035 as a reference year to understand the development of the infrastructure in the medium-term perspective. In case of linear growth, the forecasted numbers are almost 200 thousands in 2035 and almost 600 thousands in 2050. In case of exponential smoothing the worst cases show around 160 thousands of charging points in 2035 and more than 400 thousands in 2050, while the best cases are more than their double with 350 thousands in 2035 and 900 thousands forecasted in 2050.

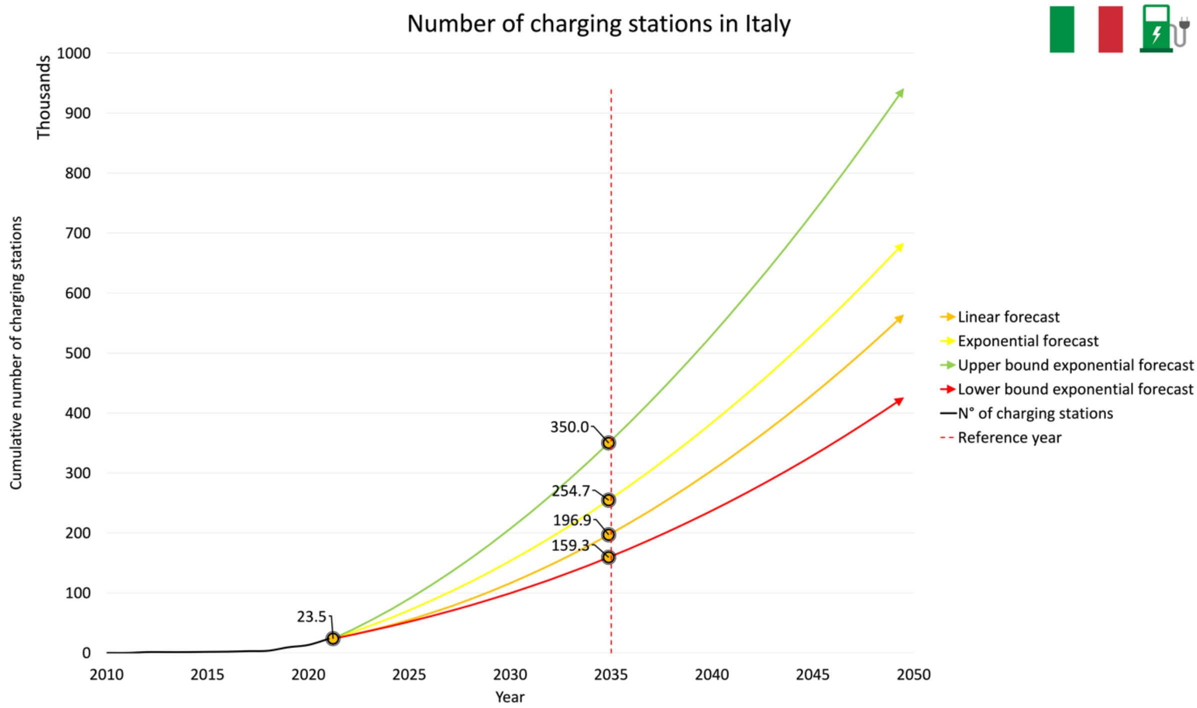

Figure 3.4: Forecasted number of charging stations in Italy

The other energy infrastructure considered is the number of hydrogen refuelling stations, which is still in the beginning phase of its development, however it is a key infrastructure to increase the decarbonization level in road transportation. The Table 3.3 shows the historical data [97] about the number of refuelling stations in Europe. It should be noted that the number of hydrogen stations are incredibly lower than the number of electric charging stations.

Year	Cumulative number of H_2 refuelling stations in EU	N° of H_2 refuelling stations per year	Year-Over-Year (YOY) growth rate
2010	N/A	N/A	N/A
2011	N/A	N/A	N/A
2012	N/A	N/A	N/A
2013	N/A	N/A	N/A
2014	N/A	N/A	N/A
2015	N/A	N/A	N/A
2016	35	35	N/A
2017	39	4	11%
2018	39	0	0%
2019	113	74	190%
2020	124	11	10%
2021	136	12	10%

Table 3.3: Number of refuelling stations in Europe EU-27

Figure 3.5 illustrates the forecasted number of hydrogen refuelling stations in Europe according to historical data and taking 2035 as a reference year to understand the development of the infrastructure in the medium-term perspective. In case of linear forecast, the forecasted values are around 374 stations in 2035 and almost 500 in 2050. In case of exponential smoothing the worst values are around 188 stations in 2035 with a flat growth up to 200 in 2050, while in the best cases have about 1400 stations in 2035 and 3000 forecasted in 2050.

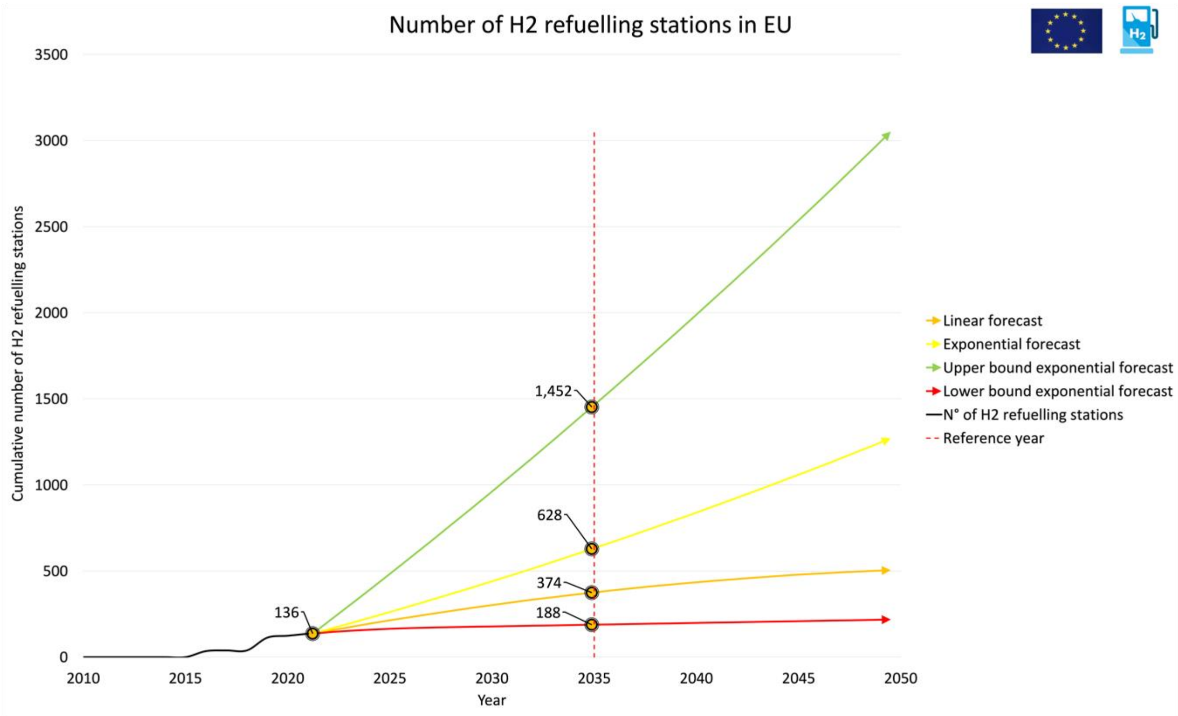

Figure 3.5: Forecasted number of hydrogen refuelling stations in Europe EU-27

It is extremely complicated to forecast the number of refuelling stations in Italy since it has just one public station in Bolzano. The last infrastructure considered is the car sharing infrastructure, which is composed by many elements such as the phone application, the integration with other means of transport and the most important one that is the number of shared vehicles. The Table 3.4 shows the historical data [100] about the number of car shared in Europe. The growth rate each two years is always positive except for 2016 that is negative with 90 cars less compared to two years before it.

Year	**Cumulative number of shared vehicles in EU**	**N° of shared vehicles per year**	**Growth rate each two years**
2006	7491	7491	N/A
2007	N/A	N/A	N/A
2008	10833	3342	45%

Year	Cumulative number of shared vehicles in EU	N° of shared vehicles per year	Growth rate each two years
2009	N/A	N/A	N/A
2010	16779	5946	55%
2011	N/A	N/A	N/A
2012	20464	3685	22%
2013	N/A	N/A	N/A
2014	57947	37483	183%
2015	N/A	N/A	N/A
2016	57857	-90	-0.2%
2017	N/A	N/A	N/A
2018	60622	2765	5%

Table 3.4: Number of cars shared in Europe

Figure 3.6 illustrates the forecasted number of cars shared in Europe according to historical data and keeping 2035 as a reference year to comprehend the progress of the infrastructure in the medium term. In case of linear forecast, the forecasted values are around 255 thousands of cars shared in 2035 and more than 400 thousands in 2050. In case of exponential smoothing the worst cases are around 71 thousands of cars shared in 2035 with a flat growth up to 72 thousands in 2050, while in the best cases are about 650 thousands of car shared in 2035 and more than 1.2 million forecasted in 2050. The growth in these years is slowed down by the pandemic crisis.

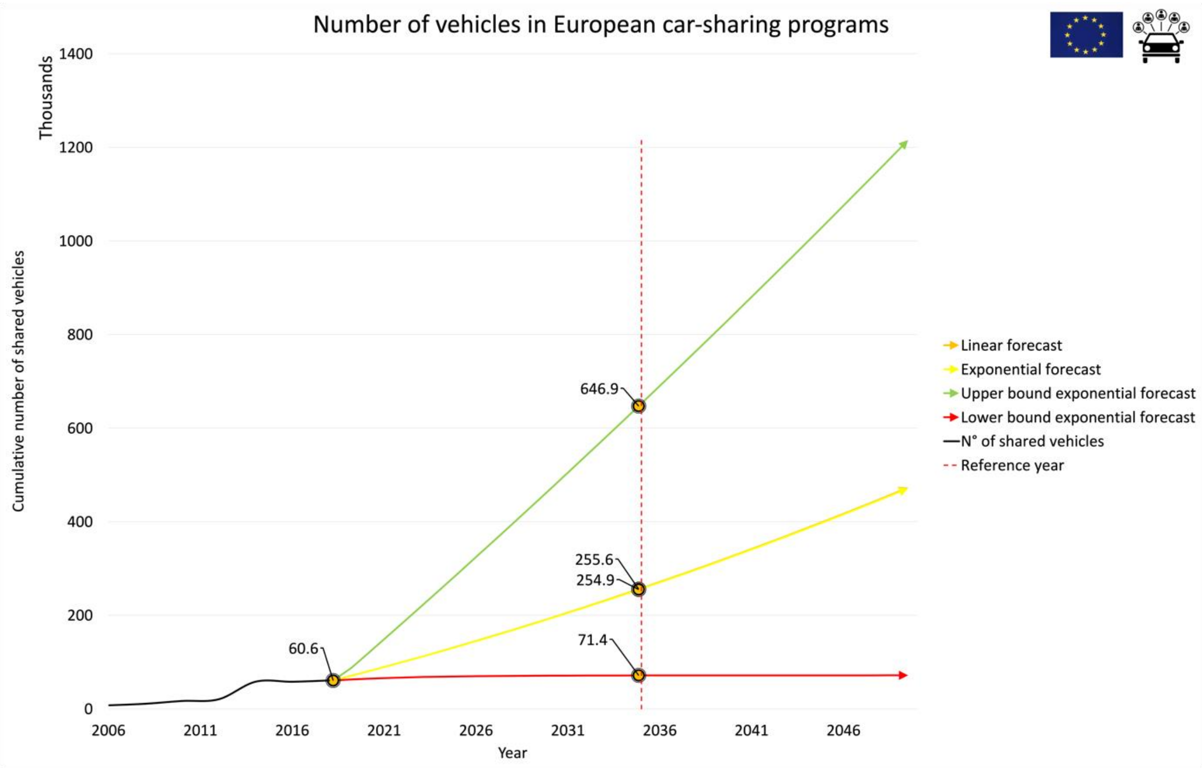

Figure 3.6: Forecasted number of cars shared in Europe

Focusing on Italy, Table 3.5 [101] shows an uptrend in the first year followed by a stable increase in the following ones registering the highest growth of the infrastructure in 2019 and a decrease of 12% in 2020 due to Covid-19 situation.

Year	Cumulative number of shared cars in Italy	% e-car on total	Year-Over-Year (YOY) growth rate
2010	N/A	N/A	N/A
2011	N/A	N/A	N/A
2012	N/A	N/A	N/A
2013	N/A	N/A	N/A
2014	N/A	N/A	N/A
2015	4500	2%	N/A

Year	Cumulative number of shared cars in Italy	% e-car on total	Year-Over-Year (YOY) growth rate
2016	5700	5%	27%
2017	6180	6%	8%
2018	6480	10%	5%
2019	8264	25%	28%
2020	7282	12%	-12%

Table 3.5: Number of cars shared in Italy

Figure 3.7 depicts the forecasted numbers of cars shared in Italy. It is noted that all the forecasts have uptrend going from 15 thousands in the worst case to 18.4 thousands in the best case in 2035 up to more than 25 thousands in 2050.

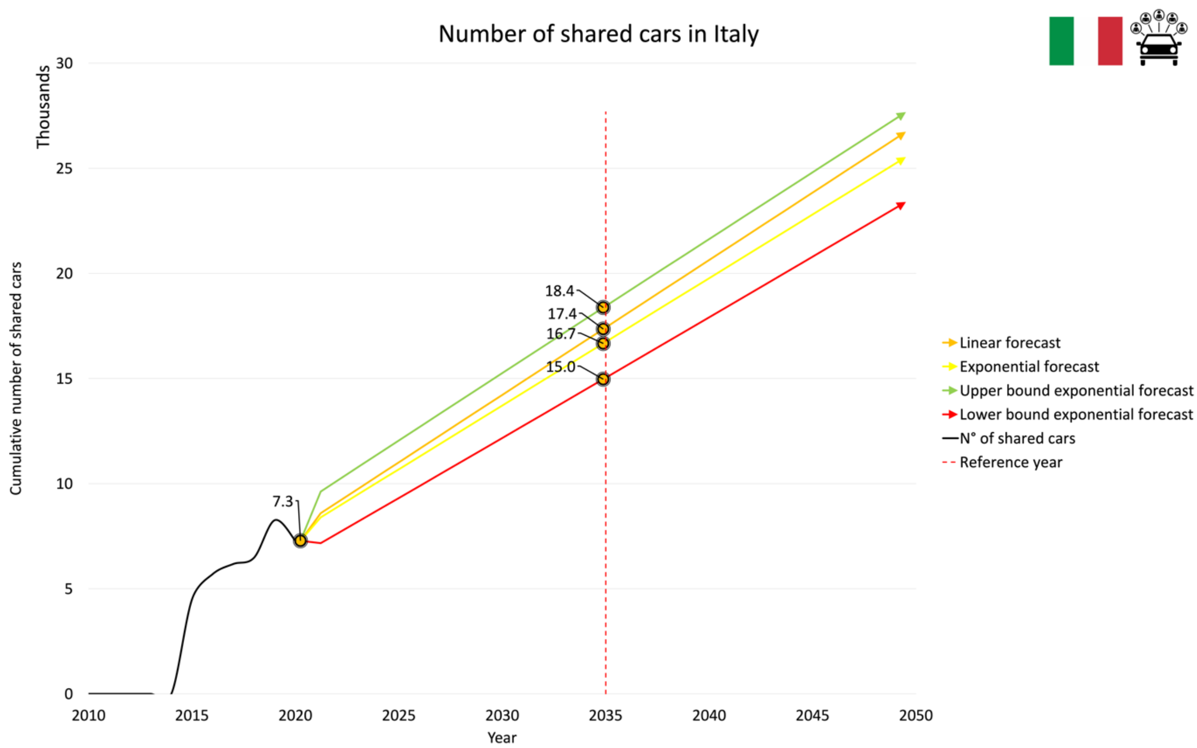

Figure 3.7: Forecasted number of cars shared in Italy

Figure 3.8 displays the prediction of the percentage of electric cars on the total shared fleet starting from 12% to 67% of 2035 up to fully electric before 2050.

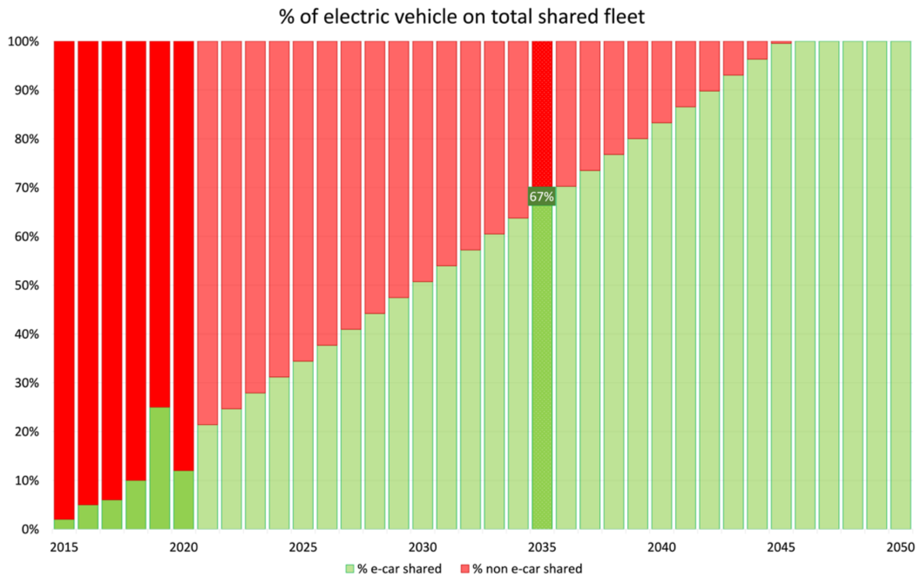

Figure 3.8: Forecasted % of electric vehicle on total shared fleet

3.1.4 European and Italian cars forecast

In order to have a deeper vision, focus also includes on the new cars registration from European and Italian perspectives. Table 3.6 [98] lists the number of ICE new cars registration in Europe showing a downtrend in the last years.

Year	N° of ICE new cars registration per year in EU	Year-Over-Year (YOY) growth rate
2010	N/A	N/A
2011	N/A	N/A
2012	N/A	N/A
2013	N/A	N/A
2014	9533332	N/A

Year	N° of ICE new cars registration per year in EU	Year-Over-Year (YOY) growth rate
2015	10515447	10%
2016	11371879	8%
2017	11757066	3%
2018	11711141	0%
2019	11621763	-1%
2020	7492595	-36%

Table 3.6: Number of ICE new cars registration in Europe

According to the historical data, Figure 3.9 depicts the exponential forecast of the number of ICE new cars registration, where in the best case reaching almost zero in 2035 that is one of the objectives of the European strategy, while in the worst case there is a slight increase up to 20 million in 2050.

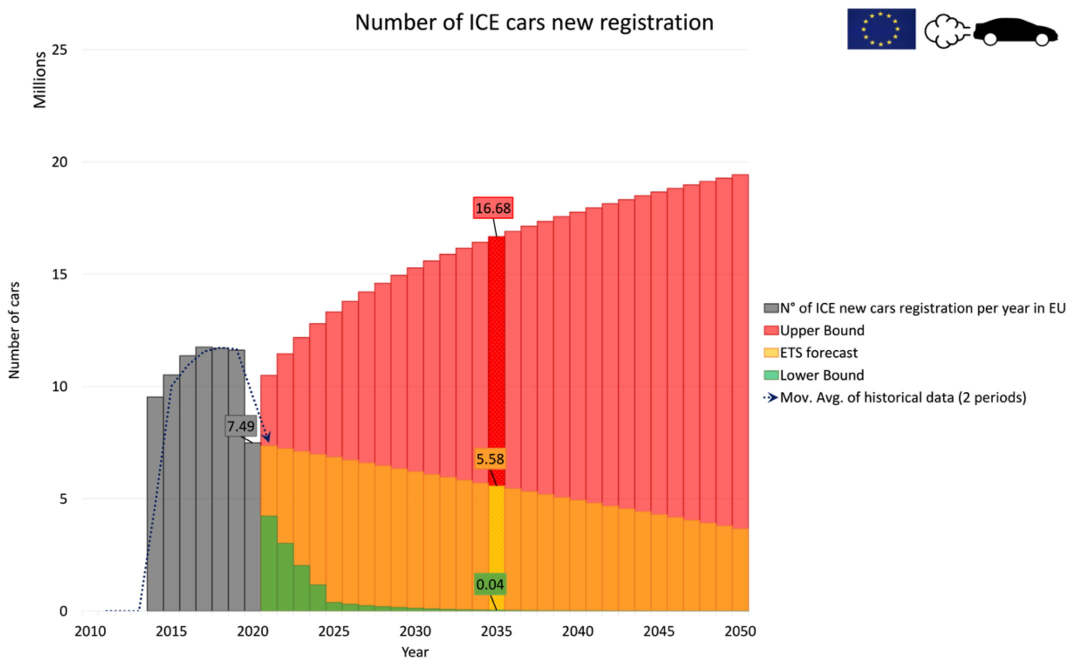

Figure 3.9: Forecasted number of ICE new cars registration in Europe

Table 3.7 [98] shows the number of electrically chargeable new cars registration in Europe presenting a positive growth peak at the beginning and a stable uptrend in the last years.

Year	N° of electrically chargeable new cars registration per year in EU	Year-Over-Year (YOY) growth rate
2010	N/A	N/A
2011	N/A	N/A
2012	N/A	N/A
2013	N/A	N/A
2014	55356	N/A
2015	119323	116%
2016	118542	-1%
2017	168901	42%
2018	240347	42%
2019	387325	61%
2020	1045082	170%

Table 3.7: Number of electrically chargeable new cars registration in Europe

Starting from the historical data, Figure 3.10 represents the exponential forecast of the number of electrically chargeable new cars registration showing an uptrend in all the cases from about 1.5 to 4.5 million, which is the best case, in 2035, while in 2050 the range is between 2 and 7 million.

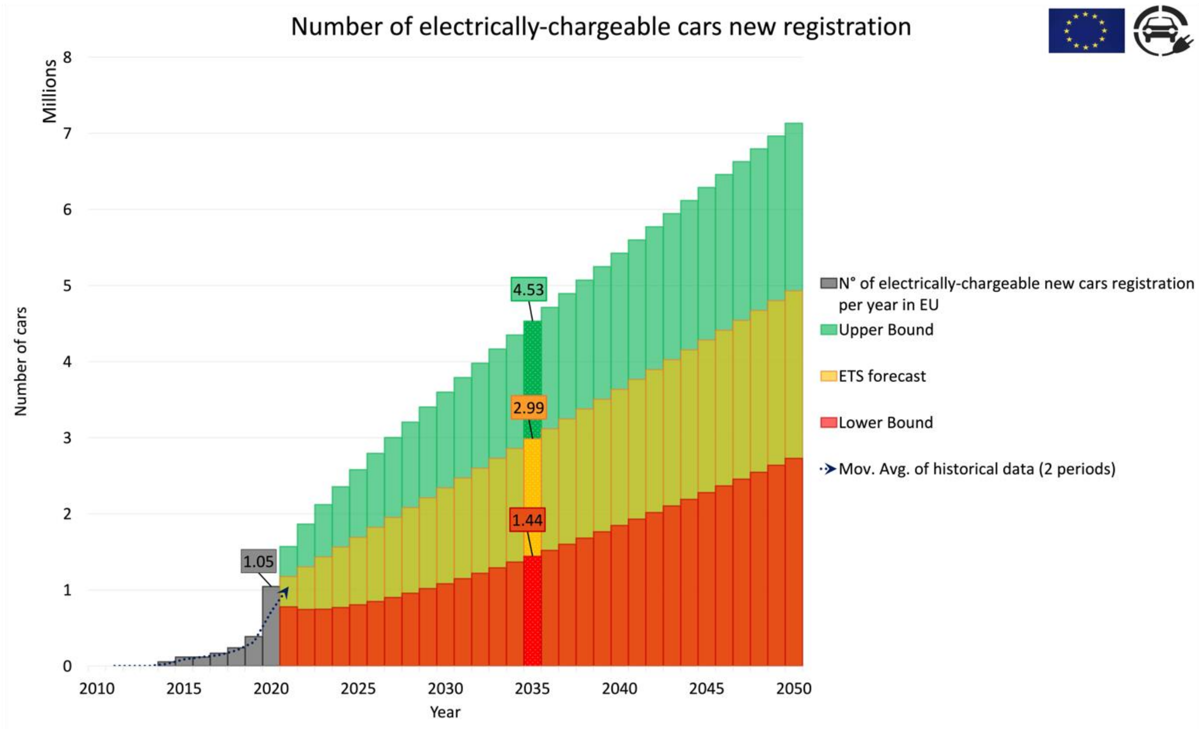

Figure 3.10: Forecasted number of electrically chargeable new cars registration in Europe

73% of all electric cars are sold in just 4 countries, which are Sweden, Netherlands, Finland, and Denmark, with some of the highest GDPs, which means an unbalanced affordability of electric car across the EU. In the Figure 3.11, Italy has a lower market share compared to northern part of Europe.

Figure 3.11: Market share of electrically chargeable cars in 2020

Table 3.8 [98] displays the number of HEV new cars registration in Europe presenting a stable uptrend in the last years.

Year	N° of HEV new cars registration per year in EU	Year-Over-Year (YOY) growth rate
2010	N/A	N/A
2011	N/A	N/A
2012	N/A	N/A
2013	N/A	N/A
2014	139280	N/A
2015	174695	25%
2016	226940	30%
2017	359093	58%
2018	503618	40%
2019	742084	47%
2020	1182792	59%

Table 3.8: Number of HEV new cars registration in Europe

Figure 3.12 shows different forecasted numbers of HEV new cars registration in Europe; the lower bound is a downtrend until almost zero after 2035, while the upper bound displays a stable uptrend with more than 14 million in 2035 and more than the double in 2050.

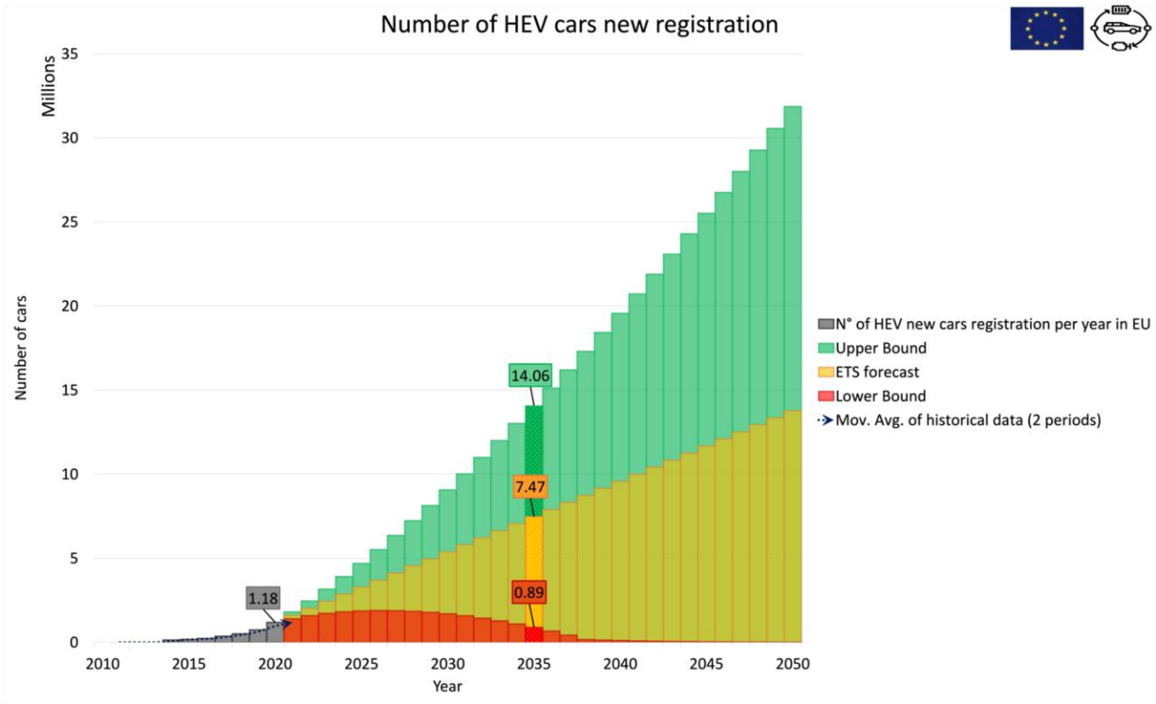

Figure 3.12: Forecasted number of HEV new cars registration in Europe

Error! Reference source not found. Table 3.9 [98] displays the number of H2 new cars registration in Europe showing an uptrend in the last years, however, considering the absolute values, the numbers are extremely small that means it is still in the developing phase.

Year	N° of H_2 new cars registration per year in EU	Year-Over-Year (YOY) growth rate
2010	N/A	N/A
2011	N/A	N/A
2012	N/A	N/A
2013	N/A	N/A
2014	32	N/A

Year	N° of H_2 new cars registration per year in EU	Year-Over-Year (YOY) growth rate
2015	165	416%
2016	113	-32%
2017	218	93%
2018	230	6%
2019	483	110%
2020	749	55%

Table 3.9: Number of H_2 new cars registration in Europe

Figure 3.13 illustrates the situation described above with a positive trend in all the forecasted number of hydrogen cars new registration with a maximum of three thousands in 2035 and almost five thousands in 2050. Hydrogen cars are highly dependent on how the infrastructure will be developed. Nowadays, this technology has been planned for heavy duty transport. Those forecasts are relative to private passenger cars; however, those numbers could highly increase after the hydrogen taxis fleets deployment in Europe [102].

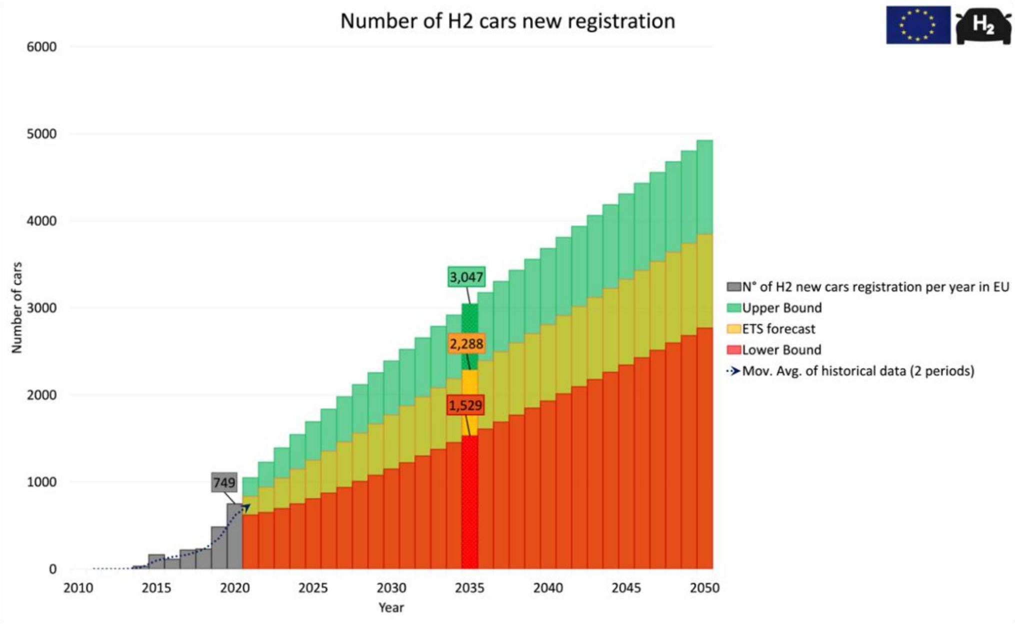

Figure 3.13: Forecasted number of H_2 new cars registration in Europe

Even if Italy has a small electric car market share in Europe, Table 3.10 [97] shows an incredibly positive trend in the last years doubling the number of BEV new cars registration year after year.

Year	N° of BEV new cars registration per year in Italy	Year-Over-Year (YOY) growth rate
2010	40	N/A
2011	117	193%
2012	507	333%
2013	836	65%
2014	1075	29%
2015	1451	35%
2016	1376	-5%

Year	N° of BEV new cars registration per year in Italy	Year-Over-Year (YOY) growth rate
2017	1957	42%
2018	4983	155%
2019	10720	115%
2020	32479	203%
2021	67361	107%

Table 3.10: Number of BEV new cars registration in Italy

Figure 3.14 depicts the exponential forecast the number of BEV cars new registration based on historical data. The range between the best and worst case goes from 131 to 51 thousands of cars in 2035 and from 100 to 200 thousands per year in 2050.

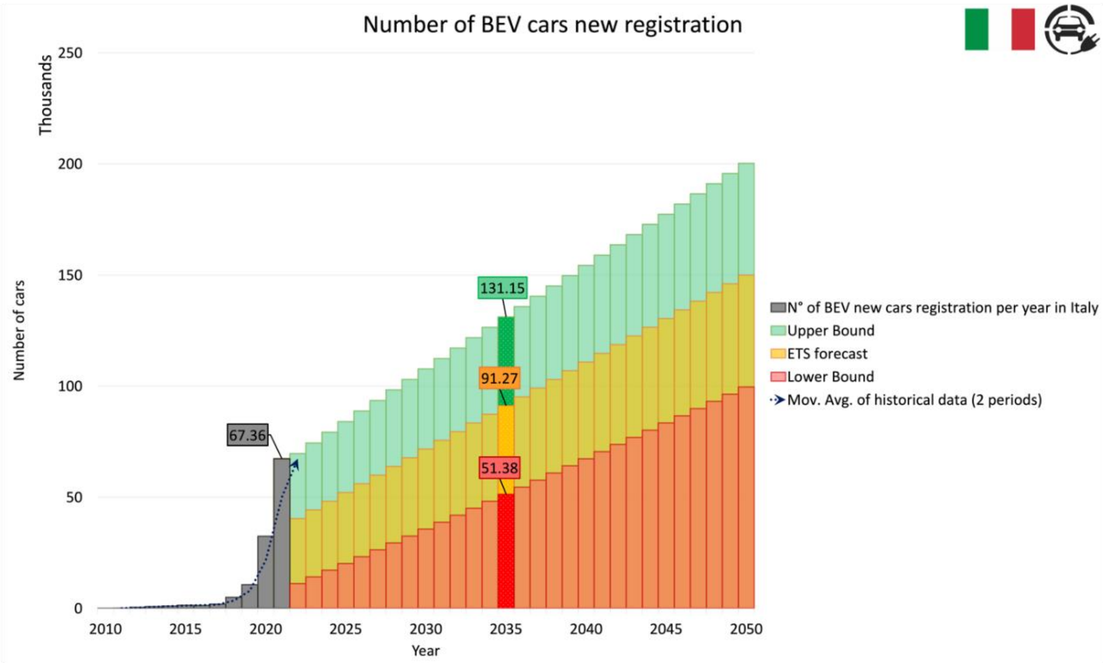

Figure 3.14: Forecasted number of BEV new cars registration in Italy

It is also important to consider the PHEV new cars registration in Italy has a three-digits increment in the last years, which can be seen in Table 3.11 [97].

Year	N° of PHEV new cars registration per year in Italy	Year-Over-Year (YOY) growth rate
2010	N/A	N/A
2011	3	N/A
2012	145	4733%
2013	218	50%
2014	446	105%
2015	891	100%
2016	1452	63%
2017	2863	97%
2018	4840	69%
2019	6482	34%
2020	27401	323%
2021	70378	157%

Table 3.11: Number of PHEV new cars registration in Italy

Figure 3.15 shows a similar situation forecasted situation as BEV in Italy with a greater increase based on affordability, range and availability of the infrastructure perceived in this moment. In the upper bound of exponential smoothing forecast, almost 173 thousands cars new registration in 2035 were obtained and more than 250 thousands in the long-term perspective.

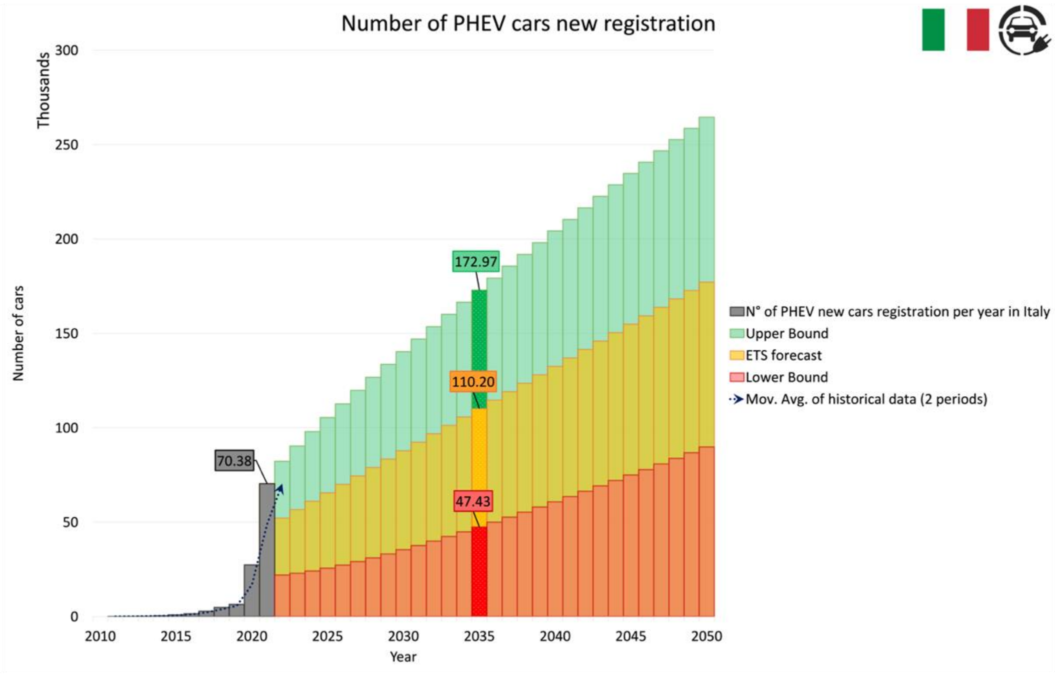

Figure 3.15: Forecasted number of PHEV new cars registration in Italy

3.1.5 Correlation between infrastructures and cars

The correlation coefficient r_{xy}, often known as the Pearson Correlation Coefficient, is a measure of how closely two variables are connected. The result of the computation might range between -1 and 1. A number of -1 implies that the two variables are extremely unconnected, whereas a value of 1 suggests that they are extremely linked. The correlation coefficient highlights the connection between energy infrastructure and car, and it is calculated in this way:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (3.14)$$

Table 3.12 shows the strong correlation between cars and the related infrastructure with the highest value of Pearson Coefficient in case of hydrogen, followed by the strong relationship in the Italian case. This means that having a big increase in the development of the infrastructure can be translated into a higher level of decarbonization in the roads given by a bigger presence of alternative fuels cars.

		r_{xy}			
		European infrastructure		**Italian infrastructure**	
Electrically chargeable		0.73		0.90	
BEV	**PHEV**	0.76	0.70	0.91	0.89
FCEV		0.95		N / A	

Table 3.12: Correlation between infrastructures and cars based on historical data

3.2 Autonomous and connected vehicles infrastructures

Many individuals have wished to possess a connected and autonomous vehicle that can be self-drive, self-park, and interact with other connected vehicles to provide safe and enjoyable journeys. Connected and autonomous technologies are currently evolving and, on their way, to become the dominant reality of future transportation systems and smart city infrastructure. Tech titans, such as Google, and car manufacturers, like BMW, Volvo, and Tesla, has already begun testing in several nations. According to some estimates, millions of connected and self-driving automobiles will be on the road by 2035. However, many scientists and vehicle manufacturers remain suspicious of these projections, particularly the predicted level of connection and automation in the following phases of connected and autonomous vehicles. Furthermore, numerous issues about the integration needs of connected and autonomous cars in future smart cities, as well as their capabilities to increase traffic efficiency, passenger safety, mobility alternatives, and municipal operations, remain unanswered. Moreover, all connected and autonomous activities and interactions with other systems must be safeguarded using modern security measures to preserve citizens' privacy and prevent potentially harmful circumstances. Thus, specialists in vehicular networking, automation, electrification, and security are collaborating intensively to solve these specific challenges and achieve the highest feasible degree of connection, autonomy, and security in the connected and autonomous cars anticipated for 2035. In the meanwhile, transportation and system experts are conducting a variety of studies to determine how they might help the future of intelligent transportation and smart cities applications. Regardless of the extent of perceived benefits, varied consequences on travel behaviour, or Level 3 or 4 or 5 preparedness, autonomous vehicles will eventually run-on infrastructure associated to the transportation and information and communication technology sectors. The key elements [103] are:

- **Infrastructure needs and consequences for traffic management**: autonomous vehicles are anticipated to rely on precise mapping during their route. Roadway maintenance work is expected to change as cities expand, resulting in changes to the road structure and the sites where cars are required to traverse. Regardless of whether updated maps/apps, geolocation cones or barriers on the site, or a virtual geofence that may be detected by autonomous cars are used, all of these settings provide a considerable challenge to them. Emergency situations, on the other hand, provide a novel scenario since the environment around the autonomous vehicles may be problematic due to the stochasticity connected with random accidents.
- **Road marking and signage**: AVs (Autonomous Vehicles) will be steered mostly by lane markings and signs, necessitating good and consistent marking and signage throughout the voyage. Both Tesla and Volvo have complained about the inadequate marking, claiming that it will stymie the adoption of autonomous vehicles. Many factors can lead AVs to become confused, including outdated marking that is no longer visible, discontinuous marking, white marking in snow conditions, and marking with weak contrast. Finally, even if road maintenance is well-specified, this does not guarantee that it meets the criteria of AVs. Similarly, faulty road signage might confound AVs, emphasising the importance of sign upkeep. The necessity for uniformity of signs, signals, and labelling across many jurisdictions and states is closely tied to the demand for high-quality static information. An opportunity for AVs may be to use their sensors to accurately report any indications or marking issues to the appropriate authorities. Furthermore, V2I communication can give a solution to the sign and marking problem. For example, 3M (a global leader in traffic signage printing, production, and marking) introduced new smart signs and marking that deliver digital information to vehicles. Advanced Road Markings is a long-lasting and detachable magnetic pavement lane marker that can be detected by AV sensors even in the most severe weather conditions.
- **Internet and connection**: AVs rely heavily on GPS and the internet for precise navigation and up-to-date incident information. Google's self-driving car, for

example, collects 1 GB of data every second, demonstrating substantial technological advancements in both short-range communication such as vehicle-to-vehicle communication and long-range communication such as maps and emergency alerts. Continuous, dependable, all-encompassing internet access and connection may not be accessible in all situations and conditions.

- **Road geometry**: As roads become smaller with tighter turning radii as a result of AVs, their geometric design may alter. However, such adjustments would be inconvenient for traditional cars and may raise the chance of accidents. In 2018, KPMG investigated various countries' infrastructure and the degree to which it is ready for AVs based on six variables: density of electric vehicle charging stations (the number of available stations at a specific distance), GSMA Global Connectivity Index for infrastructure (measures the performance of the key enablers of mobile internet adoption), 4G coverage, road quality, and LPI infrastructure score (ranks countries on six dimensions of trade including customs performance, infrastructure quality, and timeliness of shipments). According to KPMG's Change Readiness Index for technology and infrastructure, the top three ready countries are the Netherlands, Singapore, and Japan. Surprisingly, the top nations on this ranking are not always the leaders in AV R&D, production, piloting, and testing.

Many pilot studies have been done in recent years to better understand the true effects of autonomous vehicles, analyse the technology, and collaborate with service providers. Figure 3.16 displays chosen relevant pilot studies from throughout the world. Those are:

- **Arlington, U.S.A.**: The major goal of the pilot is for city council members to better comprehend the new technology around autonomous vehicles; specifically, improving public awareness and understanding the level of public acceptance of the new technology. The ultimate objective is to promote the city as an innovative testing ground on a national scale. The pilot research began with over 1500 journeys, with the goal of proving mobility and launching a cooperation. The city deployed two low-speed shuttles (each carrying 12 passengers) to transport passengers between parking lots and sports and concrete venues, as well as additional pick-up and dropping sites. Passengers were invited to fill out a survey before the conclusion of their voyage, and they were impressed with the new technology. As a consequence of the success of this pilot, the city intends to conduct a second on-street pilot study.
- **Boston, U.S.A.**: Boston has supported the introduction of AVs since 2015, and in 2016, the World Economic Forum named the city a focal city for the future

of mobility, in collaboration with two start-ups: nuTonomy and Optimus Ride. The testing began with a flexible piloting plan; for example, Optimus Ride was permitted to operate their vehicles in fog and rain for the purpose of learning, and nuTonomy began its first pilot study on the roads of the city park in January 2017, then expanded to the Seaport District and Fort Point neighbourhoods by April. The trial was not open to the public until late 2017, when Lyft joined with nuTonomy to provide ride-sharing services in the Seaport region. As a consequence of the successful pilot, the city is planning a second pilot study, and nuTonomy is mapping the whole city in preparation for the next phase of testing, which will allow AVs to operate across the city.

- **Arizona, U.S.A.**: The city is exceptional in terms of the length of time it has had AVs and the extensive dispersion of AVs around the city. AVs have been operating on city streets since 2016. In 2015, the city demonstrated its openness to allow AV testing, resulting in the entry of Waymo in 2015. Chandler was one of the first communities to test AVs on public roads, and Waymo put its vehicles on the road for several months during the mapping process with regular drivers as operators, which helped familiarise the public with AVs. AVs have been on city streets for over two years and are already a frequent sight across the city's neighbourhoods. Furthermore, General Motors has been testing its autonomous vehicles on city streets since 2016. In January 2018, Intel began testing its first fleet of 100 autonomous cars. Uber has been testing its AVs in the area since 2016, and in 2018, one of its cars was involved in a deadly accident, prompting the governor to temporarily withdraw the company's licence to operate in the state, and tests have yet to restart.
- **Gothenburg, Sweden**: From May to December 2017, the city conducted a pilot study of autonomous vehicles for rubbish trucks. Volvo Group collaborated with Swedish rubbish and recycling specialist Renova to test the vehicle for six months, demonstrating that trucks produce high levels of efficiency, decrease congestion, and improve workplace safety. The test findings revealed a 10% reduction in fuel usage and that three regular trucks may be replaced by one autonomous vehicle, with 50–70% of truck drivers predicted to be replaced by 2030.
- **Singapore**: AV pilot studies began in Singapore in 2015, and the country is considered as one of the most AV-friendly in the world. The city permitted testing of a wide range of autonomous vehicles, including driverless taxis, buses, and shuttles for both private and public usage. This climate has given the city a fruitful setting for AV firms, with over ten companies testing their cars in the city, e.g., nuTonomy, SMART (Singapore-MIT Alliance for Research and Technology), ST Kinetics & Singapore's Land Transport

Authority, Toyota, and Scania, Katoen Natie. As a result, Singapore is working relentlessly to overcome the technological hurdles of AVs, which range from linked infrastructure to safety laws. According to the testing findings, car ownership can be decreased by 15%. City officials adopted AVs to improve access to the city while preparing it to be at the forefront of international innovation.

- **Wageningen, The Netherlands**: The city is the first to try driverless shuttle journeys without drivers on public roads, according to a pilot project that began in January 2016. Multiple Easymile EZ10-dubbed WePods vehicles with a top speed of 25 km/h were deployed by the city. The research was expanded, and the city is currently deploying electric autonomous buses on a defined route between the Wageningen University and Research Center and the Wageningen train station. The successful research served as a model for other communities by providing an effective first and last mile solution in regions underserved by public transit. Furthermore, the pilots encountered a variety of scenarios during the testing period, including a crowded pedestrian zone, interactions with cyclists, and traffic lights. In 2018 and 2019, the Netherlands was ranked 1st in the KPMG Autonomous Vehicle Readiness Index. The ranking procedure took four major pillars into account: policy and legislation, technology and innovation, infrastructure, and public acceptability.
- **Helsinki, Finland**: A pilot research began in 2016 with the goal of addressing the first and last mile, improving user experience with public transportation, and lowering emissions. The city was an early backer of AVs. In 2016, the city launched a 2-year, 1.2 million SOHJOA AVs study based on autonomous shuttles provided by EasyMile with a maximum speed of 18 km/h in the suburbs north of Helsinki and Hernessaari district, and the shuttles traversed many low-density routes; the study concluded successfully in May 2018. The project is looking into more difficult areas, with the goal of becoming a leader in smart technology and becoming carbon neutral by 2035. Furthermore, the city intends to phase out the usage of private automobiles by 2050, with the second phase relying on Navya shuttles.
- **Paris, France**: A pilot study with three shuttles linking three districts at a speed of 7 km/h began in July 2017. The project was launched by Ile-de-France Mobilites in collaboration with businesses Defacto (local partner), Keolis (transport management), and Navya (shuttle technology), with the idea of deploying AVs as a first and last mile solution. The shuttles were allowed to travel without drivers, making it France's first completely autonomous test. The shuttle had a seating capacity of 14 people (11 seats and 4 passengers

standing). The study was completed successfully in December 2017. (Apur, 2018; Navya, 2017).

- **Rouen, France**: A pilot trial began in mid-2018, with 17 drop-off and pick-up zones and a speed limit of 50 km/h on three 10-kilometer routes. Rouen Normandy Autonomous Lab Initiative launched the investigation, which included four autonomous and electric Renault taxis. The experiment is located in the Technopole du Madrillet industrial park and connects 17 different locations inside the area. The primary goal is to address the first and last mile problem, and the service will be linked to the public transit system to provide extra on-demand service for the region.
- **Shenzhen, China**: A pilot study began in December 2017 with four autonomous buses travelling 1.2 kilometres at a top speed of 40 kilometres per hour. The buses have a capacity of 19 people, which is greater than that of any other city's shuttles. The buses were operated by Shenzhen Bus Group (a public transportation company). The city revealed a proposal for a second test 3 kilometres long with ten pre-planned stops near the Southern University of Science and Technology.
- **Sion, Switzerland**: In June 2016, two shuttles that can carry 11 people on 1.5-kilometer trips in the centre of Sion with strong contact with pedestrians in the old town area began a trial study. In its first year, the bus ran for 312 days and travelled 4500 kilometres at an average speed of 6 kilometres per hour. However, the research was temporarily halted in September 2016 due to a collision with a truck that resulted in no injuries. The algorithms were evaluated and improved, and in 2018, the city announced plans to expand the service to Sion's major railway station, introducing new complications and challenges. The municipality has made a notable addition to the road by installing linked traffic signals that speak with vehicles as they approach the intersection. The project was initiated by the Swiss city of Sion and Navya, which supplied the buses used.
- **Edmonton, Canada**: The city conducted the first EAV pilot project in Western Canada in the fall of 2018, with the purpose of studying public opinion regarding AVs and testing the vehicles in frigid weather. EasyMile donated the shuttle for testing at the University of Alberta. The University of Alberta Centre for Smart Transportation and the University of British Columbia are leading the initiative.

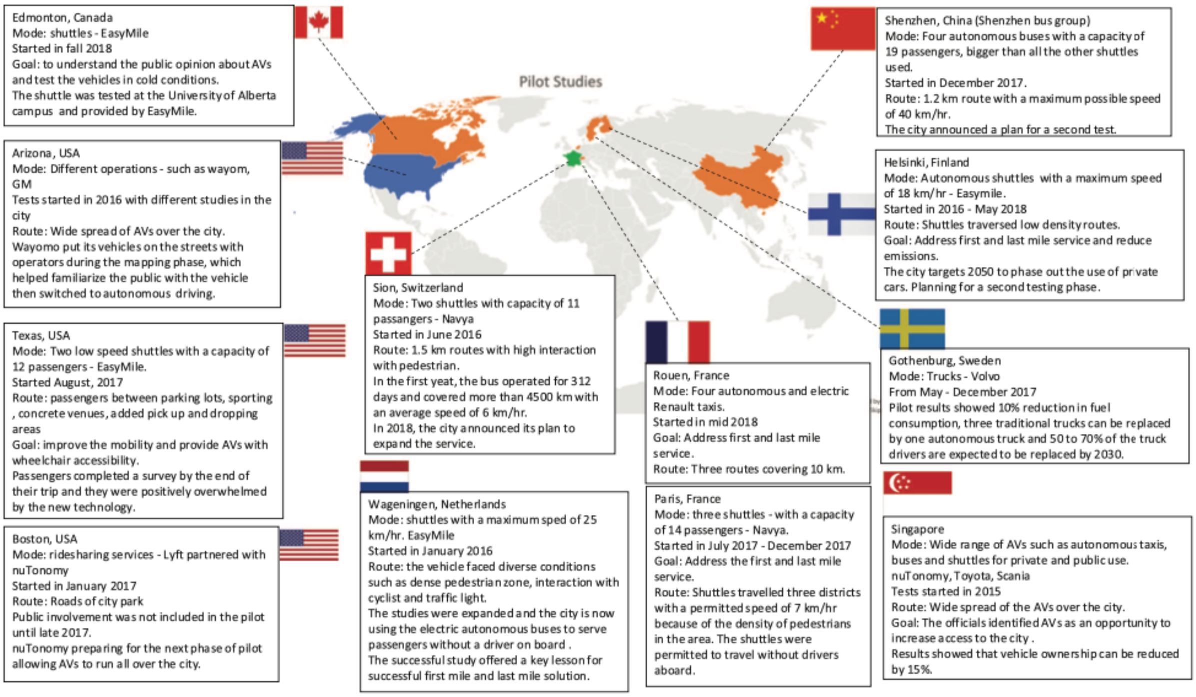

Figure 3.16: Worldwide autonomous vehicle's pilots

It is clear that the majority of pilot studies employed small-size shuttle buses, implying that the objective of the pilot research is to deploy AVs as a public transportation mode, addressing the first and last mile in an attempt to increase users and minimise automobile ownership. Additionally, pilot trials in Singapore began in 2015, and it is considered as one of the world's most AV-friendly countries, with data showing a 15% drop in car ownership by 2018, indicating a significant potential in a short period of time. The Swedish project is the only one focused on testing driverless trucks, with findings indicating a 10% reduction in fuel usage and three regular vehicles being substituted by one autonomous truck. In other words, the study revealed that the AV transportation business is very efficient. The preceding piloting landscape has highlighted the necessity for either new legislation for testing AVs or revisions to current regulations to permit this setting. Figure 3.17 is constructed to describe the status of AVs' rules all over the world, demonstrating that the majority of nations in the global north either approved AVs' piloting and testing or had particular restrictions made as a result of state/province/city local legislation.

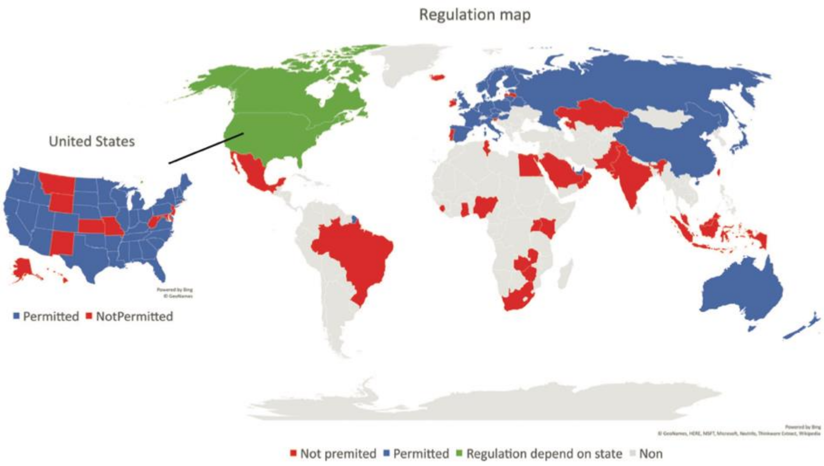

Figure 3.17: Regulation about AVs in the world

According to KPMG [104], Italy competes fine on AV attentive actions. It also established an Observatory for smart roads to track all trials in Italy and compare them to those in other countries in order to identify best practises. The government is also working on digital connectivity to enable AVs, with an emphasis on V2X connections, which let cars to talk with other vehicles and infrastructure. Anas, the state-owned firm in charge of managing Italy's main roads, is to invest 140 million € on connected car technology for around 2,500 kilometres of its network, with special work on roads such as Rome's Grande Raccordo Anulare ring freeway. This is despite Italy's government receiving the lowest score from the World Economic Forum for its future orientation, a metric that evaluates policy stability, responsiveness to change, flexibility of the legal framework to change, and the government's long-term vision. Following the smart roads directive, Italy's first and thus far only testing began in Parma and Turin in 2019. Both are managed by VisLab, an autonomous driving firm founded in 2009 by the University of Parma and bought by the US semiconductor manufacturer Ambarella in 2015. Parma City Council authorised the trials to take place around the city in February 2020. Turin is also conducting a trial of an AV minibus service run by Local Motors, which uses Olli, an EV constructed completely of 3D printed parts. Next, an Italian business, is testing modular AV minibuses in Padua that may dock or break apart and follow multiple routes based on the locations specified by passengers. All of this helps the country, but there are issues to address, such as the high cost of AV technology for customers and local public transportation providers, the latter of which has a track record of minimal investment in their vehicle fleets. The country also lacks national high-definition mapping, and there are concerns about responsibility in the event of an AV accident; the national trade organisation has published work on this, but no goods are yet available. Many drivers currently have 'black box' monitors in their vehicles for insurance purposes, which may be utilised for AV coverage. Autonomous cars usually have total 360° view all around vehicles, it becomes a tremendous value in navigating securely. Blind spot recognition innovation, which can either be used as tracking or image sensors, enables an automobile to collect information about the products that may cross its trajectory. Smart roads and smart city infrastructure including 5G technology network management sensing devices, intelligent stoplights managing, can assist reduce the latency for notifications or advisories, permitting data to be transmitted in close time to support enhance the reliability and safety of driverless cars. The Figure 3.18 [105] shows some key features of connected and autonomous vehicle road safety.

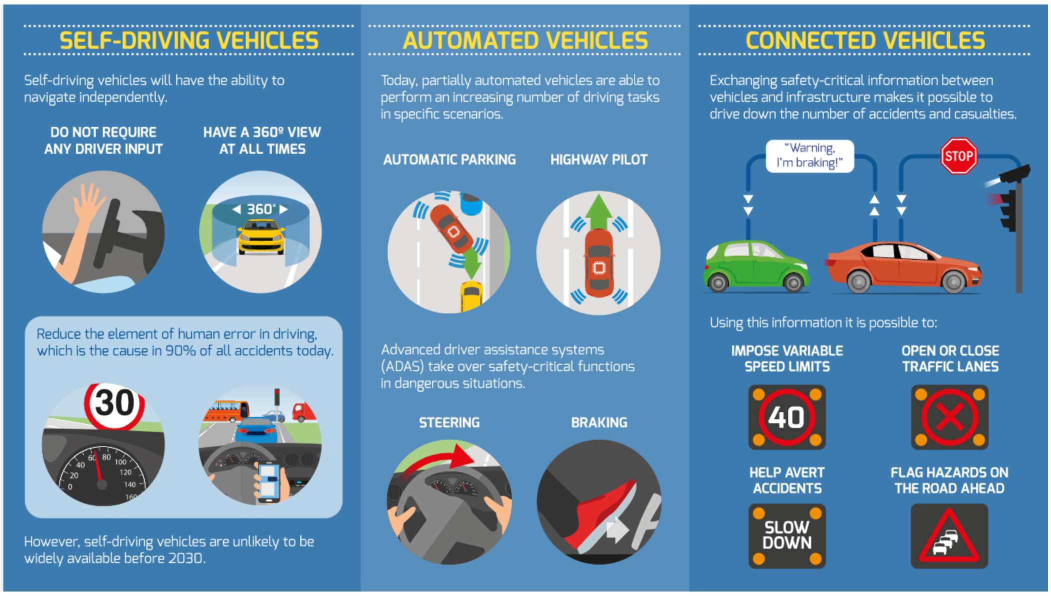

Figure 3.18: Road safety

In certain conditions, ADAS may indeed handle away controlling activities like steering and applying brake from the operator. Influential safety mechanisms like as fully AEB and LKA are types of ADAS technology which is now in use to avoid potential error rates and hinder fatalities. ADAS will also play an essential part in preparing operators as well as other commuters for the prospect of automobiles.

3.3 Socio-economic analysis

E3ME [106] is used to simulate the economic impact of decarbonizing Europe's passenger vehicles in the reference scenario where cars stay unchanged from now [107]. The E3ME model is used to analyse how the shift to low-carbon cars impacts household income, oil and petroleum commerce, consumption, GDP, employment,

CO_2, NOx, and particulates. The GDP impact is due to a change in expenditure away from imported oil and toward increased capital content in automobiles and decarbonised fuels. The increased cost of automobiles affects consumer prices and reduces real income and expenditure. It shifts expenditure away from other areas of the economy and toward the value chain for producing cars and their component parts. Better fuel efficiency, on the other hand, decreases consumer operating costs, which benefits the economy. It moves expenditure away from oil supply networks and towards other sectors of the economy. Since oil is imported into Europe whereas decarbonised fuels are produced there, the shift in fuel spending benefits the European economy and improves the trade balance. Figure 3.19 depicts the global shared mobility market highlighting the high presence of cars in the market and a value higher than 166 billion dollars.

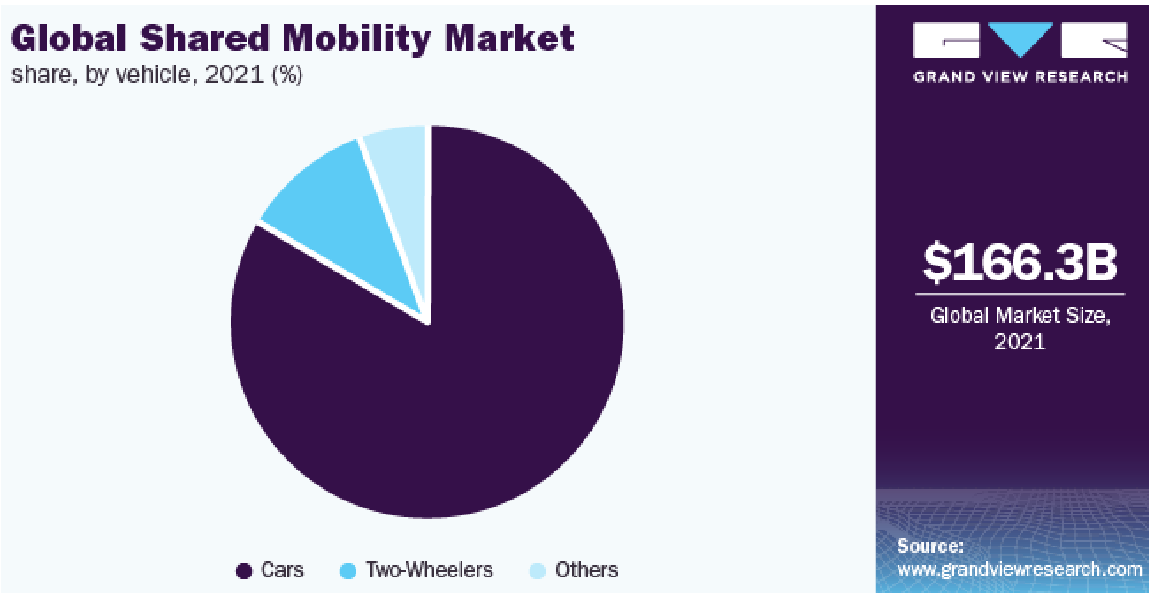

Figure 3.19: Global Shared Mobility Market

Figure 3.20 illustrates an exemplary result of mobility market models for a scenario in which autonomous technology becomes available and inexpensive by the middle of this decade and communities incentivize new and innovative forms of transportation.

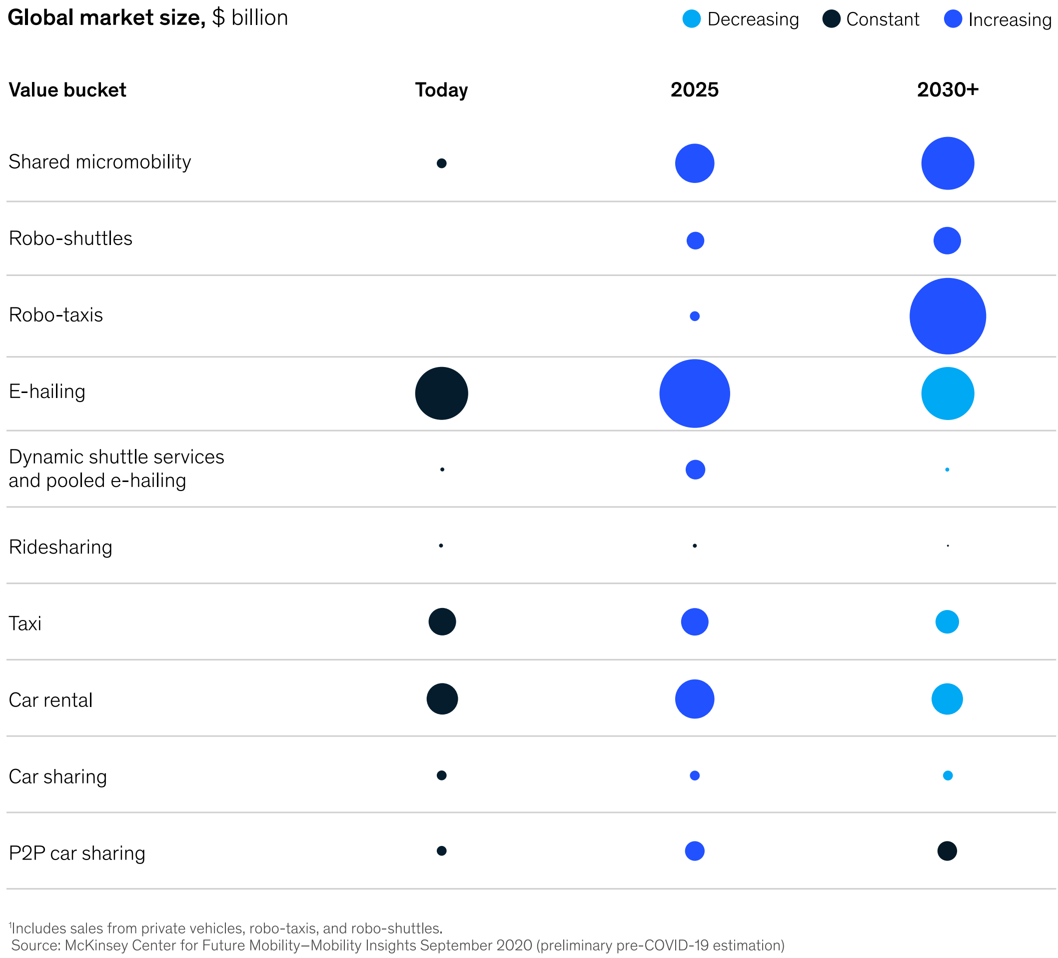

Figure 3.20: Illustrative global market size

Connected and autonomous cars are predicted to have a beneficial economic impact overall. However, certain industries will be badly impacted. For example, increased road safety is likely to result in significant economic losses for the insurance industry. In contrast, the digital industry is predicted to provide exceptional results. Improvements in freight transport and logistics efficiency, productivity, and safety have been observed [108]. Manufacturing and service industries, both large and small and medium-sized enterprises (including start-ups), will benefit from new business opportunities in automation and robotics, mobility services for citizens, more efficient logistics solutions, or the digitalization of the entire transportation system. Figure 3.21 summarises the research in chronological sequence in terms of timescale for projected impacts.

Reference	Estimated economic potential	Details/Decomposition	Region	Timeframe
Clements and Kockelman, 2017	$1,200 billion	— $418 billion from industry-specific effects — $448 billion in savings from increased productivity — $488 billion in savings from collisions — Discounting $138 billion from collision value overlap (between the $488 billion in savings from collisions and the savings in the auto repair, insurance, legal and medical sectors)	US	No timeframe
Asselin-Miller et al., 2017	$273 billion	— $210 billion from connectivity — $41.5 billion from autonomous hardware components — $15 billion from new software — $7.2 billion from autonomous driving chips	Global	2020 - 2030
World Economic Forum, 2016b	$670 billion	— Value at stake for automotive players as a result of 3 key digital themes (within the digital transformation of the automotive industry): the connected traveller, AVs and the enterprise/ecosystem — (in addition, $3.1 trillion in societal benefits coming from the digital transformation; of which more than $1 trillion would come from reduced accidents and lower insurance premiums)	Global	2025
Leech et al., 2015	£51 billion	— A £40 billion from consumers (£20 billion from a decreased value of travel time, £15 billion from more efficient trips and £5 billion from reduced costs including insurance, running costs and parking) — £2 billion from producer profits — £16 billion wider impacts (e.g. reduced travel and freight costs, telecommunication data traffic increases, growth in revenues from sectors like digital media, electronics, etc.) — £2 billion from taxation — £2 billion from improved safety	UK	2030
Leech et al., 2015 *(continued)*		— Discounting £11 billion from infrastructure investments and road maintenance costs		
Römer et al., 2016	$284 billion	— $103 billion in special equipment (on-board control, guidance, and communication systems) — $86 billion in mobile apps (V2V telematics and communication) — $95 billion in new vehicles	Global	2030
	$558 billion	— $189 billion in special equipment for high/full automation — $109 billion in mobile apps (V2V telematics and communication) — $260 billion in new vehicles — (in addition to this, $1.3 trillion in savings: $488 billion in total savings from accident avoidance, $169 billion in fuel savings and $645 billion from an increased productivity)	Global	2035
Lanctot, 2017	$7,000 billion	— $3.7 trillion in consumer MaaS — $3 trillion in business / Business-to-Business (B2B) MaaS — $203 billion in new and emerging pilotless vehicle services — (in addition to this, benefits of $234 billion in public safety costs related to traffic accidents in the period 2035-2045)	Global	2050
	$1,700 billion	Global Passenger Economy service revenues, out of the $7 trillion global revenues	Europe	2050

Figure 3.21: Estimated economic potential of connected and autonomous cars

The importance of the EU's automotive sector is evident in the fact that it employs over 5 million people, including approximately 3 million in vehicle manufacturing and close to 2 million in vehicle sales, and that it accounts for approximately 3% of EU GVA and approximately 2.5 percent of total EU employment [109].

3.4 SWOT analysis

The SWOT analysis, which stands for strengths, weaknesses, opportunities, and threats and identifies potential for development and progress, is the method used to delve deeply into the infrastructures research. The infrastructures under consideration are:

- gasoline stations;
- hydrogen refilling stations;
- recharging stations;
- car sharing;
- connected cars;
- autonomous cars.

3.4.1 Gasoline infrastructure

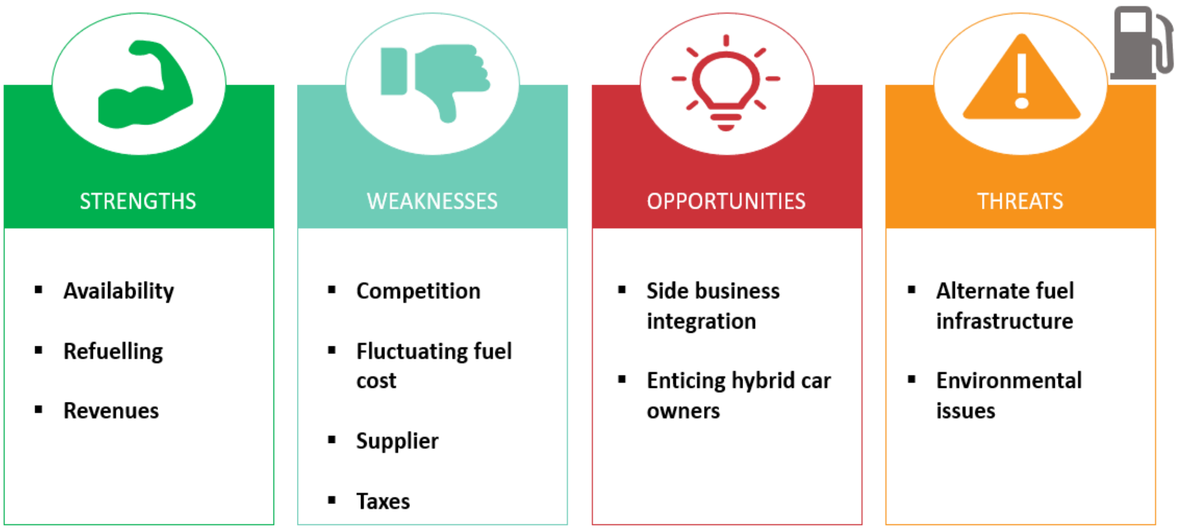

Figure 3.22: Gasoline infrastructure SWOT analysis

STRENGTHS

- **Availability**: In the current era, internal combustion engine-based vehicles are dominating. To meet demand, the establishment of infrastructure for these types of vehicles is regarded as the most important measure. A person can easily find this infrastructure within his zone and there won't be any problems if the vehicle stops somewhere. The availability is not limited just to light motor vehicles (Scooter, Car, etc.), but also to heavy motor vehicles (Truck, Bus, etc.), implying that no new infrastructure is required for heavy motor vehicles.

- **Refuelling**: More dispensers are available at gas stations to fuel the vehicle. They are quick and, in a few minutes, they can fill the vehicle's tank. This helps customers not worry about getting empty tanks as they can be refuelled quickly.
- **Revenues**: Even during economic downturns, most gas stations may stay profitable and cash flow positive. Fuel sales and purchases are a more profitable industry than ever before. Petrol stations generally sell fuels such as gasoline, petroleum, diesel, and other forms of oil. The services provided by fuel stations are second to none, regardless of where they are located.

WEAKNESSES

- **Competition**: There are several rivals in the area of gasoline stations; different corporations employ various branding to get people to utilise their fuel stations. Various firms may be found, particularly in the heart of the city. Thriving with in market is a challenging endeavour, and one must remain vigilant at all times in order to avoid losing market share and clients.
- **Fluctuating fuel cost**: The price of gasoline fluctuates on a regular basis; the profit growth of these firms is unpredictable. As a result, it is critical for franchise owners to recognise these hazards and collaborate with fuel wholesalers to guarantee that revenue growth is achieve. Furthermore, these organisations have somewhat high continuous running expenditures, particularly in terms of payroll.
- **Supplier**: The majority of firms in this market follow the provider and producer path, which isn't necessarily a negative approach. Choosing the perfect supplier, on the other hand, might require a significant amount of time, effort, and experimentation. This method, if implemented right, may save owners months of investment.
- **Taxes**: For a gas station owner, it is usually ordered to contribute self-employment taxation, which may be rather substantial. It's essential to comprehend how much the owner be getting a tax cut yearly. So, one can decide if the task ongoing is worthwhile. If it requires to sell items in many jurisdictions, the owner may be obligated to collect sales tax. Whereas this may not have a direct influence on finances, developing a methodological approach for it would be time-consuming.

OPPORTUNITIES

- **Side business integration**: Gasoline stations also provide opportunity for other enterprises such as car washes, supermarkets, and other services to inspect the vehicle's condition. The firm becomes more desirable to customers because it offers more than one service. Users will be drawn to this fuel station by services such as supermarkets and restaurants, which can also give free parking for these shops, if the client uses this gasoline station.

- **Enticing hybrid car owners**: Hybrid car development is expected to accelerate in the near future. The use of gasoline infrastructure is not restricted to ICE cars; hybrid vehicle owners are also encouraged to use it. In the event of a plug-in hybrid car, if the vehicle runs out of charge, the fuel may be utilised and immediately replenished at this station. As a result, it provides a chance for the owner to maximise profit by increasing the number of customers.

THREATS

- **Alternate fuel infrastructure**: Electric vehicles, hydrogen-based vehicles are being developed by a number of automakers. As a result, in some years, the demand for gasoline is likely to decrease significantly. Operators of gas stations may need to reconfigure their businesses to accommodate the requirements of these drivers. This is one of the most serious risks that a gas station owner must consider.
- **Environmental issues**: Gasoline is a very flammable and hazardous liquid. Greenhouse gas is also emitted when petroleum products are burned. The stored and petroleum products can emit toxins into the ecosystem from gas stations [110]. These are complicated combinations of volatile organic molecules (mostly hydrocarbons) and a number of additives combined with petroleum distillates to improve the quality and usefulness of the finished products.

3.4.2 Hydrogen refilling infrastructure

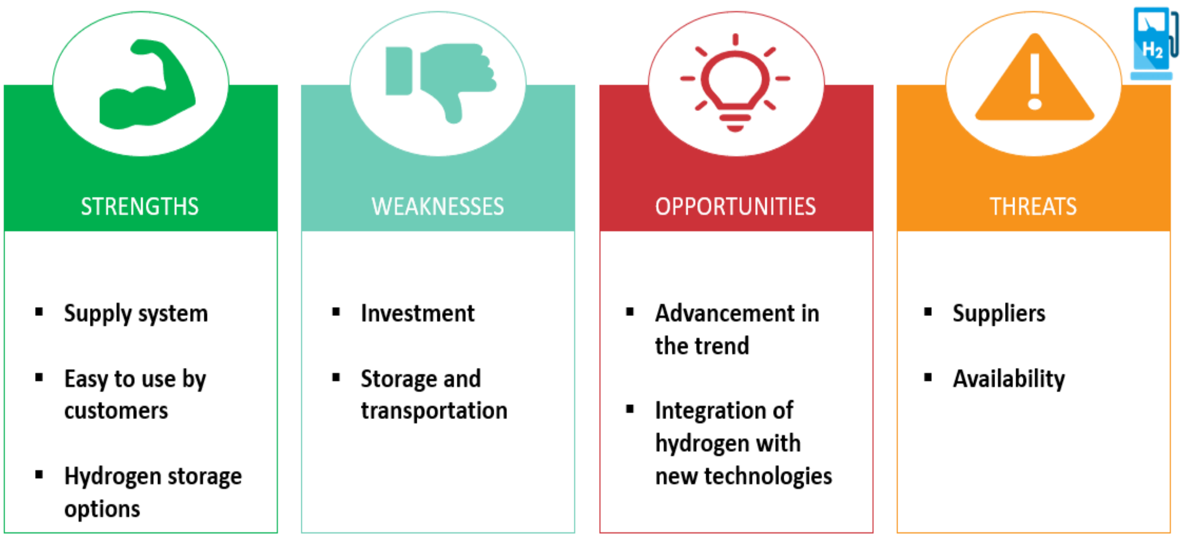

Figure 3.23: Hydrogen infrastructure SWOT analysis

STRENGTHS

- **Supply system**: Centralised and decentralised on-site hydrogen generation at filling stations are viable options. The option of centralised production near renewable energy generating centres provides for economies of scale. Multiple modes of transportation and distribution are possible, ranging from pipes to trucks and perhaps even ships, with tailored solutions for various cases. This high level of flexibility might be viewed as a significant benefit, particularly for the hydrogen market expansion.
- **Easy to use by customers**: Hydrogen refilling is identical to conventional fuelling; customers do not need to adjust their behaviour and are thus unaffected by the fuel transition. Vehicles may refill at the same sites if the transition happens by replacing gasoline with hydrogen. As a consequence, hydrogen-powered automobiles do not require extra fuelling facilities or additional store outlets.
- **Hydrogen storage options**: The capability of large-scale hydrogen storage is built in. The cutting-edge utilisation for hydrogen storage enables cost-effective seasonally storage and the accumulation of a significant energy store. Seasonal storage is an important component of a reliable supply of fuel since it provides a response to variable renewable sources of energy and times of low renewable electricity output.

WEAKNESSES

- **Investment**: Despite the fact that there are very few FCEVs on the market, they still require some basic hydrogen infrastructure to function. As a result, the initial infrastructure investment is rather significant. Integration with current hydrogen facilities vary by nation and are dependent on available uses. In most situations, although, an entirely new hydrogen infrastructure, encompassing sustainable hydrogen generation, transportation, transmission, and commerce, is needed.
- **Storage and transportation**: Liquid hydrogen transmission networks are particularly costly and demanding to maintain. Because of its lesser density, hydrogen necessitates three times the pumping pressure of methane. It is combustible, has a low density, and disperses rapidly in the atmosphere. Conservation and transportation continue to create broad usage of hydrogen challenging.

OPPORTUNITIES

- **Advancement in the trend**: Now there are just a few technological actors in the hydrogen production, however this gives a chance for nations and firms to grab leading position and accelerate the development of wide range for hydrogen fuelling facilities. In the upcoming years, many manufacturers start to establish fuel cell-based vehicles, which enhance the use of hydrogen infrastructure by proving better opportunity for the shareholders and the owners of the company.

- **Integration of hydrogen with new technologies**: Hydrogen is expected to play an important part in the development of energy systems that include a significant proportion of renewable energy. Collaborations with different innovations might also be used. Consider taking power from the fuel cell vehicle and supplying those energies to other systems, that use hydrogen as a periodic storage mechanism. This will benefit the economy.

THREATS

- **Suppliers**: The crucial elements of hydrogen infrastructure are now obtainable as made to order options for substantial electrolysis or in a small lot sequence for simply filling station apparatus. Cost-effective facility deployment has been hampered by the small number of corporate companies who supply for this infrastructure.
- **Availability**: Even if an individual or a corporation wants to buy a hydrogen fuel cell-powered car right now, it is extremely difficult to maintain it due to lack of infrastructure and this may cause the client dissatisfaction. Even if the shift from ICE to hydrogen-powered cars occurs, one consequence will be that sections of the current fossil network would deteriorate, resulting in a lock-in to traditional networks. This is a significant disadvantage for a fuel changeover. Irrespective of the nature or phase of complexation, a hydrogen transmission and logistics system are always interoperable. The finite supply of FCEVs on the industry, as well as the lack of hydrogen fuelling facilities in adjacent provinces, will have a detrimental impact on the moment of development.

3.4.3 Recharging infrastructure

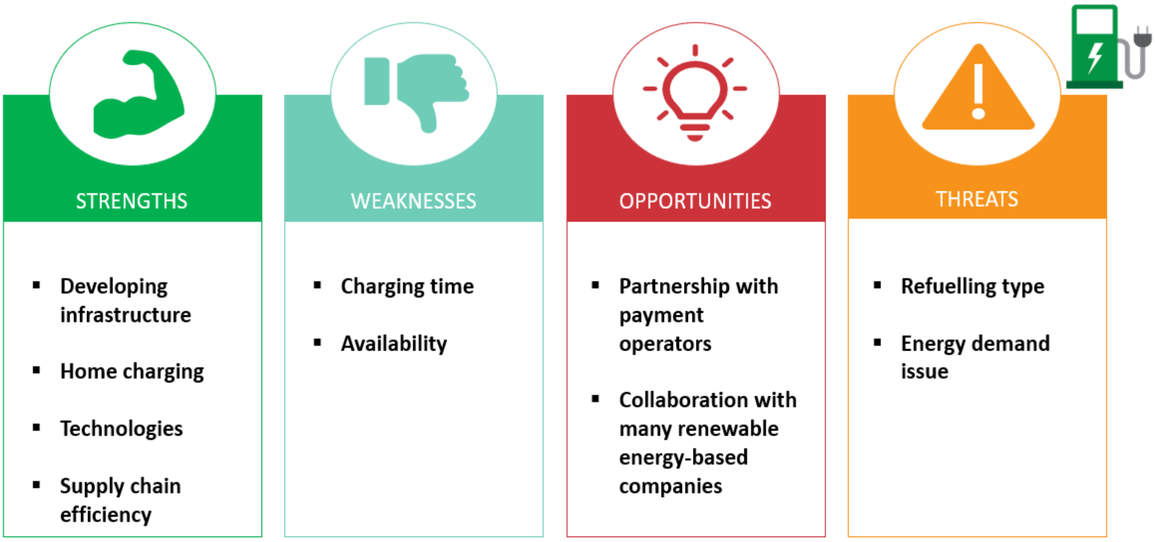

Figure 3.24: Recharging infrastructure SWOT analysis

STRENGTHS

- **Developing infrastructure**: This type of infrastructure is developing day by day with some new trends and features. Facilitating the development of charging infrastructure and enhancing the electrical grid's ability to meet continued growth from charging station. Improving the advancement of regulated standards and technical advancement, as well as investigating a competitive advantage and developing appropriate prototype initiatives.
- **Home charging**: Battery electric vehicles can be charged at residence in dedicated parking bays, in case of public charging. They are also most useful when there is a necessity for night charging as well as when the availability of infrastructure is not within the range. The home charging idea enables the use of localized sustainable energy. Conventional electric outlets might also be used for urgent situation charging. The scope of public and private charging infrastructure.
- **Technologies**: Regulated recharging improves power system adaptability by reducing and distributing maximum charging demands. Requirement for EV charging may be partially met by renewable power generation, enabling for demand-side control. Controlled charging may potentially lessen necessity transmission network expansion, based on regional conditions.
- **Supply chain efficiency**: The electric vehicle infrastructure may not require any transportation. They are more efficient because they utilise energy directly this results in decreased average electricity consumption. The requirement of

new infrastructure is not necessary. Additional interconnections emerge if pre-existing garages, and parking are outfitted with access points. As a result, the electric vehicle infrastructure can be quickly expanded, significantly reducing the necessity for new public charging stations. The same contractor can be retained if the EV infrastructure is replaced with the conventional one.

WEAKNESSES

- **Charging time**: Charging time is one of the most significant disadvantages of electric automobiles. Fast charging is not always an option since they might harm the battery if frequently used. As a result, while purchasing an electric car, owners must make a charging trade-off. When the number of users is immense, the demand to charge the car increases, and customers must wait for their turn to charge the vehicle. This issue creates problem with EV automobile customers not to opt for electric vehicles.
- **Availability**: Electric vehicle infrastructure is still being developed, and availability is not evenly spread in many regions, particularly in small towns, and the infrastructure is not suited for all types of vehicles in one location. There is a distinction in the type of vehicles; for example, passenger cars and heavy-duty vehicles such as trucks and buses cannot share the same infrastructure; so, a separate infrastructure is required.

OPPORTUNITIES

- **Partnership with payment operators:** Customer incentives might assist them in selecting a certain infrastructure. It might be discounts, reward points to be redeemed later. Many start-up and e-commerce businesses collaborate to provide additional choices available for the company's future development.
- **Collaboration with many renewable energy-based companies**: This can also create opportunity for the establishment of charging equipment in office space, restaurants that can promote the concept of V2X technologies.

THREATS

- **Charging type**: Charging battery electric vehicle is distinct from traditional fuelling. This has an influence on charging activity and hence must be coordinated. A shift in the switchover may create difficulties among users since the configuration and setup to charge will be different. They can't charge it as rapidly as they used to, and it takes more patience until required charge.
- **Energy demand issue**: If the demand for car purchases increases while infrastructure is still being developed, there may be an issue with energy supply, and it will be difficult to analyse the effects on utility systems. Power

system enhancements are expected to be required due to increased demand for power generation from the transport industry.

3.4.4 Car sharing

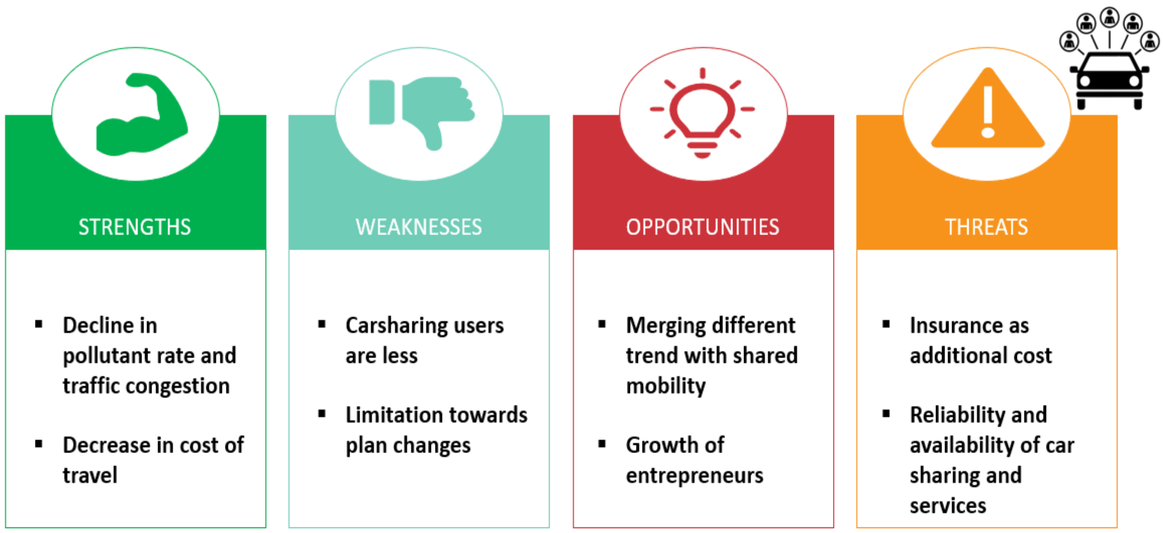

Figure 3.25: Shared mobility infrastructure SWOT analysis

STRENGTHS

- **Decline in pollutant rate and traffic congestion**: It is expected that each shared car decreases CO_2 emissions by using more fuel-efficient, low-emission automobiles. Using one car for a person may result in more pollution and also leads to traffic congestion. If individuals establish the practise of utilising shared transportation, it may lower overall emissions when compared to person using his own car. If the trend changes and people start to show interest in alternate fuel types such as electric or hydrogen cars including autonomous vehicles can eventually help to reduce pollution.
- **Decrease in cost of travel**: Shared mobility may be more appealing to persons who can commute in a range of choices. This is intended for individuals out there that could not afford to have their own automobile. They use this sort of trend to meet their needs instead of purchasing it also the owner doesn't have to purchase a parking permit or look for an affordable or free parking spaces because the value is added in the service charge that is collected for the travel. They also receive bonuses while utilising it, which is an added benefit for customers.

WEAKNESSES

- **Carsharing users are less**: Several individuals prefer to drive in personal cars because they believe that car-sharing subscribers are paid additional taxes on with their membership and use costs, because there is no differentiation between standard car hire and car-sharing and the tariff would be as expensive. This rise is added to the original price plan; therefore, it increases the customer's financial cost and may affect low-income consumers also during covid pandemic, the users prevented utilizing this trend as it may lead to spread of the virus.
- **Limitation towards plan changes**: It is advised that the people use car sharing and also E-hailing need to stick with the plans and it cost them extra amount if they go beyond the travel range, and it is crucial to discern the economic efficiency of car-sharing since they only examine the gasoline expense per trip instead of the contribution margin and the price of the trip may vary also depending upon the environmental factors like when there is a demand for the vehicle due to heavy rain, unavoidable traffic congestion may lead to hike in the travel price as a result, an individual car-sharing trip appears to be economically high. It is a sort of problem that is mostly concerned by the users, and they lose their freedom and need to always be specific with the plans.

OPPORTUNITIES

- **Merging different trend with shared mobility**: Besides the traditional automobiles, alternative fuels such as hydrogen and electric vehicles can be employed. This can also serve to accelerate the expansion of many of these vehicle types. The role of connected automobiles and self-driving cars in the future can be employed in the shared mobility industry to improve the user experience and future technologies.
- **Growth of entrepreneurs**: In the future, investment in shared mobility may rise. As driverless cars become more prevalent in the market, there may be a surge in the number of entrepreneurs. Everyone has access to this infrastructure and can learn about this field. Various business models will also be created in order to stabilise the economy.

THREATS

- **Insurance as additional cost**: If a person rents a car from this type of company, insurance is required. It is required for the vehicle and the passengers within the automobile. Car-pooling firms sometimes charge an additional fee for insurance, which raises the cost of the journeys. Despite the fact that it is a safety risk for the passengers, it adds to the owner's charge.

- **Reliability and availability of car sharing and services**: In the event of a negative encounter, user trust might simply be broken. A particularly traumatic event of one customer might affect many other users in case the word is disseminated. Car sharing services are few, and they are not suited for persons who need to drive great distances or in rural areas. In the event of an emergency, it would be impossible for the corporation to trace the car.

3.4.5 Connected cars infrastructure

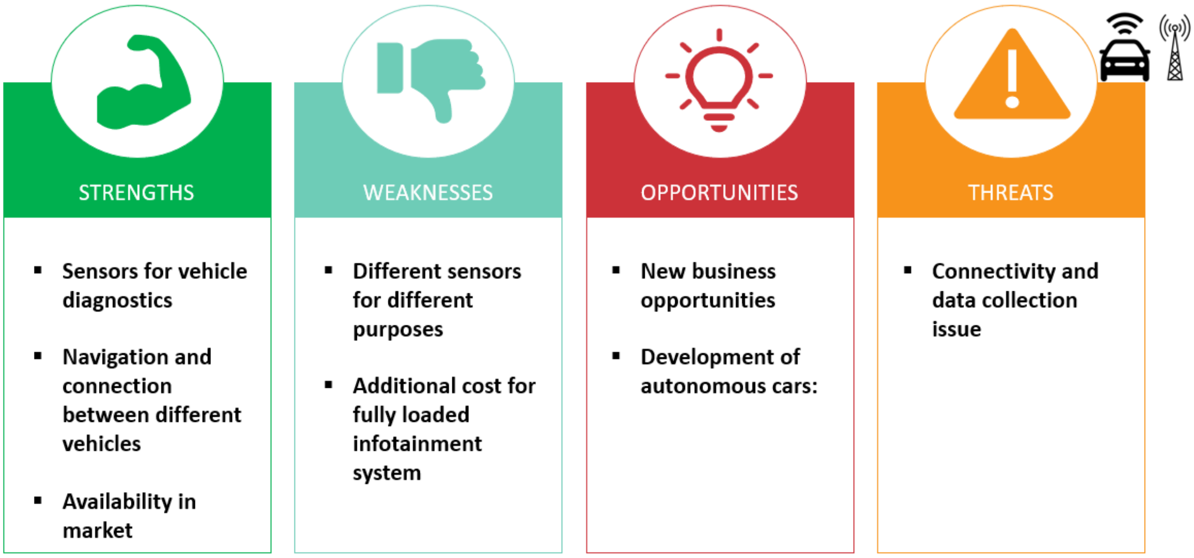

Figure 3.26: Connected cars infrastructure SWOT analysis

STRENGTHS

- **Sensors for vehicle diagnostics**: A large number of monitoring and measurement data are accessible to provide details on vehicle information like tyre pressure, engine diagnostics and so on. Sensor networks able to identify details about the driver's state, such as distraction or fatigue. Although these technologies are currently on the industry, its use is constrained to luxury automotive characteristics.
- **Navigation and connection between different vehicles**: Maps can be used while travelling are helpful and are inbuild. The technology can also be used to interact with other vehicles and share data if required. Routing locations must include specific details such as travel lanes, obstacles, traffic details.
- **Availability in market**: Sensors like reverse parking are available at an extra cost in the market, and these can be purchased if the car company not

provided it. These gadgets are included as an additional features to the car safety. Nowadays, the cars are manufactured in a way that most necessarily required sensors are considered as mandatory and are preinstalled in the car.

WEAKNESSES

- **Different sensors for different purposes**: In addition to in-vehicle monitoring, devices that detect the vehicle's surroundings, such as radar, cameras, are present at greater levels of innovation characteristics. They are associated with certain sensing tasks due to its appropriate software benefits and shortcomings. Extremely precise detector configurations can be assigned for this purpose. This also implies that a range of options are often used to offer related details thus, it increases the cost of the vehicle.
- **Additional cost for fully loaded infotainment system**: Some businesses are now entering the market to manufacture infotainment systems with additional functions. This contains features such as a large touch screen with voice command, internet to connect between gadgets and so on. This raises the price of the infotainment system, and most customers feel obligated to pay a premium price for a vehicle's additional amenities.

OPPORTUNITIES

- **New business opportunities**: It must be adaptable in order to be consistent with evolving communications networks during the vehicle's lifespan, such as 5G, which is expected to be the mainstream technology in the near future. The proposed system must provide dependable, flawless, and continuous connectivity in all territories and marketplaces where the automobiles are marketed and operated. Companies with this technology will play a major role in this market of connected cars. Thus, different companies trade in to bid for the manufacturing of sensors and infotainment systems.
- **Development of autonomous cars**: As sensors become more widely used, their rates continue to fall, making complex structures better accessible to all of us. With some extra sensors and adequate control systems, the existing in-vehicle sensor network might be leveraged for enhanced automated and connected driving capabilities, allowing for the development of autonomous automobiles.

THREATS

- **Connectivity and data collection issue**: The expense and complication of gathering relevant and administering registrations will rise as the numbers of linked automobiles and the massive volumes of information they create increases. It will really push automakers to closely look for special consideration to the various criteria, including the collaborators companies choose. Numerous factors can influence the expense of connection. These include the specific area and the network services operators selected. Encryption is also a significant concern for every firm that uses the system, and cybersecurity still hasn't been emphasized in the car sector.

3.4.6 Autonomous cars infrastructure

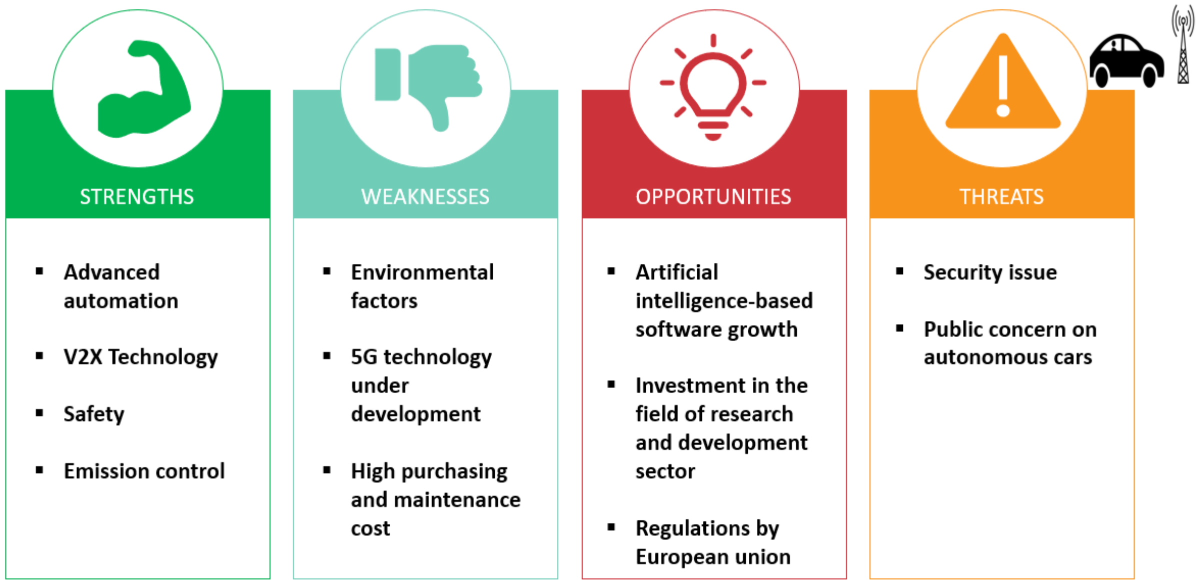

Figure 3.27: Autonomous cars infrastructure SWOT analysis

STRENGTHS

- **Advanced automation**: Self driving car, which is reported to be substantially greater if the operator has past knowledge with Advanced Driving Assistance Systems, which give lesser degrees of mechanization that can aid an operator by detecting potential hazards and attempting to prevent them. Whenever the level 6 is activated, the software manages all handling functions, removing necessity of the traveller, to control the car. The technology is capable of operating the car in all-weather including all roads. The car does not require a physical operator to function.
- **V2X Technology**: As per intelligent transport system employ it is noted that platforms which help vehicles on road to interact with one another. Such approach has previously successfully proven scientifically in a number of major experiments. Vehicle-to-x communication is based on the idea that interconnected automobiles that includes integrated smart road network, disseminated sensor systems, and individual and public ownership centres.

As one component exchanges information with those around, a cooperating ecosystem is formed, laying the groundwork for novel ICT facilities for public entities, accessibility enterprises, and final consumers.

- **Safety**: Safety factors are mostly concerned with this type of vehicle. Company manufacturing such cars are mostly involved safety of the passenger inside and people outside the car. Among the most significant advantages of automated processes appears to be automotive safety. Greater levels of automation, known as self-driving technology, exclude the driver behind the wheel from the chronology of activities that might result in an accident. The benefits of this emerging technology are still under development, this will help to safeguard commuters, also bicycles and walkers.
- **Emission control**: The automobile sector is approaching in the field of automation and electrification, to enhance sustainability and regulatory policies. Considering greater usage of self-driving with ride sharing business and minibus services, automotive technology may eliminate the requirement for personalised parking bays. Furthermore, electrification brings up opportunities to enhance productivity with much less individual operating, resulting in additional cutbacks of environmental pollution from the transportation industry.

WEAKNESSES

- **Environmental factors**: Roadways can be exceedingly variable and fluctuate from location to location. There seem to be clean and well-marked wide roadways in certain situations. In some circumstances, the roads are severely degraded and there is no lane indication. Lanes are not well demarcated. Another stumbling block is the season in which under some circumstances, the vehicle may be able to function in an appropriate way due to the climate change and monitoring of the vehicle by the company operators will lead to malfunctioning.
- **5G technology under development**: Wi-Fi range is not as high, 5G communication technology must be established for autonomous cars; if infrastructure is not developed at the same rate as car manufacturing, there will be a problem between infrastructure and car manufacturing. As in the case of autonomous cars, 5G technology plays a major role in connecting cars with each other and also helps steer the car with the use of 5G technology. So, in this case, the technology needs to be developed in all countries so that everyone in the country can utilise this particular technology, or else it would be very difficult and usually depends only on the Wi-Fi range.

- **High purchasing and maintenance cost**: Autonomous vehicles will be pricey, particularly during initial purchase. According to research firms, a self-driving automobile might price at high cost. Regrettably, this seems to be true for the vast majority of technology. As years pass and technological innovations, the cost might fall dramatically. Often these technicians' experience is limited because the innovation underlying driverless cars is still in its early stages. Many auto repair companies cannot afford to properly address faults with autonomous cars, and customers of such vehicles may very well have difficulty locating anyone that is skilled even in this sector to service their vehicle. It is also applicable for the software issue inside the car that can prevent driver to use his car when needed. As a result, maintaining self-driving automobiles may be complex and expensive.

OPPORTUNITIES

- **Artificial intelligence-based software growth**: Many scientific expenditures have indeed been undertaken in order to implement appropriate Artificial intelligence based in the automobile sector. Particularly important is the advancement of machine learning algorithms, particularly the technique of Neural Network Models, and its implementation to automatic operation. Nonetheless, a wide variety of augmented deep learning architectures emerge. Dynamic network configurations are employed for purposes in automatic driving because they offer numerous benefits. Furthermore, the development of such deep learning architectures varies greatly.
- **Investment in the field of research and development sector**: Research and advancement of technologies is indeed required to offer trustworthy solutions for driverless cars. Many attempts are undertaken by both business and government supported initiatives like infrastructural development to surmount current barriers and reduce disparities. The significance of R&D has grown inside its sector, and government research programmes will include relevant themes in the upcoming years. For connected and autonomous driving to succeed, technical resources must be provided.
- **Regulations by European union**: Technology innovation is being driven by transformation in the automotive manufacturing environment. Governments bear a tremendous deal of interest for ensuring the proper and long-term adoption of automation and driverless driving. Though they have previously simply governed the automobile, they should now provide a regulatory precedent for the operator in the shape of the ADS. The administration will also give incentives because this sort of car emits no pollutants. The government is eager to reduce the cost of automobiles once they enter the market in full swing.

THREATS

- **Security issue**: Cybersecurity threats are becoming increasingly common and have a profound influence on businesses. As the automobile sector advances toward a future automated, self-driving car security problems become increasingly difficult and crucial. The obvious dangers, such as infected with malware, autonomous vehicles colliding is considered if there is a malfunction of any of the sensors. Self-driving automobiles have the potential to store large quantities of user information, rendering them a valuable target for attackers. Furthermore, the vehicle may pose a safety risk to operators as well as other commuters. Some others suggest that the data may breach, and privacy issue may occur.
- **Public concern on autonomous cars**: The user would have no one to talk with because there is no person driving to soothe their anxieties, comfort them, or confront the causes of the issue. The drop point must be precise and changing it at the completion of the journey is challenging. Selecting a location that is outside the car's spectrum to interact is a huge challenge. Some believe that it will result in the loss of jobs for people such as taxi drivers, traditional auto mechanics, and so on.

3.5 Scenarios

The main scenarios created are four with sub scenarios inside of them covering most of the cases which can happen in the future trends considered, which are electric and hydrogen infrastructures, sharing mobility relative to passenger cars, autonomous and connected cars. The scenarios are:

1st) **Current scenario (or Business as Usual BAU)**: there are no big changes, just maintaining the same trend as to use cars with internal combustion engines with a slight decrease in rate and use of shared cars at the current rate as population and income develop over days passes. The interest on electric cars and new technologies are still developing.

2nd) **Hybrid scenario (HYB)**: the customers keep a conservative behaviour not changing their habits but increasing their care to the environment mixing electric technology with conventional car. Electric vehicles take a little market share which is comparatively higher than the previous scenario. Hydrogen and autonomous stay a niche. Shared vehicles are at the current rate as population and income grow overtime. In the sub scenario customers increase their awareness for hydrogen vehicles.

3rd) **Environment scenario (ENV)**: infrastructure is rapidly increasing, and customers feel more comfortable and show more interests to buy an electric vehicle. Electric vehicle market become dominant in middle term perspective. Some customers do not agree with the charging time, but they show interests in environment and start reflecting about hydrogen and shared mobility services. Autonomous cars are still under development with the development of telecommunication infrastructure. In the sub scenario, considering a bigger presence of hydrogen infrastructure.

4th) **Connectivity scenario (CON)**: customers increase attention to electric and hydrogen vehicles. They are more focused on the driving experience, for example they prefer not to drive the car in congestion and making car drive by themselves. Shared mobility services increase, and sometimes they are coupled with automated driving experience.

After creating the scenarios, three different levels of the development of the infrastructures were defined: low, moderate, and high as it is displayed in Figure 3.28.

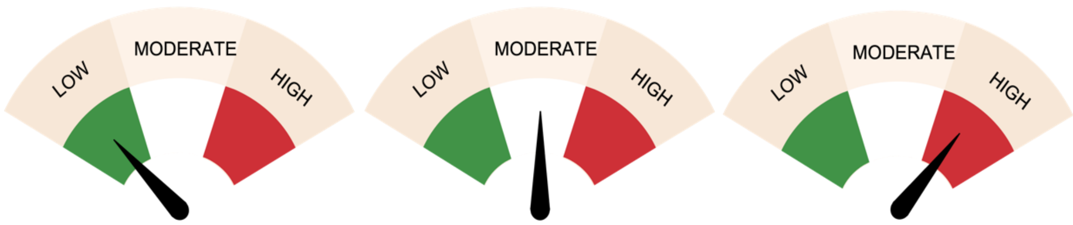

Figure 3.28: Defined levels about the infrastructure

Table 3.13 describes the investigated infrastructures in respect to the three tiers.

Level / Infrastructure	Low	Moderate	High
Conventional	No more new gasoline stations built and upgrade of the existing ones to alternative fuel stations.	Few gasoline stations developed and conversion of some of them to alternative fuel stations.	New gasoline stations are being built, and some old ones are being linked to alternative fuel stations.

Level / Infrastructure	Low	Moderate	High
Electric	Deployment of new charging stations in major cities.	Spread of charging infrastructure and increase the number of fast charging stations in cities and highways.	High diffusion of charging infrastructure and availability in remote areas.
Hydrogen	Pilot projects are being developed.	Deployment of refuelling stations in highways.	Spread of refuelling stations in major cities.
Shared	Shared cars focus just on the major cities.	Upgrade of shared cars to Mobility as A Service level.	Extension of shared cars to all the cities.
Connected and autonomous	Implementation of pilot projects by upgrading the V2X infrastructure.	Development of telecommunication infrastructure in highways and cities.	Growth of infrastructure interconnecting travel in various countries.

Table 3.13: Infrastructure-level descriptions

Table 3.14 connects the various level with the scenarios and infrastructures from mid and long-term perspectives that can be classified in this way:

- **Current scenario (BAU)**: linkage of a part of the gasoline infrastructure with a slow spread of the other trends.
- **Hybrid scenario (HYB)**: the main case considers a decrease of gasoline infrastructure with a transition toward hybrid vehicles, while the sub scenario includes a greater presence of fully electric vehicles.
- **Environment scenario (ENV)**: the main case outlines a decline of the conventional infrastructure converting the existing one and promoting a more sustainable vision about hydrogen and shared and connected infrastructures with a great uptrend in the electric one. The sub scenario adds the spread of refuelling hydrogen stations in cities.
- **Connectivity scenario (CON)**: diffusion of autonomous, connected, and shared infrastructure with a moderate growth in the energy part.

Infrastructure \ Scenario	BAU	HYB main	HYB sub	ENV main	ENV sub	CON
Conventional	↑	→	→	↓	↓	↓
Electric	↓	↓	→	↑	↑	→
Hydrogen	↓	↓	↓	→	↑	→
Shared	↓	↓	↓	→	→	↑
Connected and autonomous	↓	↓	↓	→	→	↑

Table 3.14: Infrastructure-scenario with levels

Table 3.15 summarizes the main variables starting with main actors in value chain analysis, key technologies, and partnerships to comprehend the effects combining variables and different hypothetic scenarios.

Variables	BAU	HYB	ENV	CON
Main actors in value chain	Car manufacturers is the main player without big involvement in the infrastructure. Government is a key actor to try to convince automotive consumers on other alternatives more sustainable.	Car manufactures are still important, however electric supply parts begin to increase their impact on vehicles and infrastructures. Government has a similar role as in BAU case.	Battery suppliers and energy providers coupled with innovative technologies. In case of the spread of hydrogen infrastructure fuel cell supplier is a key actor. Gigafactories are expanding all over Europe to support the electric vehicle trend. Government involvement to push people for the transition is playing a major role in the society.	Research and development towards the connected and autonomous are rapidly growing with new technologies. Improvement in the 5G sector is seen throughout the globe and this can help in the advancement of the connected and autonomous cars.
Partnerships	Businesses such as vehicle washes, frequent automobile inspections, supermarkets, and so on. This can open up new options within the same infrastructure and increase profits.	With the PHEV, the user can utilise both the gasoline and electric infrastructure. Thus, the station owners can collaborate with different fuel types of stations and promote their business.	Partnerships with digital payment companies can help them grow their business by directing users to a specific station and allowing them to take advantage of the benefit.	An increase in the demand for infotainment systems and other sensors attached to the car can create opportunities for different manufacturers of similar products to fulfil the demand and to profit.

Variables	BAU	HYB	ENV	CON
Incentives	With the increase in the price of fuel, the government is not showing much interest in providing incentives for fossil fuel-based vehicles and respective infrastructure.	Some concessions are being provided to plug-in hybrid electric vehicles as they contribute to reducing CO_2 emissions to a certain amount. Thus, the electricity infrastructure may gain access to be built in most areas to promote business.	The electric and hydrogen-based vehicles are indeed contributing the most towards the emission. The government may provide approval for the reconstruction of the existing gasoline stations to hydrogen stations and, in some cases, electricity infrastructure with concessions and other benefits.	The government offers incentives for the construction of smart roads and the development of smart cities. Autonomous vehicles with an increased number of shared cars benefit from many concessions from the government.
CO_2 emissions	Emissions will rise unless there is a significant change in the energy industry.	As more hybrid vehicles are deployed, local emissions begin to fall.	As electric and hydrogen infrastructures expand, passenger car emissions and pollutants are drastically decreased.	Connected and autonomous vehicles support in driving in more sustainable ways; for example, a soft brake increases energy efficiency, which is related to emissions. Shared mobility contributes to a reduction in the number of automobiles on the road that means less emissions.

Variables	BAU	HYB	ENV	CON
Congestion	Increased car sales result in a situation in which the market with gasoline infrastructure begins to occupy more spaces to meet user demand, causing congestion.	The traditional gasoline infrastructure may begin to exhibit indications of transition by switching to electric infrastructure. If both the infrastructure increases, there is a risk of a high congestion rate.	Implementation of two distinct infrastructures, one for hydrogen fuelling and the other for electric cars, with the option of replacing the normal gasoline infrastructure in the case of hydrogen. This can encourage the construction of hydrogen stations, which take no extra space for this new infrastructure.	As the need for gasoline and other fuel stations drops, the tendency to use it in the shared mobility sector might assist to minimise traffic congestion. In addition, new infrastructure for dependency is not necessary.
Parking ownership	The existence of private parking is mostly determined by people's preferences.	The greater the number of PHEVs, the greater the demand for private parking to charge the vehicles.	Having a private parking space can contribute to the expansion of the electric infrastructure.	Having private parking is not necessary with the proliferation of connected, shared, and autonomous vehicles which can free up public places.

Variables	BAU	HYB	ENV	CON
Socio-economic	Reduced oil imports and increased employment in transition industries.	Increased employment and specialised expertise in relation to hybrid systems aiding in pollution reduction.	New job opportunities in the energy sector, both in production and distribution. It may even rise as hydrogen infrastructure expands.	The adoption of new digital and revolutionary technology that aid in the decrease of human-caused road accidents has significant economic implications. The influence of technology is crucial in the use of shared mobility.
Energy demand	The demand for fossil fuels is increasing as the number of conventional cars purchased grows. If people do not consider sustainable energy fuels, it is possible that fossil fuels may be fully depleted.	The overall situation is similar to BAU; however, increasing the number of PHEVs lessens reliance on fossil fuels.	Reducing fossil fuel usage will be accelerated if hydrogen and electric infrastructures are widely distributed.	Energy consumptions will be reduced as the number of connected and autonomous cars increases.

Table 3.15: Correlation between variables and scenarios

4. Methodology and results

The methodology used in this chapter to clarify the vision about the future of automotive value chain is Q methodology, also known as Q sorting. It is a distinct set of psychometric and operational principles that, when combined with statistical applications of correlational and factor-analytic techniques, provides researchers with a systematic and rigorously quantitative procedure for examining the subjective components of human behaviour. Subjectivity is defined in the context of Q methodology as a person's transmission of a point of view on any topic of personal or social relevance. The double premise that subjective opinions are communicable and advanced from a position of self-reference is a consequence. One essential premise aimed at preserving self-reference and subjective communicability is that "measurements and observations of a person's subjectivity can only be made by himself" [111]. As a result, subjective communicability is available for objective analysis, provided the analytical tools do not modify or alloy the self-referent qualities with the investigator's external frame of reference in the process. The term methodology highlights the concept that "Q" is first and foremost a technique based on modern science's core principles and mathematics. It is a technique that gives operations that aid in the research of subjectivity. As a result, the technique effectively overcomes the frequently reified, categorical differences assigned to opposing sides of the quantitative and qualitative research split. According to Stephenson's letter to Nature, it is obvious that the Q methodological innovation that spans across disciplinary boundaries is relevant to numerous disciplines ranging from sociology to many social sciences. Q approach, which is mostly an exploratory strategy, was founded on a simple modification of the quantitative technique known as factor analysis. The Q approach was separated from the existing methodology (R), which is based on the correlation of objective features, in which people assume their traditional role as units of analysis rather than variables in the transposed matrix. Anyone with a basic understanding of statistical principles may conduct studies, especially with the software tools available that execute the statistical computations required for data analysis. Familiarity with the basics of factor analysis and its accompanying statistical findings, such as factor loadings and eigenvalues, is required before beginning work on a Q method project or comprehending the research presented by others. Furthermore, Q approach integrates qualitative and quantitative research. Quantitative techniques are frequently criticised by hermeneutical and phenomenological supporters due to their reliance on statistical analysis.

4.1 Methodological principles

Q is an approach for researching human subjectivity. Subjectivity refers to the communication of a personal point of view in the methodology's vocabulary; hence, subjective communicability is a crucial principle guiding the methodology. Subjective communications occur when a person says: "It seems to me…", "In my view…" or "I agree (or disagree) …" Since these are personal beliefs, they are neither right nor incorrect, nor demonstrable nor refutable. They are not testimonials to facts from one's life, but rather depictions of events, things, and people from one's personal experience. The concourse of communication is a key concept in Q technique, and it is analogous to a target population for sample in traditional survey research. Concourse refers to the number of notions about a topic and concourses provide the "raw material" for Q studies by providing "self-referent notions" [112] that enrich the methodology's perspective on subjectivity. Representative items from a concourse are chosen and delivered to participants in the form of a Q sample in a Q-methodological research. After the Q sample is produced, it is delivered to individuals functioning as participants in a study. Respondents are asked to use these items to represent their thoughts in a modified rank-ordering technique that results in a Q sort. The NQ sorts are correlated one with another, yielding an N×N correlation matrix, which is then subjected to factor analysis to discover the range and type of really independent perspectives that are embedded and frequently difficult to differentiate in the enormous contours of the concourse. In essence, Q methodology provides a systematic way to investigate human subjectivity. Q-methodological research are normally carried out in the following order:

- Step 1: A sample of an issue domain (concourse of communication) is selected (Q sample).
- Step 2: Participants in the research are chosen. Participant samples, also known as person samples or P-sets, can be created in a variety of ways.
- Step 3: Participants express their subjectivity by modelling their points of view using the operational medium of a Q sort. This "modelling" is performed by ranking the Q sample stimuli based on a condition of instruction (describing an object, person, or event, typically by sorting items from those "most characteristic" to "most uncharacteristic" of a point of view).
- Step 4: Q sort data analysis entails intercorrelating the NQ sorts as variables and factor analysing the N×N correlation matrix using Stephenson's original formulation. The resulting factors are subjective operants, and the magnitude of the factor loadings indicates a participant's relationship with these subjective states. Factor scores are then calculated for each Q sample item for each of the factors, yielding a condensed set of "composite Q sorts" that distil

the fundamentally varied ideas implied in the wider concourse using a mix of statistical and pragmatic approaches. The latter, known as factor arrays in Q work, thus play an important role in factor interpretation: first, as previously stated, each factor array constitutes a composite Q sort and thus is a generalisation of a subjective viewpoint; and second, these scores allow statistical means to be used to assess the significance of different statement locations within different factor arrays.

- Step 5: Finally, factor interpretation, or the task of distilling the core meanings revealed by the aforementioned technical means, is accomplished in terms of consensual and divergent subjectivity, with a special emphasis on Lasswell's succinct expression of the contextuality principle: "The meaning of any detail depends on its relation to the whole context of which it is a part". Rather than focusing on the placement of individual statements, an effort is made to investigate the patterns of meaning within the larger contextual constellation provided by a given factor array, with emphasis on the applicability of such patterns to existing or new theories and propositions.

4.2 Q samples and Q sorting

Beginning with communication concourses, the Q method serves as a basis for scientific research. What Q identifies as concourses may be demonstrated to have shape and structure, and hence context-specific meaning, when exposed to Q-sorting processes and suitable statistical analysis. Concourses emerge from shared understandings, even if the precise content is not normative for everyone; meanings can change even for a single individual depending on the unique situation of subjective communicability. Due of the infinite volume of a concourse, practicality requires a limitation in size for research purposes. As a result, a Q sample is taken from the broader concourse, and its items are rank ordered using the Q sort mechanism. Q technique is based on two forms of sampling:

1) items sampled from concourses that form a Q sample.
2) samples of persons who do Q sorting (person sample or P-set).

Q methodology, of the two, stresses the statement domain (Q sort items), represented by N, rather than the number of participants (or the number of Q sorts), represented by n. Q samples, as models of communication settings, do not cover all communication options. A Q sample is intended to provide a thorough yet manageable picture of the concourse from which it was drawn. There are two methods for sampling goods. The first is unstructured sampling, in which objects are chosen without regard for specific experimental design principles in order to assure comprehensive coverage. An unstructured sample, particularly for concourses where theory is lacking or undeveloped, may give a suitably representative number of statements from which to proceed, but it carries the danger of under- or oversampling some perspectives. Structured samples, on the other hand, are systematically created and given a suitably extensive and theoretically detailed experimental design, are less likely to raise the concerns about representativeness that unstructured samples do. This application may be deductive or inductive in nature. A priori hypothetical or theoretical ideas support a deductive design. This application may be deductive or inductive in nature. A priori speculative or theoretical ideas underpin a deductive design. Patterns occur when statements are gathered, and inductive designs form. In addition, both kinds might have basic or complicated design dimensions. Q sorting is a process in which a person models self-reference by spreading Q sample stimuli along a continuum defined by an instruction condition. Subjectivity becomes operant when objects are sorted. Q sorting is a synthesis activity as well. The sorter creates functional links among the Q sample components while deciding on item ranks. No item is assessed in isolation. Its position is contextual, meaning it interprets and is understood by others. Unlike R-methodological scaling, which intentionally maintains the independence of scale items and test results, scores given Q sample items are unavoidably dependent on comparisons of one with another, indicating the synthetic character of the Q sort distribution. The placement of O sample item X at one end of the O sort distribution (+5) affects the opposite meaning of Q sample item Y at the other end of the distribution (-5), a dynamic that is ostensibly and normatively banned in standard R-methodological measurement. Items in a Q sample are rank ordered according to an instruction condition that acts as a guide for the sorting process. Many are simple inquiries for agreement or disagreement. Q sorting can be more labour-intensive than other data-gathering approaches, and if too many sorting are tried in a short amount of time, a participant may become less attention to the procedure [113].

Step	*Procedures*
1. Familiarity with Q sample items	The participant reads the Q sample items to become familiar with their content. As this is accomplished, the items are classified into three different piles: Those with which the participant agrees are on the right, those with which he or she disagrees are on the left, and those in the centre are neutral, ambivalent, or uncertain.

Step	*Procedures*
2. Dispersion of items	The items are distributed in the usual left (negative) – centre (neutral) – right (positive) order. This first sorting expedites contextual reading of the elements and facilitates in comparisons.
3. Selection of strong agreement items	Examining the items to the right, two items are chosen that are most strongly agreed with (or the number of items necessary) and placed in the column under the +5 marker. The order is irrelevant; for example, those put beneath the +5 marker are scored the same.
4. Selection of strong disagreement items	Turning to the left, the two most strongly disagreed with items (or the number specified) are chosen and placed under the -5 marker.
5. Continuation of item selection	Respondent repeats the selection procedure, working from the positive and negative ends of the Q sort continuum toward the centre (0).
6. Recording the Q sort distribution	The finished Q sort item scores are recorded on a score sheet that replicates the Q sort distribution. Questions written below the distribution of scores might be used to collect additional demographic or other information.
7. Post sorting interviews	The advantage of having Q sorts done in the researcher's presence is that respondents may be interrogated in post sort interviews for information useful to understanding and interpreting findings. Interview

Step	*Procedures*
	approaches differ; one good method is to encourage participants to elaborate on the meanings of and motivations for allocating things, particularly those at the extreme ends of the spectrum.

Table 4.1: Steps in the Q-Sorting Process (readapted from Q methodology Bruce McKeown Dan B. Thomas)

The nature of the study determines the range of a distribution and the number of items under each marker. According to Brown, Q samples less than N = 40 can safely use a range of +4 to -4; from 40 to 60, a range of +5 to -5 is commonly used; and most Q samples include 40 to 50 items and use a range of +5 to -5 with a quasi-normal flattened distribution. The nature of the subject being investigated may also influence the number of items placed under each marker. A flatter distribution, which allows for more items at the extremes, can help with contentious situations associated with strong beliefs and emotions. Less controversial issues may benefit from a distribution that is similar to an inverted normal curve. Even though a person sample of 25 to 50 participants is often considered adequate for such purposes, studies trying to assess the nature and range of points of view on a given topic are substantial by Q's standards [114]. As a result, the nature and goal of the study determine whether it is little or large, intensive, or extensive. The selection of large person samples is frequently influenced by pragmatic concerns such as who is accessible. Since the goal is to explore attitudes in a population, a task obviously preceding ascertaining the numerical incidence and demographic correlates of such opinions, no special effort is made to ensure complete representativeness across respondent characteristics (age, party identification, religion, etc.). Simultaneously, every effort is taken to guarantee as much variability in the composition of the P-set as is practical given the circumstances [115]. Given the non-random character of the person sample, no claim is made that the opinions represent the whole spectrum of attitudes on a given issue. If one suspects that alternative points of view exist, expanding the person sample net is an easy way to find them. Nothing prevents new respondents from being added to the pool. Nonetheless, as Brown points out [116], the variables that emerge are generalisations of views held by those who define the elements. As a result, they allow for direct comparisons of attitudes as attitudes, regardless of the number of people that fill them.

4.3 Q set

The Q set is the selection of statements of crucial importance to answer to the research question. It is constituted 50 statements touching all the infrastructure trends considered. The statements are divided in three main block of variables: input, contextual and output. Input variables refer to economic input, which can either be seen as subsidies from the government to fund a particular infrastructure or private investments from private investors who see as an entrepreneurial opportunity, location to understand where to install a particular infrastructure and timing. Contextual variables define the context in which input leads to output, such as partnerships between infrastructure providers, innovation environment and market change given by supply of infrastructure and demand for it. Output variables are oriented on the Triple Bottom Line Vision [117] and they are economic, environmental, and social output from infrastructure implementation. The table below lists the statements dividing them in those three main groups.

No.	Statement
	GROUP 1: Input variables
1	Private investors should invest in 5G telecommunication infrastructure in this decade (2022-2030).
2	Private investors should invest in smart road infrastructure in this decade (2022-2030).
3	Private investors should invest in e-autos for car sharing.
4	Government should fund the development of charging infrastructure.
5	Government should fund the development of hydrogen infrastructure.
6	Government should fund the spread of the 5G telecommunication infrastructure.
7	Government should provide incentives to electric car shared infrastructure, e.g., charging stations for e-autos.
8	Having a private parking place might help to expand the electric infrastructure.

No.	Statement
9	Having a private parking space is necessary for autonomous vehicles.
10	Hydrogen fuelling infrastructure should be developed more on highways.
11	5G telecommunication infrastructure should be developed only on highways.
12	Cities are the best places to develop the infrastructure related to autonomous cars.
13	Cities are the best places to develop e-autos for car sharing.
14	The availability and distribution of charging stations across Europe will be balanced before 2035.
15	Hydrogen fuelling stations will be installed across Italy by 2050.
16	5G telecommunication infrastructure will be ready to connect most of the car in this decade (2022-2030).
17	Smart roads and smart cities for autonomous vehicles will be ready before 2035.
18	Before 2035, FCEVs will become an eco-efficient option for car sharing services, pushing the growth of hydrogen fuelling stations within the cities.
19	Between 2030 and 2040, hydrogen fuelling stations will compete with electric charging infrastructure.
20	New hydrogen stations will be deployed only on the highways before 2035.
21	E-autos for car sharing will be autonomous between 2035 and 2050.
	GROUP 2: Contextual variables
22	Gigafactories help Europe to accelerate the growth of electric charging infrastructure.
23	Hydrogen fuelling stations should cooperate with electric charging stations for the faster development of each infrastructure.

No.	Statement
24	Partnerships with payment operators benefit the development of e-autos for car sharing.
25	Dynamic charging reduces the driver's concern about range.
26	The transition from gasoline infrastructure to electric and hydrogen infrastructures will be slowed down by the adoption of hybrid vehicles.
27	Autonomous vehicles require a lot of power, thus collaborating with fuel cell technology is the ideal solution that helps in the growth of hydrogen fuelling infrastructure.
28	The development of battery swapping could increase the usage of e-autos for car sharing.
29	If electricity prices rise, people may prefer FCEVs, thus the number of H2 fuelling stations will increase.
30	The increase of e-autos for car sharing decreases the cost of travel per km (€/km) within the cities.
31	The availability of hydrogen infrastructure across Europe is sufficient to meet consumer demand.
32	The availability of 5G telecommunication infrastructure increases the users' willingness to pay for connected cars.
33	The availability of smart roads and smart cities increases the users' willingness to pay for autonomous cars.
	GROUP 3: Output variables
34	Investing in charging infrastructure in this decade (2022-2030) generates positive ROA to the automotive value chain actors who contributed to its development.
35	Investing in H2 fuelling stations in the next decade (2030 - 2040) generates positive ROA to the automotive value chain actors who contributed to its development.

No.	Statement
36	The spread of 5G telecommunication infrastructure generates a positive ROA to the automotive value chain actors who contributed to its development.
37	The creation of smart roads and smart cities generates a positive ROA to the automotive value chain actors who contributed to its development.
38	Investing in e-autos for car sharing in the cities and related infrastructure (e.g., charging stations, parking stations) generates a positive ROA to the automotive value chain actors who contributed in its development.
39	The growth of highway charging infrastructure produces a good return on investment for the automotive value chain actors involved in its development.
40	Highways are the best place to develop the H2 fuelling stations. They generate a good return on investment for the automotive value chain actors who contributed to its development.
41	Increasing the number of electric vehicles increases the number of charging stations, so it contributes to the reduction of CO2 emissions.
42	Increasing the number of FCEVs increases the number of H2 fuelling stations, so it contributes to the reduction of CO2 emissions.
43	The growth of 5G infrastructure increases the spread of connected cars that contributes to the reduction of CO2 emissions.
44	The development of smart roads and smart cities contributes to the reduction of CO2 emissions.
45	The increase of e-autos and related infrastructure for car sharing contributes to the reduction of CO2 emissions.
46	Charging stations are perceived unsafe by the users.
47	Hydrogen fuelling stations should be far from cities since they are perceived as dangerous.
48	5G telecommunication infrastructure will enhance road safety.

No.	Statement
49	The vast volume of personal data collected and shared by smart road and smart cities poses significant privacy problems.
50	Data privacy is a significant problem in car sharing services.

Table 4.2: Statements used in the expert interviews

4.4 P-set

This phase entails selecting the Q participants. This group of people is known as the P-set. The participants in Q are not chosen at random; rather, they are purposely chosen to be as diverse as possible. Q methodology often entails "a structured sample of respondents who are theoretically relevant to the problem under consideration; for instance, persons who are expected to have a clear and distinct viewpoint regarding the problem" [118]. In this analysis, experts are classified according to their position in the automotive value chain.

Id	Group	Id	Group
1	Other	14	Finance and insurance
2	Integrators	15	Vertical solutions
3	Vertical solutions	16	Finance and insurance
4	Vertical solutions	17	Vertical solutions
5	Other	18	Integrators
6	Universities / consulting	19	Finance and insurance
7	Universities / consulting	20	Vertical solutions
8	Start-up	21	Car manufacturer
9	Finance and insurance	22	Vertical solutions
10	Vertical solutions	23	Infrastructure mobility

Id	Group	Id	Group
11	Integrators	24	Infrastructure mobility
12	Infrastructure mobility	25	Infrastructure mobility
13	Integrators		

Table 4.3: P-set

After the P-set was constructed, participants were instructed to sort the statements by rank, with their responses ranging from 11 (completely agree) to 1 (strongly disagree). This Q-sorting is characterised by a quasi-normal forced distribution, in which only a restricted number of items may be placed in each column. The software used to collect the data was Q-tip [119].

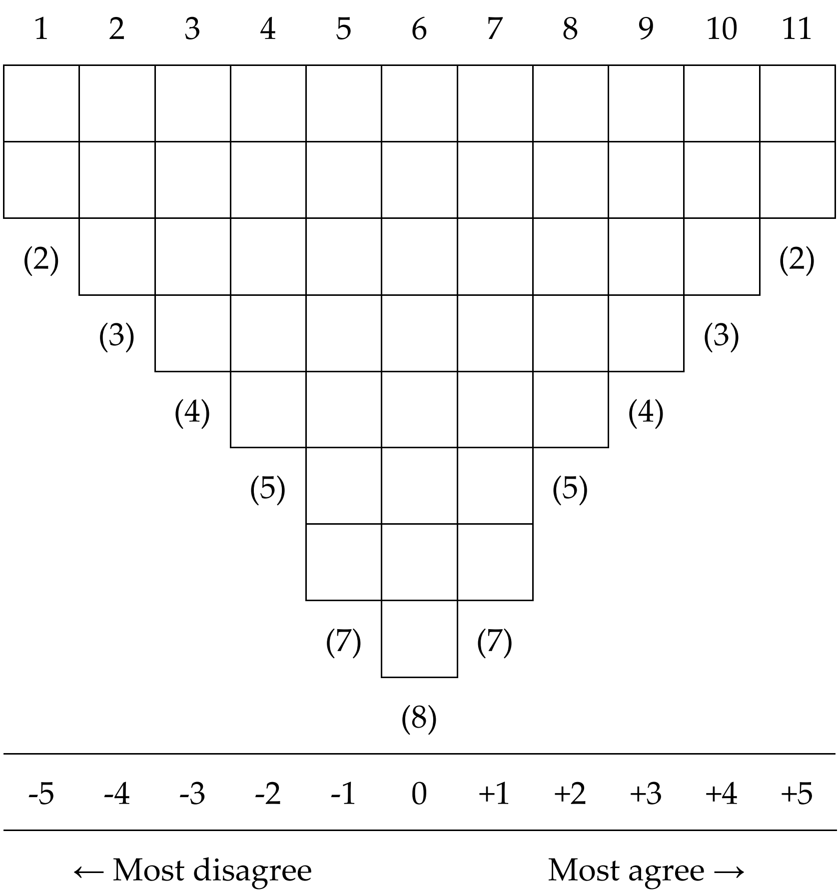

Figure 4.1: Fixed quasi-normal distribution

4.5 Results

After the completion of the Q-sorting procedure, different statistical analyses were performed. In Q methodology, data analysis entails the sequential use of three sets of statistical procedures: correlation, factor analysis or PCA, factors score computation.

4.5.1 Correlation matrix

The correlation matrix is a table that displays the correlation coefficients between variables, and it is employed to summarise data. The method used to measure the correlation between two variables is **Pearson product-moment correlation coefficient** (or Pearson correlation coefficient). The correlation coefficient, is a measure of the strength of the linear relationship between two variables and. It is calculated as follows:

$$r = \frac{Cov(x, y)}{\sigma_x \sigma_y} \tag{4.1}$$

With σ_x and σ_y are the standard deviations and they are calculated as:

$$\sigma_x = \sum (x - \bar{x})^2 \tag{4.2}$$

$$\sigma_y = \sum (y - \bar{y})^2 \tag{4.3}$$

The correlation varies from -1 to 1. A number close to or equal to 0 indicates that there is little or no linear connection between two variables. The closer it gets to 1 or -1, the stronger the linear connection. In the analysis the correlations are expressed in percentage and most of the participants have a positive correlation among them with some exceptions with slightly negative values.

	Group	Other	Integrators	Vertical solutions	Vertical solutions	Other	Universities / Consulting	Universities / Consulting	Startup	Finance and Insurance	Vertical solutions	Integrators	Infrastructure mobility	Integrators	Finance and Insurance	Vertical solutions	Finance and Insurance	Vertical solutions	Integrators	Finance and Insurance	Vertical solutions	Car manufactur	Vertical solutions	Infrastructure mobility	Infrastructure mobility	Infrastructure mobility
Group	**Participant**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Other	**1**	100	35	46	12	12	10	20	-11	20	37	30	26	-14	35	39	47	55	30	29	23	29	36	-2	41	14
Integrators	**2**	35	100	65	28	8	34	32	30	28	38	18	49	9	18	37	55	32	35	13	30	23	58	4	29	41
Vertical solutions	**3**	46	65	100	28	27	17	29	13	4	52	49	42	16	33	59	47	35	54	45	41	29	60	6	48	45
Vertical solutions	**4**	12	28	28	100	8	30	29	33	11	44	20	17	2	23	9	30	33	29	9	39	18	43	17	19	8
Other	**5**	12	8	27	8	100	2	39	-9	1	31	27	19	7	28	11	14	19	-1	25	33	25	20	22	37	28
Universities / Consulting	**6**	10	34	17	30	2	100	28	57	63	10	-20	26	-24	7	37	0	22	7	17	30	14	53	18	32	6
Universities / Consulting	**7**	20	32	29	29	39	28	100	31	17	41	13	39	0	46	26	30	35	-7	23	38	28	23	12	36	17
Startup	**8**	-11	30	13	33	-9	57	31	100	46	22	-11	47	-18	21	15	21	23	4	-2	27	26	33	9	20	21
Finance and Insurance	**9**	20	28	4	11	1	63	17	46	100	11	7	38	-40	18	3	17	46	-7	9	30	29	38	14	37	11
Vertical solutions	**10**	37	38	52	44	31	10	41	22	11	100	57	46	18	42	33	56	45	53	40	56	31	58	16	40	29
Integrators	**11**	30	18	49	20	27	-20	13	-11	7	57	100	25	9	26	19	42	35	43	34	22	41	36	15	28	25
Infrastructure mobility	**12**	26	49	42	17	19	26	39	47	38	46	25	100	-9	26	26	49	45	16	23	31	39	46	18	46	50
Integrators	**13**	-14	9	16	2	7	-24	0	-18	-40	18	9	-9	100	-7	13	15	-20	27	16	7	-2	-8	-5	-17	1
Finance and Insurance	**14**	35	18	33	23	28	7	46	21	18	42	26	26	-7	100	31	33	44	29	14	41	26	33	19	34	20
Vertical solutions	**15**	39	37	59	9	11	37	26	15	3	33	19	26	13	31	100	24	29	42	18	27	23	39	16	28	34
Finance and Insurance	**16**	47	55	47	30	14	0	30	21	17	56	42	49	15	33	24	100	53	30	12	37	27	54	-5	41	31
Vertical solutions	**17**	55	32	35	33	19	22	35	23	46	45	35	45	-20	44	29	53	100	19	16	48	37	44	6	59	32
Integrators	**18**	30	35	54	29	-1	7	-7	4	-7	53	43	16	27	29	42	30	19	100	26	7	0	44	21	19	12
Finance and Insurance	**19**	29	13	45	9	25	17	23	-2	9	40	34	23	16	14	18	12	16	26	100	42	22	39	-16	26	25
Vertical solutions	**20**	23	30	41	39	33	30	38	27	30	56	22	31	7	41	27	37	48	7	42	100	38	53	-3	36	35
Car manufacturer	**21**	29	23	29	18	25	14	28	26	29	31	41	39	-2	26	23	27	37	0	22	38	100	30	14	38	35
Vertical solutions	**22**	36	58	60	43	20	53	23	33	38	58	36	46	-8	33	39	54	44	44	39	53	30	100	24	57	41
Infrastructure mobility	**23**	-2	4	6	17	22	18	12	9	14	16	15	18	-5	19	16	-5	6	21	-16	-3	14	24	100	16	24
Infrastructure mobility	**24**	41	29	48	19	37	32	36	20	37	40	28	46	-17	34	28	41	59	19	26	36	38	57	16	100	47
Infrastructure mobility	**25**	14	41	45	8	28	6	17	21	11	29	25	50	1	20	34	31	32	12	25	35	35	41	24	47	100

Table 4.4: Correlation matrix

4.5.2 Factor extraction

The summation of the squared discrepancies between the identified and recreated correlation matrices is minimized in this factor extraction approach. Principal components analysis is considered suitable as a data lessening approach for condensing a bigger range of measurements into a fewer, relatively tolerable level of composite variables that can be used in future work. A recipient's rating on a principal component can be calculated using PCA. Eigenvalues are also known as characteristic roots. Eigenvalues reflect the percentage of variation explained by a certain component out of the overall variance.

Nm	Participant	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
1	1	0.553	-0.1705	-0.1044	-0.5917	-0.017	0.0456	-0.2171	0.2327
2	2	0.6483	0.0209	0.3918	-0.0775	-0.0378	-0.2096	0.28	0.1673
3	3	0.7498	-0.3438	0.2158	-0.0356	0.0452	-0.2426	-0.07	0.0785
4	4	0.4656	0.0825	0.2274	0.2697	-0.233	0.5098	0.0051	-0.1373
5	5	0.373	-0.167	-0.54	0.394	0.1456	-0.0937	-0.1725	0.0661
6	6	0.4152	0.6639	0.3618	0.1259	-0.0288	-0.1228	-0.386	-0.0075
7	7	0.5307	0.1561	-0.2822	0.3525	-0.2009	0.0696	-0.0025	0.4458
8	8	0.3986	0.6168	0.2743	0.2479	-0.1187	0.0421	0.2605	-0.0112
9	9	0.4155	0.6867	-0.0429	-0.2307	0.0031	0.0168	-0.0909	-0.234
10	10	0.7526	-0.2873	0.0133	0.1477	-0.14	0.2585	0.0315	-0.1363
11	11	0.5191	-0.4757	-0.1988	-0.113	0.1297	0.1941	0.0617	-0.3941
12	12	0.669	0.2033	-0.0316	0.0018	0.0992	-0.1858	0.3992	-0.0326
13	13	-0.0084	-0.6002	0.2279	0.4123	-0.1915	-0.1218	0.1582	0.0686
14	14	0.5514	-0.0314	-0.2329	0.0524	0.0336	0.3638	-0.1373	0.3722
15	15	0.5422	-0.1444	0.3056	-0.0046	0.2235	-0.224	-0.2619	0.4108
16	16	0.6707	-0.1815	0.0312	-0.2396	-0.1873	0.1326	0.4479	0.0883
17	17	0.6981	0.1502	-0.2462	-0.3437	-0.0677	0.2068	0.0374	0.0673
18	18	0.4567	-0.4689	0.5245	-0.074	0.1919	0.238	-0.1574	-0.0986
19	19	0.4444	-0.2643	-0.0932	0.078	-0.3324	-0.3698	-0.4162	-0.3259
20	20	0.6524	0.0613	-0.1757	0.2364	-0.3954	-0.033	-0.1276	-0.0753
21	21	0.5295	0.0788	-0.3399	0.0435	0.0617	-0.1078	0.1486	-0.1906
22	22	0.803	0.0797	0.2516	-0.0153	0.0394	-0.0187	-0.1276	-0.2277
23	23	0.2169	0.1072	0.0238	0.3383	0.762	0.2985	-0.0658	-0.0677
24	24	0.6908	0.1318	-0.2493	-0.1392	0.1814	-0.1162	-0.0878	-0.0255
25	25	0.5505	-0.0384	-0.1146	0.1277	0.3363	-0.4346	0.2853	-0.0691

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Eigenvalues	7.8325	2.6237	1.713	1.4427	1.344	1.2904	1.21	1.0842
% explained variance	31	10	7	6	5	5	5	4
cumulative % explained variance	31	41	48	54	59	64	69	73

Table 4.5: Unrotated factor matrix and factor characteristics

The table shows that factor 1 has the largest eigenvalue of 7.8325, and it decreases when more factors are added. When it comes to percentage of variance explained, factor 1 has roughly 31% and is at the top of the list when compared to other factors. For a factor to be kept, certain conditions must be satisfied. First, the Kaiser (K1) criterion must be met, which states that eigenvalues must be bigger than 1 in order for factors to be preserved [120]. Second, a Scree test should be performed to look for breaks or discontinuities [121]. This test should demonstrate that a few significant factors account for the majority of the explained variation, which is above 50% [122] and is regarded as satisfactory.

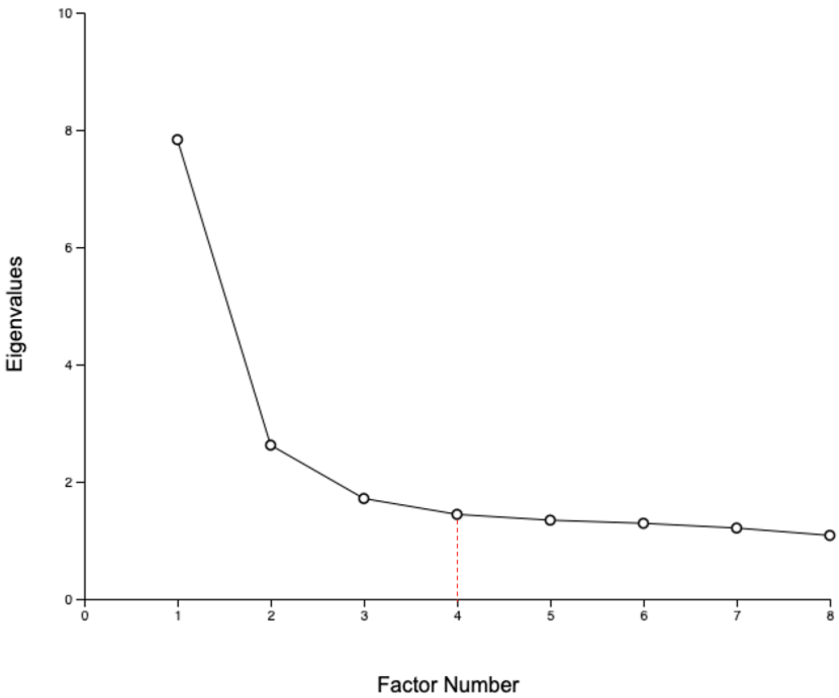

Figure 4.2: Scree plot

4.5.3 Factor rotation

Factor loading matrices are not unique; there are an endless number of orientations of the factors that describe the original data as well for each solution involving two or more factors. The factor loading matrices are rotated in an attempt to find the solution with the best simple structure. Rotation can be classified into two types:

- Orthogonal rotations (**Varimax**) make the factors uncorrelated. Although typically preferred, it is impossible to expect the elements to be uncorrelated in many circumstances and requiring them to be uncorrelated reduces the likelihood that the rotation provides a solution with a simple structure. It provides few factor loadings far from zero and several factor loadings close to zero reduction.
- Oblique rotations (**Promax / Judgmental**) allow the components to be connected with one another.

The varimax rotation is performed in the analysis, and it can be seen that the explained variance differs for each factor considered.

4.5.4 Factor loadings

Factor loading is the correlation coefficient between the variable and the factor. The variation explained by the variable on that particular factor is shown by factor loading. The factors that have the greatest impact on the statement and so have the highest factor loadings. Factor loadings, like correlation coefficients, can range between -1 and 1. The closer factors are to -1 or 1, the greater their influence on the variable. A factor loading of 0 indicates that there is no influence.

Group	Participant	Factor 1	Factor 2	Factor 3	Factor 4
Integrators	13	**-0.6786**	-0.1491	0.3031	0.0879
Finance and Insurance	9	**0.6608**	0.5021	-0.0202	0.1005
Vertical solutions	17	**0.6288**	0.0682	0.3549	0.4034
Other	1	**0.5657**	-0.2462	0.5428	0.1438
Universities / Consulting	6	0.2618	**0.8241**	0.1104	-0.0069
Startup	8	0.1678	**0.7970**	0.0492	0.1013
Vertical solutions	4	-0.0797	**0.4258**	0.3248	0.2342
Infrastructure mobility	23	-0.1375	**0.3001**	0.0263	0.2529
Integrators	18	-0.1889	0.0212	**0.8173**	-0.0696
Vertical solutions	3	0.0305	0.0773	**0.7896**	0.3128
Integrators	2	0.1589	0.3677	**0.6428**	0.0812
Vertical solutions	22	0.2329	0.4205	**0.6332**	0.2876
Vertical solutions	10	-0.0172	0.1031	**0.6186**	0.5266
Finance and Insurance	16	0.2939	-0.0043	**0.6126**	0.2819
Vertical solutions	15	0.0136	0.2078	**0.5907**	0.1258
Integrators	11	0.0726	-0.3136	**0.5074**	0.4324
Other	5	-0.0979	-0.0816	-0.0327	**0.7723**
Universities / Consulting	7	0.0679	0.2993	0.0566	**0.6422**
Vertical solutions	20	0.1146	0.2700	0.2657	**0.5996**
Car manufacturer	21	0.2774	0.0857	0.1372	**0.5485**
Finance and Insurance	14	0.1909	0.0674	0.2573	**0.5048**
Infrastructure mobility	24	0.4651	0.1385	0.3090	**0.4951**
Infrastructure mobility	25	0.0955	0.1487	0.3019	**0.4600**
Infrastructure mobility	12	0.3234	0.3428	0.3361	**0.3936**
Finance and Insurance	19	-0.0203	-0.0569	0.3625	**0.3835**
Explained variance (%)		10	11	19	15
No. of Defining Variables		4	4	8	9
Avg. Rel. Coef.		0.8	0.8	0.8	0.8
Composite Reliability		0.941	0.941	0.97	0.973
S.E. of Factor Z-scores		0.243	0.243	0.173	0.164

Table 4.6: Rotated matrix

4.5.5 Outputs and interpretations

The goal of interpreting the Q methodology results was to discover the similarities and contrasts between the four mindsets, as well as the features in their component makeup. For each factor, distinguishing statements were discovered and studied. These were the statements with the highest z-scores in a specific factor when compared to the other factors. Finally, consensus statements (similar z-scores among components) provided a crucial information about which themes were agreed upon by all experts. Furthermore, the post-surveys, in which participants were asked to determine the motivations behind their rankings and to add some comments, were useful to have a clearer vision. A composite or "idealised" Q-sort for each of the four factors is computed based on the standardised z-scores of each statement, which are similar across all variables. We turned them into the following mindsets after a thorough investigation of the factors: "socially oriented", "safety concerned", "development enthusiast", and "electro smart". In the table below, the largest connections occur between development enthusiast and electro smart (0.5246), as well as between socially oriented and safety concerned (0.4316). Socially oriented and development enthusiast have the lowest correlation (0.2628). In the Appendix A, a more extensive investigation of the associations between components is presented.

	Factor 1 (socially oriented)	**Factor 2 (safety concerned)**	**Factor 3 (development enthusiast)**	**Factor 4 (electro smart)**
Factor 1 (socially oriented)	1	0.4316	0.2628	0.3834
Factor 2 (safety concerned)	0.4316	1	0.2892	0.3146
Factor 3 (development enthusiast)	0.2628	0.2892	1	0.5246
Factor 4 (electro smart)	0.3834	0.3146	0.5246	1

Table 4.7: Correlations among factors

4.5.5.1 Factor 1: socially oriented

The experts here want to encourage the government and society to construct infrastructure for all of the alternatives that were considered, so that they can adapt to any type of alternate vehicle if the infrastructure for that specific vehicle is enhanced in the future. Furthermore, these experts feel that investing in charging infrastructure in this decade could not yield a high return on assets, and with that of smart roads and smart cities, they feel it would not improve customer willingness to spend additional money for the purchase of autonomous cars.

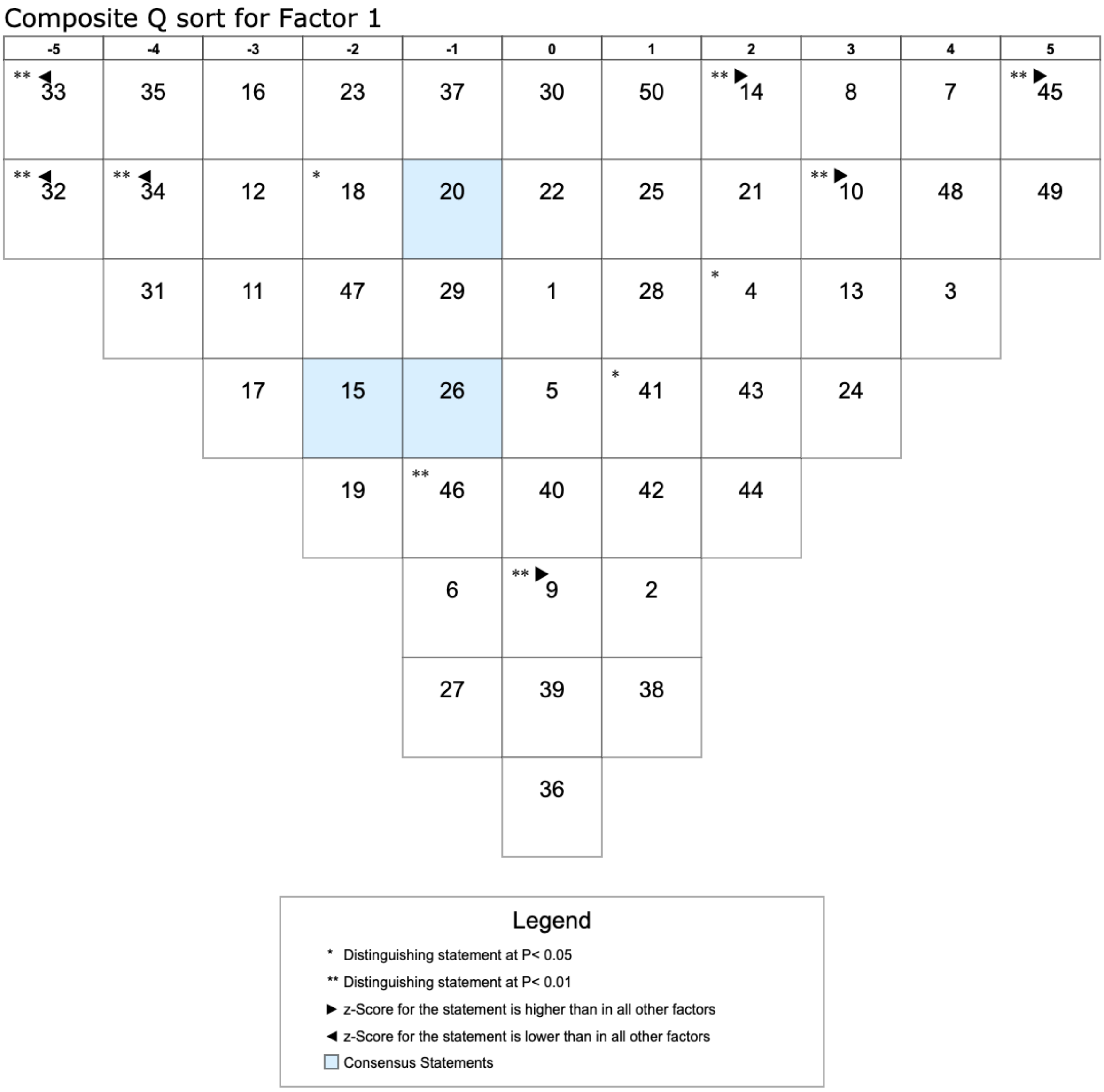

Figure 4.3: Composite Q sort for Factor 1 (socially oriented)

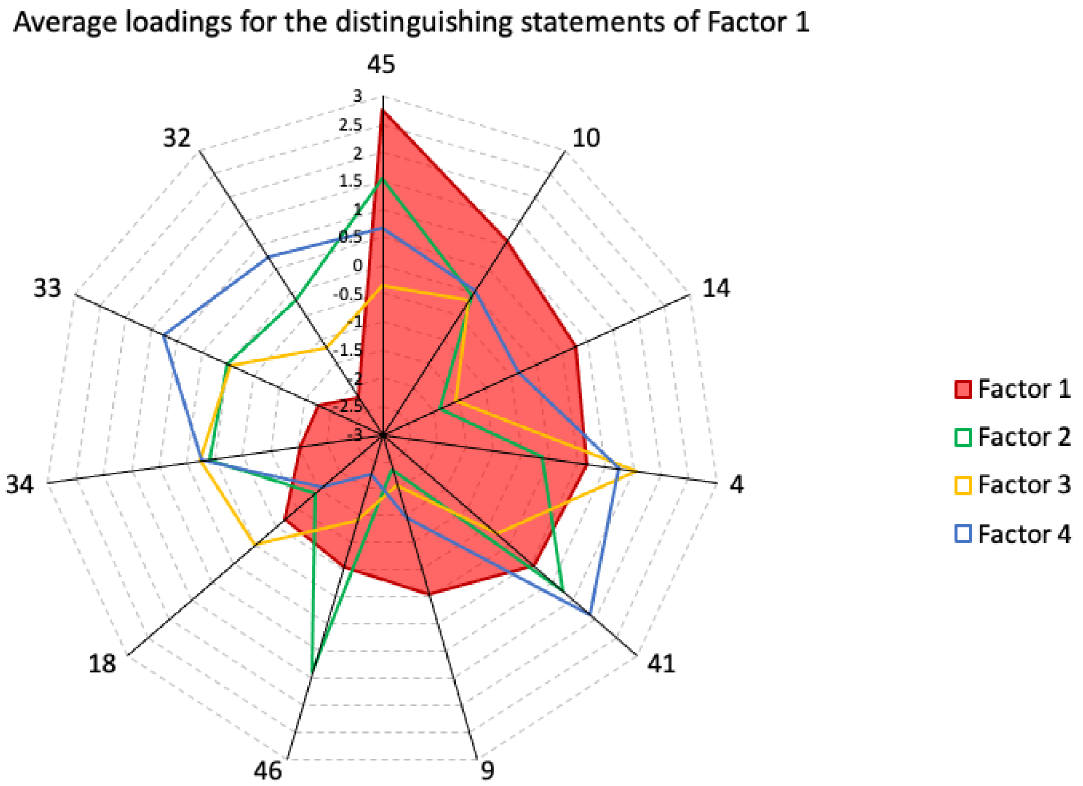

Figure 4.4: Average loadings for the distinguish statements of Factor 1

No.	Statement	Q-Value	Z-Score	Threshold
45	The increase of e-autos and related infrastructure for car sharing contributes to the reduction of CO2 emissions.	5	2.77	P<0.01
10	Hydrogen fuelling infrastructure should be developed more on highways.	3	1.07	P<0.01
14	The availability and distribution of charging stations across Europe will be balanced before 2035.	2	0.77	P<0.01
4	Government should fund the development of charging infrastructure.	2	0.67	P<0.05
41	Increasing the number of electric vehicles increases the number of charging stations, so it contributes to the reduction of CO2 emissions.	1	0.55	P<0.05
9	Having a private parking space is necessary for autonomous vehicles.	0	-0.06	P<0.01
46	Charging stations are perceived unsafe by the users.	-1	-0.56	P<0.01
18	Before 2035, FCEVs will become an eco-efficient option for car sharing services, pushing the growth of hydrogen fuelling stations within the cities.	-2	-0.7	P<0.05
34	Investing in charging infrastructure in this decade (2022-2030) generates positive ROA to the automotive value chain actors who contributed in its development.	-4	-1.55	P<0.01
33	The availability of smart roads and smart cities increases the users' willingness to pay for autonomous cars.	-5	-1.76	P<0.01
32	The availability of 5G telecommunication infrastructure increases the users' willingness to pay for connected cars.	-5	-2.21	P<0.01

Table 4.8: Distinguish statements of Factor 1

4.5.5.2 Factor 2: safety concerned

When it comes to safety, everyone in this world is mostly concerned about it. In this way, experts in various fields are more concerned about these factors. They are mainly focused on the infrastructure and its development with proper care in such a way that it does not harm any individual. It can be seen that they are focused on the emission of CO_2 and also suggest that the infrastructure for both electric vehicles and fuel cell electric vehicles is perceived to be unsafe. It is to be noted that this particular group does not think that cities are the best places for the development of autonomous car infrastructure, and they also think that a private place may not promote the growth of electric infrastructure.

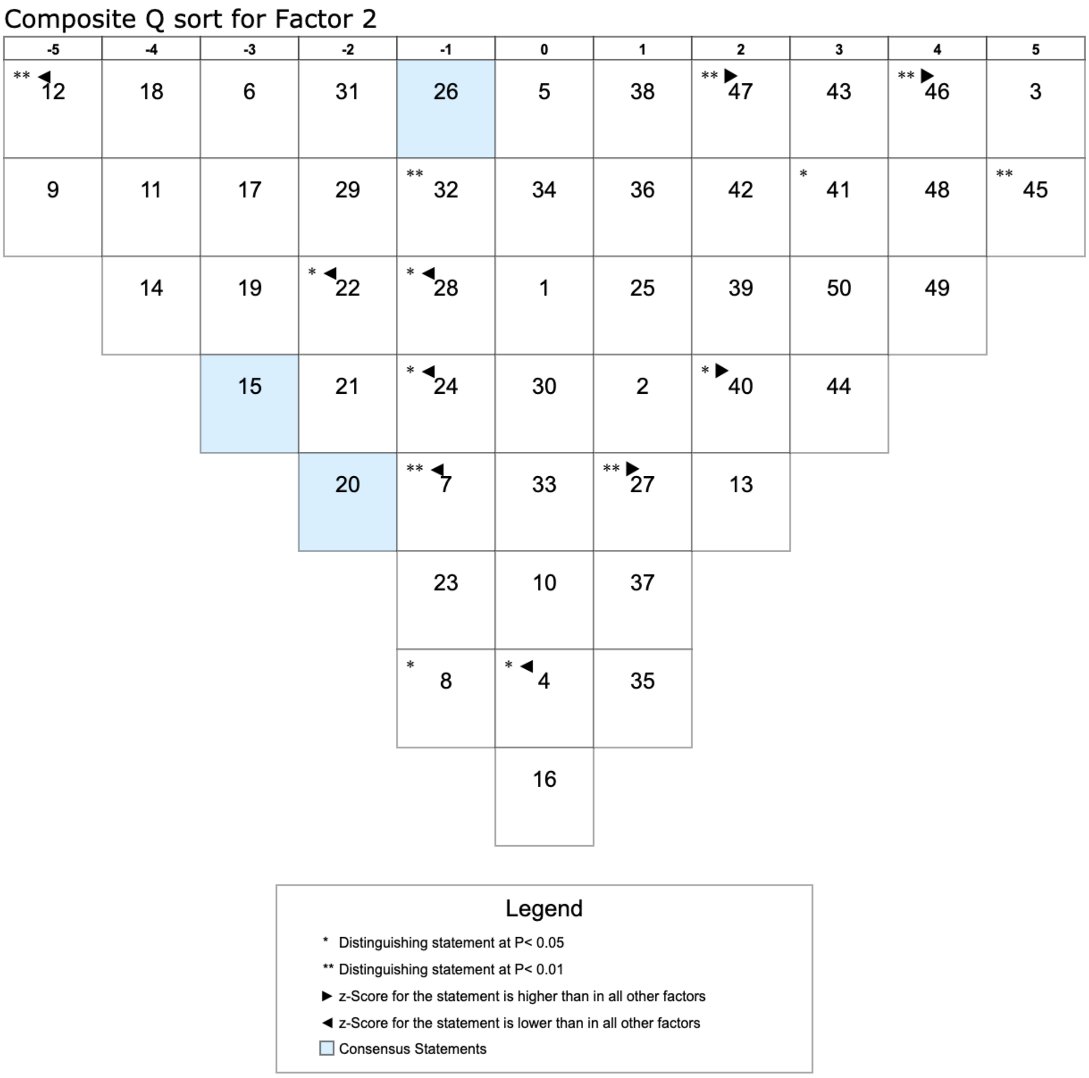

Figure 4.5: Composite Q sort for Factor 2 (safety concerned)

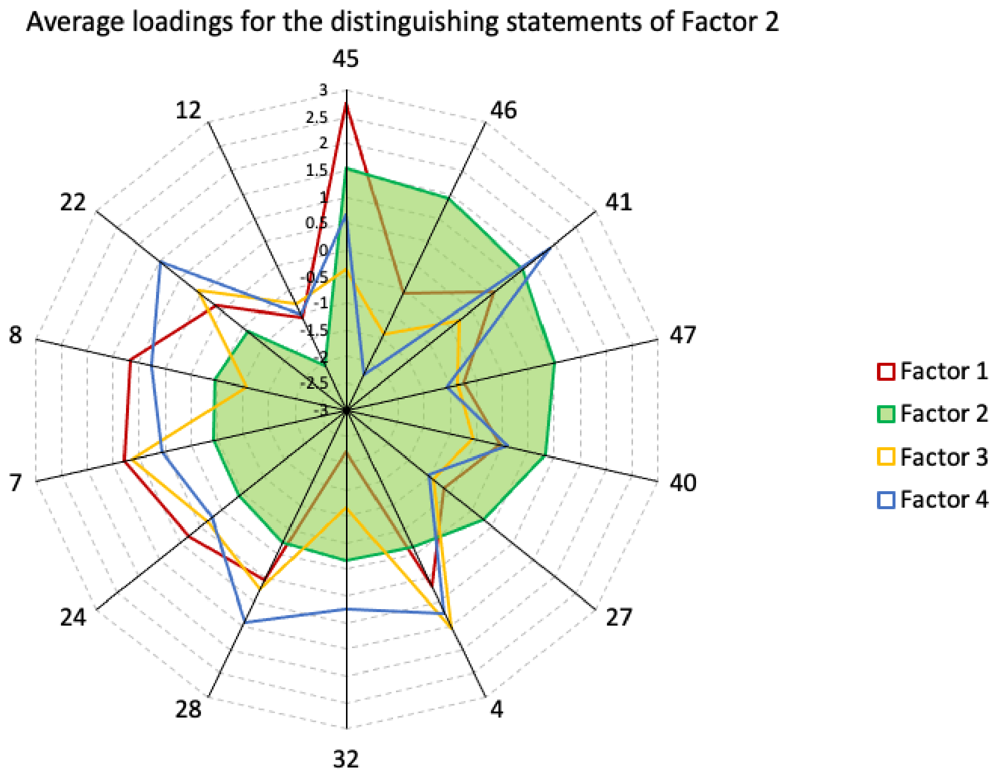

Figure 4.6: Average loadings for the distinguish statements of Factor 2

No.	Statement	Q-Value	Z-Score	Threshold
45	The increase of e-autos and related infrastructure for car sharing contributes to the reduction of CO2 emissions.	5	1.54	P<0.01
46	Charging stations are perceived unsafe by the users.	4	1.41	P<0.01
41	Increasing the number of electric vehicles increases the number of charging stations, so it contributes to the reduction of CO2 emissions.	3	1.23	P<0.05
47	Hydrogen fuelling stations should be far from cities since they are perceived as dangerous.	2	1.01	P<0.01
40	Highways are the best place to develop the H2 fuelling stations. They generate a good return on investment for the automotive value chain actors who contributed in its development.	2	0.83	P<0.05
27	Autonomous vehicles require a lot of power, thus collaborating with fuel cell technology is the ideal solution that helps in the growth of hydrogen fuelling infrastructure.	1	0.3	P<0.01
4	Government should fund the development of charging infrastructure.	0	-0.14	P<0.05
32	The availability of 5G telecommunication infrastructure increases the users' willingness to pay for connected cars.	-1	-0.18	P<0.01
28	The development of battery swapping could increase the usage of e-autos for car sharing.	-1	-0.23	P<0.05
24	Partnerships with payment operators benefit the development of e-autos for car sharing.	-1	-0.4	P<0.05
7	Government should provide incentives to electric car shared infrastructure, e.g., charging stations for e-autos.	-1	-0.42	P<0.01
8	Having a private parking place might help to expand the electric infrastructure.	-1	-0.47	P<0.05
22	Gigafactories help Europe to accelerate the growth of electric charging infrastructure.	-2	-0.62	P<0.05
12	Cities are the best places to develop the infrastructure related to autonomous cars.	-5	-2.09	P<0.01

Table 4.9: Distinguish statements of Factor 2

4.5.5.3 Factor 3: development enthusiast

Experts in this particular group are focused and show much more interest in the field of technological development than others. They believe that particular technologies can help the automotive sector shape up in a better way. As can be seen, experts are more focused on the statement "cities are the best people to develop e-autos for car sharing", and they also have a greater interest in dynamic charging technology, as well as the development of smart cities and smart roads. So basically, the mindset of these experts here is clearly seen in such a way that if the technology is developed, then the transition from fossil fuel vehicles and their infrastructure can be changed to other alternative fuel-based vehicles. From the negative perspective, the experts believe the 5G telecommunication infrastructure does not much enhance road safety and also, in the case of CO_2 emissions, it is clear from the table that the experts are more negative towards the statement that charging stations are perceived as unsafe by the users.

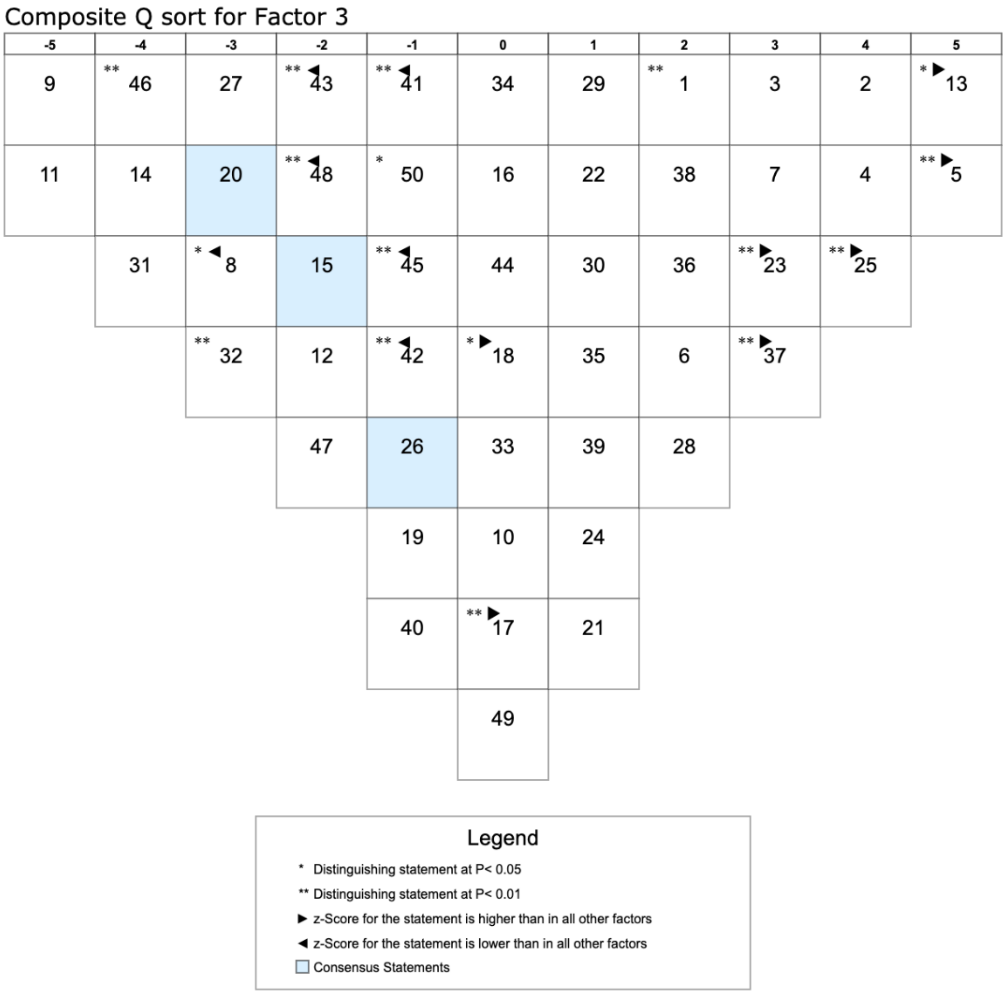

Figure 4.7: Composite Q sort for Factor 3 (development enthusiast)

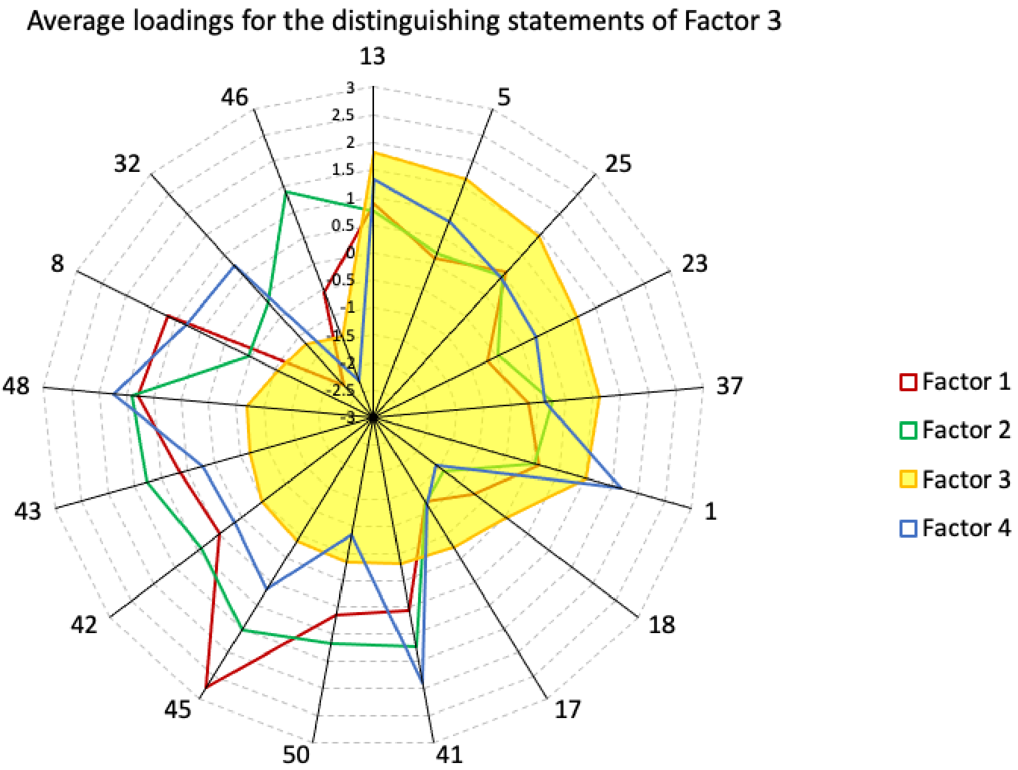

Figure 4.8: Average loadings for the distinguish statements of Factor 3

No.	Statement	Q-Value	Z-Score	Threshold
13	Cities are the best places to develop e-autos for car sharing.	5	1.81	P<0.05
5	Government should fund the development of hydrogen infrastructure.	5	1.63	P<0.01
25	Dynamic charging reduces the driver's concern about range.	4	1.45	P<0.01
23	Hydrogen fuelling stations should cooperate with electric charging stations for the faster development of each infrastructure.	3	1.12	P<0.01
37	The creation of smart roads and smart cities generates a positive ROA to the automotive value chain actors who contributed in its development.	3	1.12	P<0.01
1	Private investors should invest in 5G telecommunication infrastructure in this decade (2022-2030).	2	1	P<0.01
18	Before 2035, FCEVs will become an eco-efficient option for car sharing services, pushing the growth of hydrogen fuelling stations within the cities.	0	0	P<0.05
17	Smart roads and smart cities for autonomous vehicles will be ready before 2035.	0	-0.24	P<0.01
41	Increasing the number of electric vehicles increases the number of charging stations, so it contributes to the reduction of CO2 emissions.	-1	-0.31	P<0.01
50	Data privacy is a significant problem in car sharing services.	-1	-0.35	P<0.05
45	The increase of e-autos and related infrastructure for car sharing contributes to the reduction of CO2 emissions.	-1	-0.36	P<0.01
42	Increasing the number of FCEVs increases the number of H2 fuelling stations, so it contributes to the reduction of CO2 emissions.	-1	-0.48	P<0.01
43	The growth of 5G infrastructure increases the spread of connected cars that contributes to the reduction of CO2 emissions.	-2	-0.68	P<0.01
48	5G telecommunication infrastructure will enhance road safety.	-2	-0.69	P<0.01
8	Having a private parking place might help to expand the electric infrastructure.	-3	-1.08	P<0.05
32	The availability of 5G telecommunication infrastructure increases the users' willingness to pay for connected cars.	-3	-1.18	P<0.01
46	Charging stations are perceived unsafe by the users.	-4	-1.41	P<0.01

Table 4.10: Distinguish statements of Factor 3

4.5.5.4 Factor 4: electro smart

Experts in this group perceive that electric vehicles and their charging infrastructure are the most concerning aspects that might help with CO_2 emissions reduction. They also feel that the concept of gigafactories can help to accelerate the expansion of electric vehicles. Experts also believe that battery swapping technology, which can be employed for e-autos for car sharing, can assist in boosting the range and utilization of this trend. On the other hand, we can certainly see that they are in a position where specialists believe that charging stations throughout Europe will not be balanced until 2035. They also feel that charging stations are secure but feel that privacy for car sharing is always an issue.

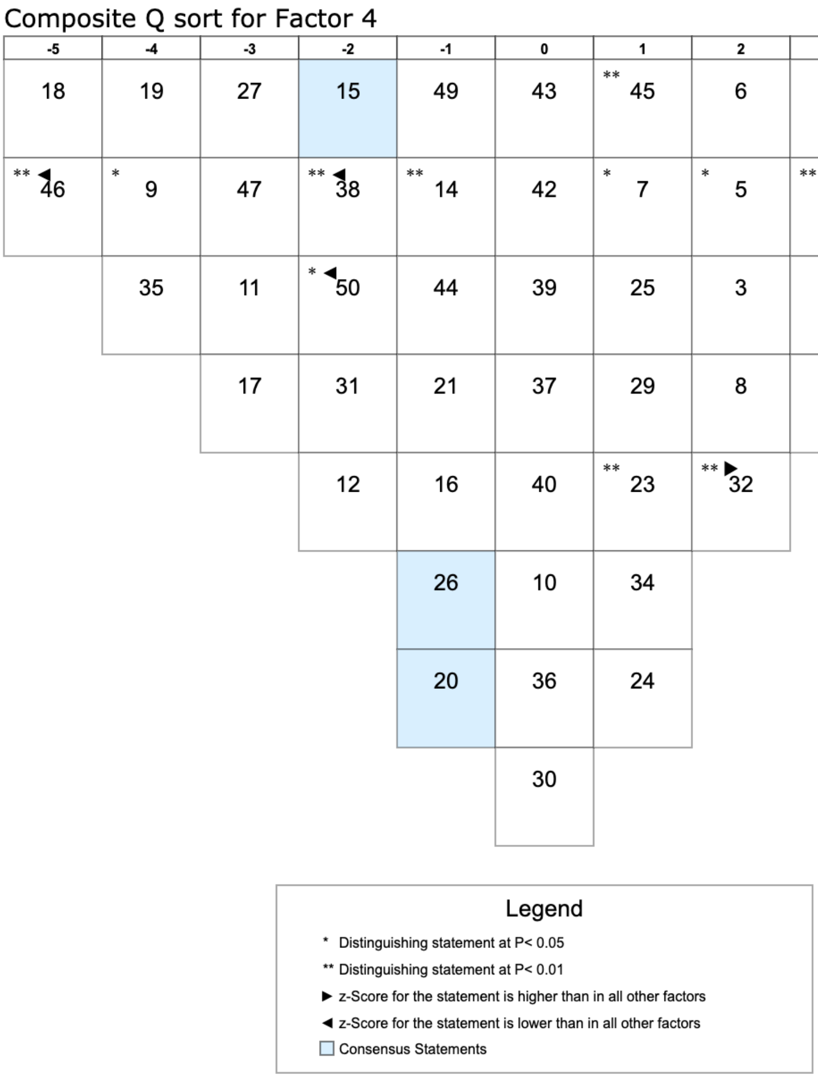

Figure 4.9: Composite Q sort for Factor 4 (electro smart)

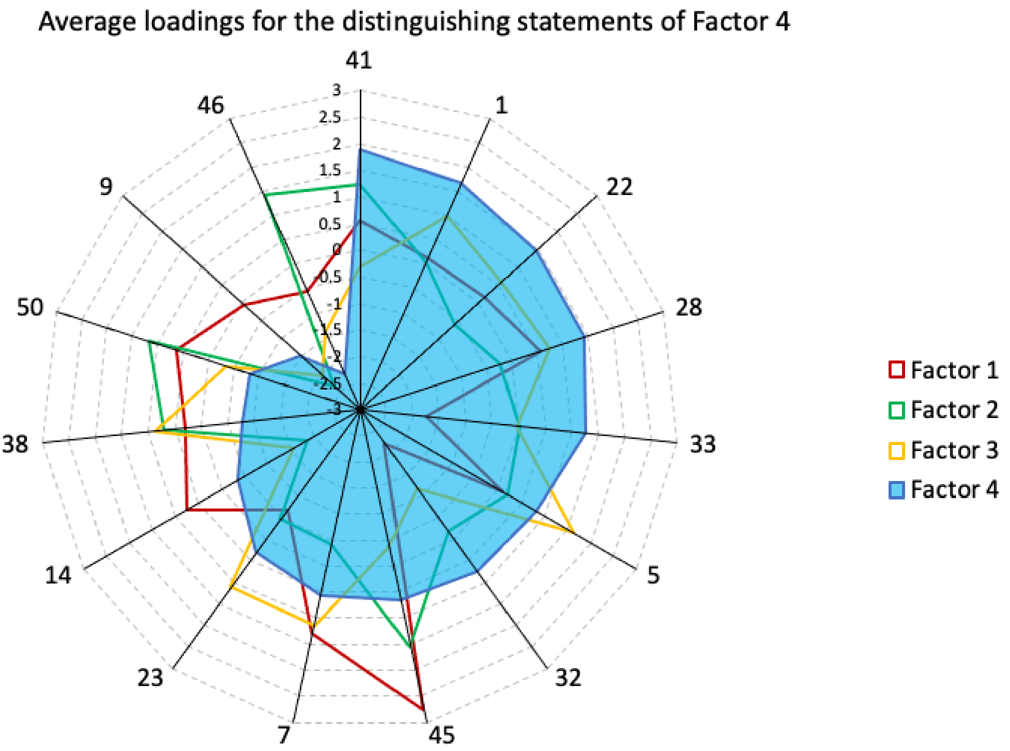

Figure 4.10: Average loadings for the distinguish statements of Factor 4

No.	Statement	Q-Value	Z-Score	Threshold
41	Increasing the number of electric vehicles increases the number of charging stations, so it contributes to the reduction of CO2 emissions.	5	1.89	P<0.05
1	Private investors should invest in 5G telecommunication infrastructure in this decade (2022-2030).	4	1.66	P<0.01
22	Gigafactories help Europe to accelerate the growth of electric charging infrastructure.	4	1.47	P<0.01
28	The development of battery swapping could increase the usage of e-autos for car sharing.	4	1.43	P<0.01
33	The availability of smart roads and smart cities increases the users' willingness to pay for autonomous cars.	3	1.27	P<0.01
5	Government should fund the development of hydrogen infrastructure.	2	0.81	P<0.05
32	The availability of 5G telecommunication infrastructure increases the users' willingness to pay for connected cars.	2	0.75	P<0.01
45	The increase of e-autos and related infrastructure for car sharing contributes to the reduction of CO2 emissions.	1	0.66	P<0.01
7	Government should provide incentives to electric car shared infrastructure, e.g., charging stations for e-autos.	1	0.56	P<0.05
23	Hydrogen fuelling stations should cooperate with electric charging stations for the faster development of each infrastructure.	1	0.3	P<0.01
14	The availability and distribution of charging stations across Europe will be balanced before 2035.	-1	-0.36	P<0.01
38	Investing in e-autos for car sharing in the cities and related infrastructure (e.g. charging stations, parking stations) generates a positive ROA to the automotive value chain actors who contributed in its development.	-2	-0.79	P<0.01
50	Data privacy is a significant problem in car sharing services.	-2	-0.84	P<0.05
9	Having a private parking space is necessary for autonomous vehicles.	-4	-1.48	P<0.05
46	Charging stations are perceived unsafe by the users.	-5	-2.27	P<0.01

Table 4.11: Distinguish statements of Factor 4

4.5.5.5 Consensus statements

Consensus statements identify themes on which experts gave comparable scores and agreed. The three assertions in the table demonstrate the experts focus, which implies that the majority of the experts concur with the three claims in the table. As we can see, the majority of them disagree with the remarks about hydrogen. For example, experts anticipate that by the year 2050, the Italian hydrogen infrastructure will not be spread much. Furthermore, experts believe that deploying new hydrogen stations on highways before 2035 is still a debate. There is always a dispute over whether alternative fuel-based cars, such as battery electric vehicles and hydrogen electric vehicles, will not be slowed down with the expansion of hybrid electric vehicles.

		Z-Score			
No.	**Statement**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
15	Hydrogen fuelling stations will be installed across Italy by 2050.	-0.76	-1.4	-0.71	-0.76
20	New hydrogen stations will be deployed only on the highways before 2035.	-0.24	-0.68	-0.93	-0.73
26	The transition from gasoline infrastructure to electric and hydrogen infrastructures will be slowed down by the adoption of hybrid vehicles.	-0.55	-0.18	-0.52	-0.69

Table 4.12: Consensus statements

4.5.5.6 Group associations

The Table 4.13 depicts that the majority of respondents in the automotive value chain have a mindset towards technological development, in particular they believe that it is the right time to invest in innovative technologies to create smart roads and smart cities and step by step follow the transition towards a more sustainable future mobility. Nonetheless, the other mindsets also consider in the process the social aspects being careful about the safety.

Group	Socially oriented	Safety concerned	Development enthusiast	Electro smart	Total
Car manufacturer				1	1
Finance and insurance	1		1	2	4
Infrastructure mobility		1		3	4
Integrators	1		3		4
Other	1			1	2
Start-up		1			1
Universities / consulting		1		1	2
Vertical solutions	1	1	4	1	7
Total	4	4	8	9	25

Table 4.13: Associations

4.5.5.7 Comments from experts

In this process experts think that it is critical that purchasing incentives coexist with those for charging infrastructure. They also think that 5G technology is established and ready for widespread use and V2X is a key enabler to enhance road safety.

"It is important that incentives to purchase go hand in hand with those for charging infrastructure."

"5G technology is already mature and ready for mass market deployment."

"The application of 5G technology in V2X systems could significantly increase safety on the roads."

5. Discussion

The principal goal of this dissertation is to understand how the role of automotive infrastructures, in particular the passenger vehicle infrastructures, may actually impact the future of the automotive value chain, aided by automotive professionals' perspectives. Considering automotive infrastructure is a complex field, the emphasis is on these key trends affecting the automotive transition: charging infrastructure, H_2 fuelling, 5G telecommunications, smart roads, smart cities, and shared mobility. As extensively documented in the scientific literature [123], the market penetration of electric vehicles is rising, and survey findings revealed that the majority of experts agreed with this assessment, stating that the expansion of charging infrastructure is strong. Another key insight is the criticality in the process to balance charging infrastructure availability across Europe. This will benefit the value chain by generating more interest to EVs and speeding up the energy transition process. In transport, where electrification is difficult, hydrogen is a possible alternative. Regional or local electrolysers can readily provide hydrogen refuelling stations, but their implementation will need to be based on a precise understanding of fleet demand and varied needs for light- and heavy-duty vehicles. To encourage hydrogen deployment and build a market in which new producers have access to customers, hydrogen infrastructure should be open to everybody without discrimination. This aspect of the hydrogen EU plan is also accepted by experts who believe that hydrogen infrastructure should work in harmony with charging infrastructure and are doubtful about the deployment of more hydrogen stations across Italy. This means that hydrogen infrastructure for passenger cars is nowadays weak, and it needs a good planning for the following years. Moreover, the literature suggests us that FCEV has the greatest value of technological maturity among the four choices, which are ICE, BEV, HEV and FCEV, implying that its growth is nearly flat. However, BEV has the lowest technological maturity, whereas HEV has a similar technology maturity. This means that BEV and HEV have a bigger potential for technical advancement and quick expansion, while FCEV has very little [124]. With reference to another literature [125], the future of hydrogen transportation in Europe is also described in a roadmap paper produced in 2019 by the "fuel cells and hydrogen 2 joint undertaking". The paper includes a projection for the number of HRSs needed to meet the demand of the emerging FCEV industry. The number of cars expected for 2050 was calculated using a no-consolidated scenario and an ambitious scenario, yielding 2.5 million and 53.4 million FCEVs, respectively. In the case of smart city, how a city might become smart is frequently depicted in literature. To that aim, successful examples of smart cities with high-quality plans are presented, as well as insights into how they achieved their goals and became smart cities, where 5G is classified as a technology [126]. From the experts' point of view, investing in 5G communications infrastructure this decade is the greatest choice that will expand even more in the future. The majority of experts also believe that consumers are willing to pay a premium to incorporate the safety and privacy problems related with the expansion of smart cities and smart roads, as well as the development of 5G. As a result, it is clear that infrastructure for autonomous and connected vehicles is on its way to the market. According to the relevant literature, most vehicle sales after 2040 will be electric and capable of autonomous driving, with connection being a key condition for autonomous driving and a possible factor for shared ownership [127]. Although the majority of experts believe in the infrastructure for autonomous and connected cars, other experts argue that it raises concerns about safety and privacy due to the possibility of data breaches. Even if there has been a less negative reaction to this kind of infrastructure, many experts claim it is safe. For example, the use of 5G technology in V2X systems might considerably improve road safety; some believe they are currently in use on a large scale. According to the literature [128], experience with car-sharing services, particularly electric vehicle as sharing, can lead to greater awareness of EV technology, resulting in greater market dispersion. Car sharing, particularly e-autos, is always a viable alternative for expanding the infrastructure of both car sharing and electric automobiles. According to experts, car sharing could minimize CO_2 emissions and traffic congestion. They also anticipated that investing in e-autos now will yield a profit and a strong return on assets in the future. With the advancement of this trend, it may become more beneficial for all individuals to use e-autos in the future. This thesis enables a new holistic vision of the infrastructures integrating the researchers' scientific publications with a broad vision given by SWOT and Q-methodology with experts from companies. SWOT analysis get a complete overview of the main aspects of each infrastructure by summarising the key points. Analyses with Q-methodology, which have previously been applied in the literature in other areas, allowed us to compare and sometimes even support the views of the researchers. It is of vital importance to plan the infrastructure well together with all players in the value chain. In this process, Q-methodology can show concordant or diametrically opposed points of view regarding the different actors and try to understand what mindsets could characterise and shape the automotive sector in different time perspectives. Coopetition between energy and transport sectors could be the key to a sustainable, innovative, and brilliant development for future mobility. The advent of new technologies, such as gigafactories and smart grids, will greatly increase the common interest in an exciting future.

6. Conclusions

The main objective of this dissertation is to comprehend how the role of automotive infrastructures may truly transform the environment and influence the future of the automotive value chain supported by the visions of automotive experts, focusing on charging, hydrogen, connectivity, and car sharing infrastructures. In the first chapter, the current scenarios of those infrastructures were presented. The strong presence of petrol infrastructure is still dominating, especially in Italy, which has the highest number of petrol stations in Europe due to the high demand from the population. Rising emissions, high gasoline prices, and incentivization all contributed to the expansion of charging and hydrogen infrastructure. However, hydrogen infrastructure availability is lower than that of electric infrastructure. According to the current picture, connectivity can be achieved only with proper policies, switching the situation from pilot testing to real implementation. In this process, car sharing can help to relieve congestion, especially within cities, by reducing the total number of vehicles on the roads. Germany is the biggest car-sharing market in Europe. The second chapter examined the elements that form the automotive value chain: actors, technologies, and infrastructures. As these trends expand, fresh actors, like as battery, fuel cell, and sensor suppliers, will enter the value chain. According to automotive customers, one of the primary reasons for preferring an electric car is worry about climate change; consequently, governments should respond to society's changing requirements by encouraging the growth of those new trends. The main responsibilities of the various infrastructures are highlighted in the value chain analysis. Public charging stations boost the visibility of the growth of electric infrastructure, particularly DC fast charging, which increases the attraction of electric mobility. Home charging in coupled with a smart grid shifts the paradigm of charging from outside to inside the houses and is a significant enabler of low-cost charging. To minimise the cost of electric cars, Gigafactories are required for large manufacture of batteries. In the case of hydrogen, green hydrogen infrastructure may not only assist to reduce emissions, but it can also be combined with renewable energy generation, potentially providing Italy a strategic position in the market. Smart roads and smart cities minimise traffic congestion while enhancing road safety, which may be converted into societal benefits. Mobility as a service allows car sharing to be combined with other modes of mobility. If the shared vehicle is electric, battery swapping improves usage efficiency. It is also emphasised that all of the trends are interrelated, which means that the expansion of one might have a direct influence on another. The thesis focuses on various trends that can serve as an upgrade for the conventional car and its infrastructure. According to the study and methodology used, each alternative investigated has its own set of advantages and disadvantages. The fundamental issue with the trends discussed here is the infrastructure that is currently under development. According to the forecast analysis conducted for Europe in general and specifically for Italy, electric infrastructure seems to dominate, however this is only a prediction, and anything may change in the future. The infrastructure for FCEVs is designed in such a way that they are very low because the investment for establishment is high. In terms of connected cars and autonomous cars, the infrastructure requires a significant change in the market and increases vehicle costs, but it can be developed as soon as possible and is also showing faster development. Regarding e-autos as car sharing, this initiative also increases the growth of the electric vehicle and its infrastructure supporting technologies such as dynamic charging and battery swapping. The analysis done so far is based on individual perception, so asking experts about the future of automotive infrastructure is a wise way to understand it. Thus, a survey with 50 statements was conducted with the help of Q methodology, which makes the experts opt for the best statements according to what they believe is being agreed or disagreed. It was possible to comprehend each expert's perspective on the various trends under investigation. Each expert was classified based on how similar they thought the future trend will be. It could also be noted that many experts believe that if the infrastructure is developed for any trend considered so far, people will be ready to hop on the trend to replace the conventional vehicle and its infrastructure. Some experts believe that the infrastructure for connected and autonomous cars is established and ready to use. According to our analyses and our mindsets, the nearest and most interesting opportunity is the electrification of car sharing fleets together with the implementation of MAAS apps. This will be followed by the massive spread of electric charging infrastructures, in particular dynamic charging and gigafactories will be the game changer in the future mobility landscape. In the development of smart road and smart cities safety and privacy should be the pillars. In the case of hydrogen, public and private investors should cooperate and plan wisely for the infrastructural development. This thesis can be considered as the first step to try to understand the right timing to deploy each infrastructure in a strategic perspective and how carmakers should involve themselves in the construction of such infrastructures.

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A. Appendix A

These graphs depict comparison of the four variables discovered in the study. The 50 statements are depicted on the horizontal axis. Positive Z-scores represent statements where each group agrees with each factor, and negative Z-scores represent statements where each group disagrees with each component. It is even more clear that mindsets of factors 3 and 4 are similar.

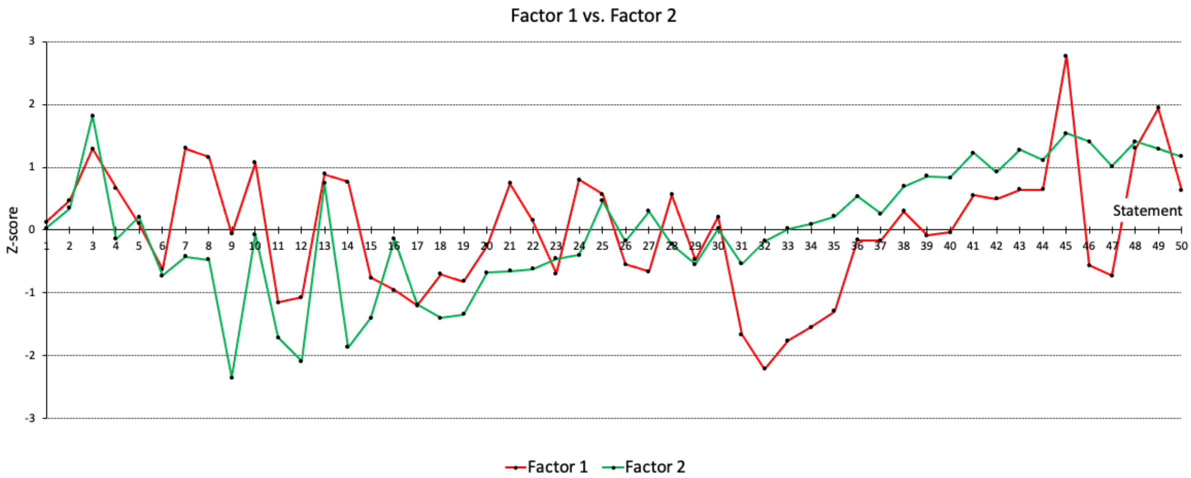

Figure A.1: Comparison of factor 1 and factor 2 by statement

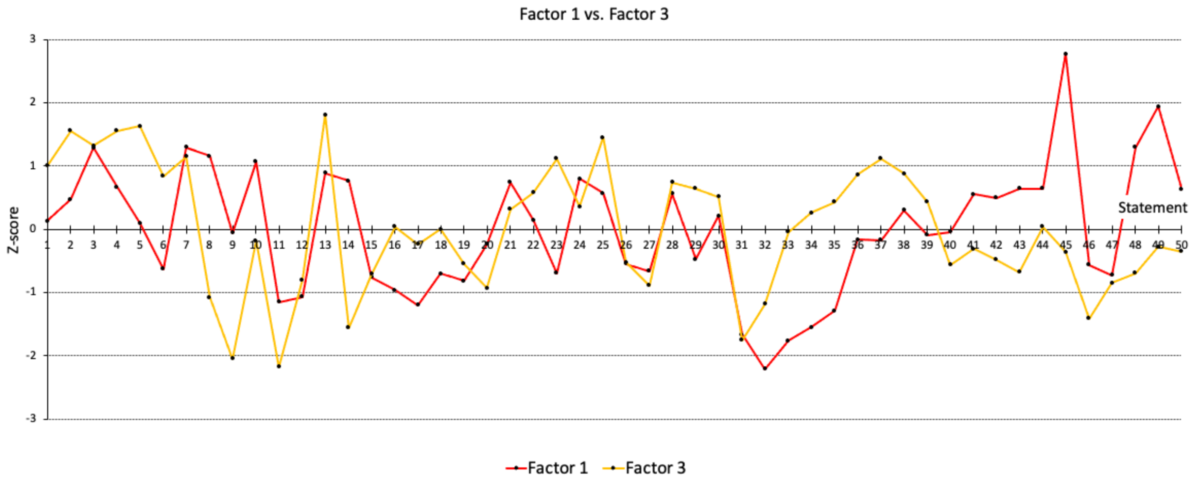

Figure A.2: Comparison of factor 1 and factor 3 by statement

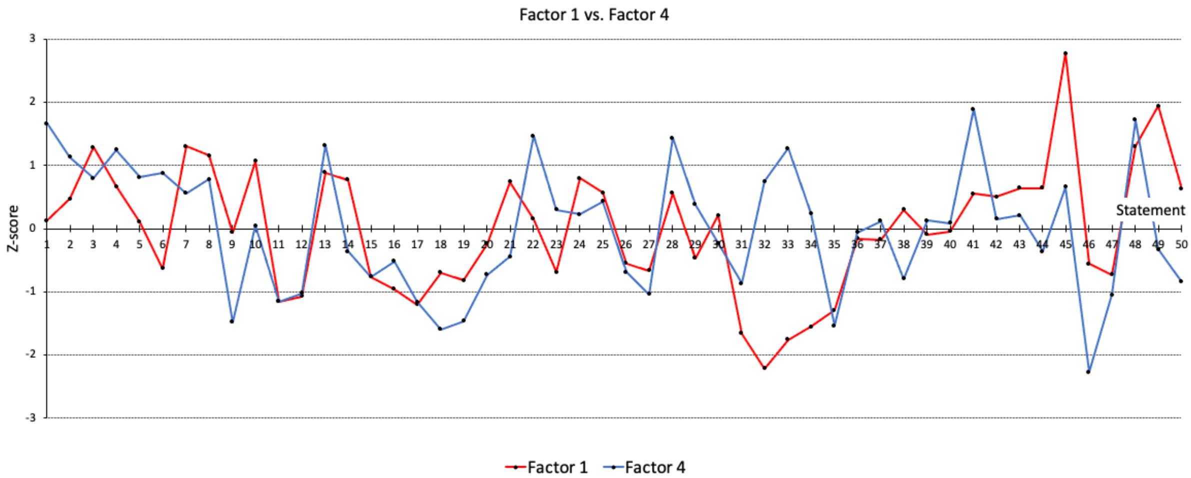

Figure A.3: Comparison of factor 1 and factor 4 by statement

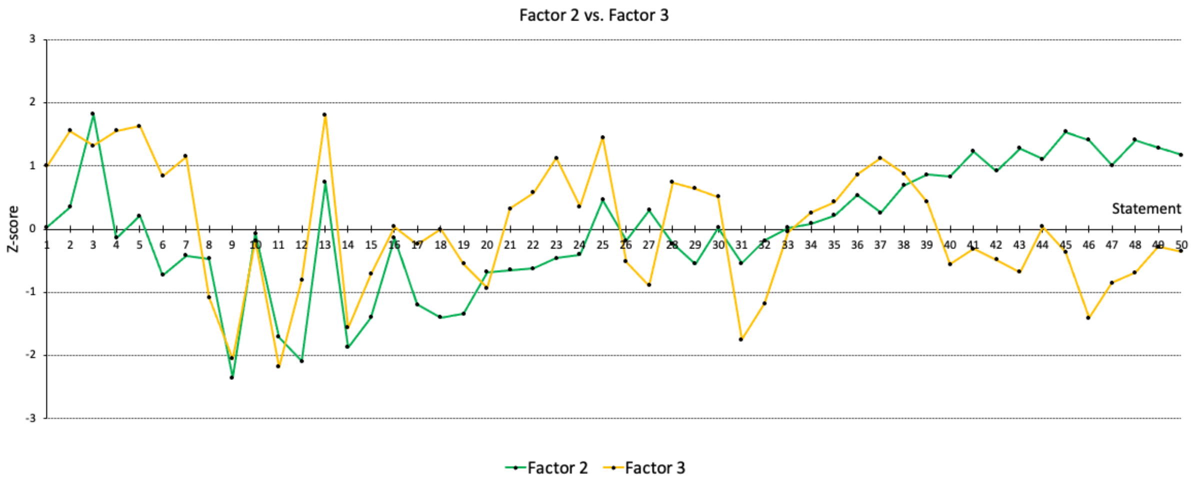

Figure A.4: Comparison of factor 2 and factor 3 by statement

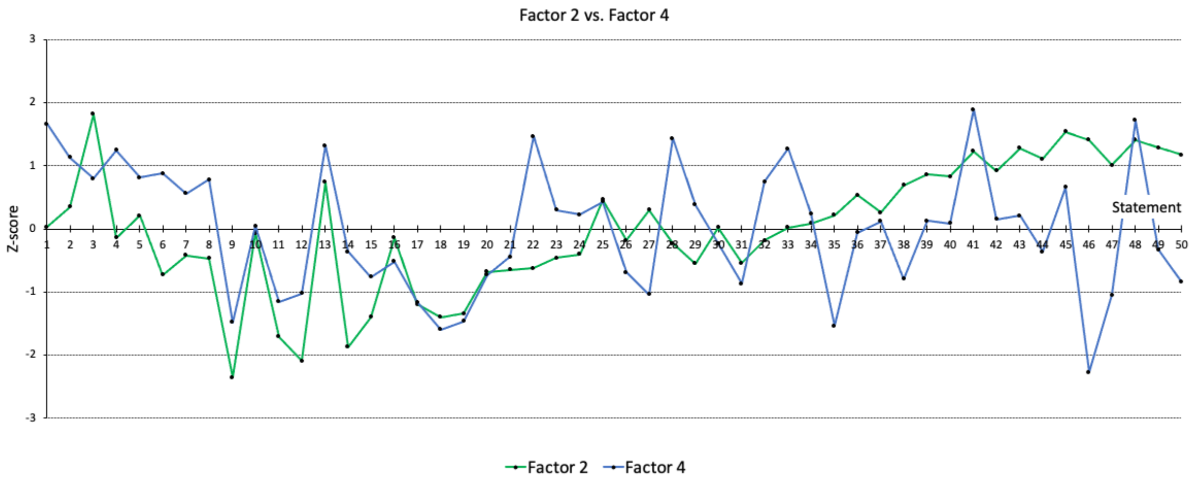

Figure A.5: Comparison of factor 2 and factor 4 by statement

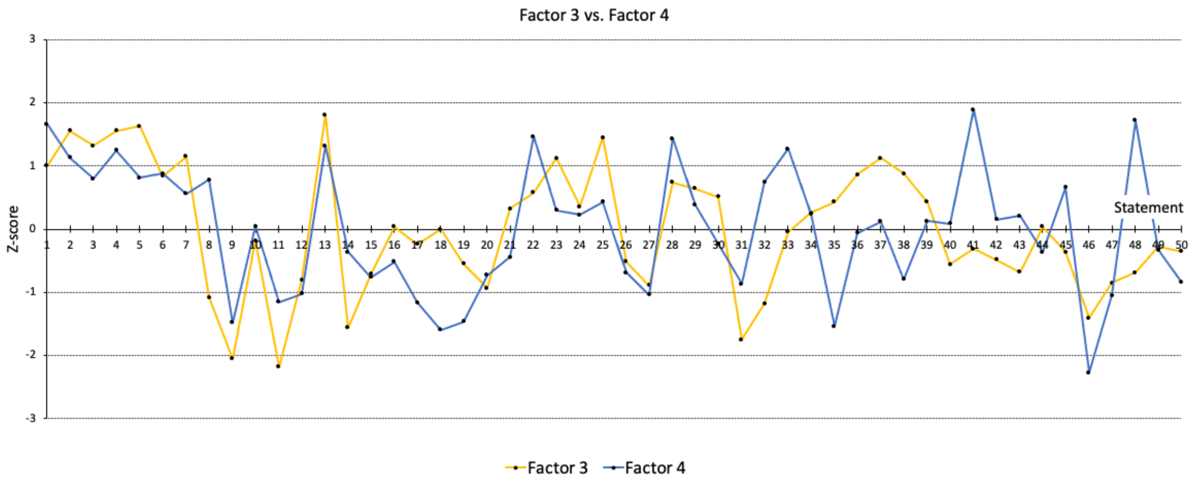

Figure A.6: Comparison of factor 3 and factor 4 by statement

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2. List of Symbols

Variable	Description
a	intercept
b_t	growth term
E	error or irregular
h	time period
k	number of season in a year
ℓ	level term
m	slope
r_{xy}	Pearson correlation coefficient
S	seasonal term
T	forecast trend
$\bar{x}, \bar{y}$	averages of historical values
α	constant
β^*	constant
γ	constant

3. List of Acronyms

Acronym	Description
ABS	Automated Braking System
AC	Alternating Current
ADS	Automated Driving System
ADAS	Advanced Driver Assistance Systems
AEB	Automated Emergency Braking
AHSS	Advanced High-Strength Steel
AM	Amplitude Modulation
API	Application Programming Interface
AV	Autonomous Vehicle
BAU	Business As Usual
BEV	Battery Electric Vehicle
BMS	Battery Management System
B2C	Business-to-Consumer
CAGR	Compound Annual Growth Rate
CCS	Combined Charging System
CEO	Chief Executive Officer
CO	Carbon monoxide
CO_2	Carbon dioxide

CON	Connectivity scenario
C-V2X	Cellular-Vehicle-to-Everything
DC	Direct Current
DoD	Depth of Discharge
DSCR	Dedicated Short Range Communication
EAV	Electric and Autonomous Vehicle
EEA	European Economic Area
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMS	Engine Management System
ENV	Environment scenario
ETS	ExponenTial Smoothing
EU	European Union
EV	Electric Vehicle
E3ME	Macro-econometric model for assessing energy-environment-economy issues and policies
FCEV	Fuel Cell Electric Vehicle
GDI	Gasoline Direct Injection
GDP	Gross Domestic Product
GPF	Gasoline Particulate Filter
GPS	Global Positioning System
GVA	Gross Value Added

HEV	Hybrid Electric Vehicle
HYB	Hybrid scenario
HV	High Voltage
H_2	Hydrogen
H35	350 bar
H70	700 bar
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IT	Information Technology
IEA	International Energy Agency
IoT	Internet of Things
LKA	Lane Keeping Assistance
LPI	Logistics Performance Index
LTE	Long Term Evolution
LV	Low Voltage
MAAS	Mobility As A Service
MEMS	Microelectromechanical Systems
MMR	Mid-Range Radar
NCAP	New Car Assessment Program
NMVOC	Non-Methane Volatile Organic Compounds
NO_x	Nitrogen Oxides

NO_2	Nitrogen Dioxide
NVH	Noise, Vibration and Harshness test
OBC	On-Board Charger
OEM	Original Equipment Manufacturer
OTA	Over The Air
PCA	Principal Component Analysis
PHEV	Plug-in Hybrid Electric Vehicle
PNRR	Piano Nazionale di Resistenza e Resilienza
PM	Particulate Matter
P2P	Peer-to-Peer
R&D	Research and Development
RADAR	Radio detection and ranging
ROA	Return On Assets
SMR	Steam Methane Reforming
SoC	State of Charge
SoH	State of Health
SO_x	Sulphur Oxide
SRR	Short-Range Radar
SWOT	Strengths, Weaknesses, Opportunities, And Threats
UK	United Kingdom
US	United States

USD	United States Dollar
UV	Ultraviolet
VC	Value Chain
V2C	Vehicle-to-Cloud
V2G	Vehicle-to-Grid
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
YOY	Year-Over-Year

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Alessio and Seetharam