ISCTE Business School
INSTITUTO UNIVERSITÁRIO DE LISBOA

WHAT CAN MOTORSPORTS DO TO AUTOMOTIVE INDUSTRY DEVELOPMENT

Rodrigo Ferreira Santo

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Supervisor:

Prof. Renato Pereira, ISCTE Business School, Department of Marketing, Operations and Management

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Resumo

Desde o aparecimento do Homem que a evolução acontece, a qual aconteceu graças a invenções revolucionárias, e com essas invenções, surgiram inovações. Desde o momento em que o carro foi inventado que houve necessidade de o melhorar, fazê-lo mais rápido, fiável e eficiente, o qual se traduz em inovações constantes a surgir na indústria automóvel. Existem inúmeros exemplos de inovação automóvel desde o início do século XX, e assim que a invenção do carro se deu que apareceu também a ânsia de o comparar com os restantes existentes em termos de desempenho.

No momento em que a comparação entre automóveis começou a competição automóvel nasceu. Este tipo de competição tornou-se um “veículo” onde grandes inovações aconteceriam no automóvel. Permitir a construtores testar novas tecnologias nas mais árduas condições permitiu à competição automóvel tornar-se a montra da engenharia automóvel. A análise a algumas destas tecnologias adotadas em carros de série que tinham como destino um carro de corrida permitiram concluir o que a competição automóvel pode fazer pela inovação na indústria automóvel.

Palavras-chave: Inovação, Indústria Automóvel, Competição Automóvel

Abstract

Ever after the appearance of mankind, evolution has taken place, which occurred thanks to ground breaking inventions, and with those inventions, came innovations. Since the invention of the car itself, there has always been a necessity to make it better – faster, more reliable and efficient and that translated in constant innovations appearing in the automotive industry. There are countless examples of innovation in the automotive industry dating as back as to the beginning of the 20th century and from the moment the car was invented that comparing different cars' performances has become kind of a necessity.

At the moment comparing became competition motorsport was born. This sort of competition and sport became the "vehicle" where major innovation in the automotive takes place. Allowing manufacturers to test new technologies at the harshest conditions let motorsport be the somewhat of the showcase of automotive engineering. The analysis of some of these technologies adopted in road cars that were meant to be in a racing car allowed to conclude what can motorsports do for the automotive industry innovation.

Keywords: Innovation, Automotive, Motorsports

JEL Classification System: Automobiles (L62); Innovation (O31)

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1. Introduction:

Ever after the appearance of mankind, evolution has taken place, which occurred thanks to ground breaking inventions. We know that in the beginning hunting was done with stones, which evolved with the invention of the spear, but the spear started having changes in itself, becoming sharper and, consequently, more effective. In this example, the spear was the invention, and the further improvements are innovations, these pre historic innovations were the first in the history of mankind. From then on, innovating started turning into something we see every day and that has become part of our daily lifestyle, something present in every sector in the market.

There are multiple examples of innovation going right and going wrong, and of some wars within this specific concept. We can bring up the VHS/Betamax example in what home video is concerned, which took place again a few decades later with the HD DVD/Blu-ray Disc war. From this examples we can conclude that innovation sometimes goes in a different way in what the market needs are concerned, and when this happens, the market itself chooses which way is better. In what the automotive industry is concerned, there have been continuous innovations almost ever since its invention took place.

Since the invention of the car itself, there has always been a necessity to make it better – faster, more reliable and efficient and that translated in constant innovations appearing in the automotive industry. There are countless examples of innovation in the automotive industry dating as back as to the beginning of the 20th century, and there are obvious some inventions that stood their ground until the present day, but some were not that successful. There is the example of the concept car Saab manufactured, based on the Saab 9000, known as Prometheus (Gil *et al*, 2013), where the Swedish brand tried to make a ground breaking innovation in terms of safety, by removing the steering wheel (invented as soon as the automobile itself), and replacing it with a “joystick” in the centre console (see Figure 1). It would improve heavily the safety of the car, as there would be a bigger space for a frontal airbag for the driver, but the “joystick” proved being not practical and too sensitive, as the turning angle was only 180 degrees opposing to the nearly 1000 in the steering wheel (Golson, 2017), and quite tiring, as the drivers' hand could not leave the device at any given time.

Fig. 1: The driving system of the Saab "Prometheus"

Source: Saab Planet; https://www.saabplanet.com/saab-9000-drive-by-wire-1992/

Since the introduction of the very first innovation in a car that comparing cars' performances has become kind of a necessity. In the early ages there used to be "street races" – races in a designated route, to see which car was faster; that was the birth of motorsport. From then on, there started to be substantial evolutions in cars and in almost no time there started to be racing championships, with some modifications being made in road cars – at this point in time there were proper circuits and off road tracks already.

In that moment, motorsport began advancing in a different pace comparing to the "standard" automotive industry.

At a certain point, modifying road cars seemed not to be enough, so prototypes started being made. This happened due to the improvements in terms of R&D, but also due to aerodynamics and the possibility of making specific improvements in prototypes' mechanics and making them lighter than a normal car, not to mention the availability in terms of "space" to balance the car in terms of weight, grip and power distribution.

Over the years, both modified cars and prototypes have evolved substantially, not only in a visual way, but also in terms of mechanics, used composites and technology. All these details made the cars break records in terms of speed, efficiency and overall performance. Nowadays, there is even technology involved and, for example, in a Formula 1 car, almost everything is controlled with the aid of technology, electronically, but if we look back 30 years, almost everything worked in a mechanical way. This evolution in F1 (the most famous way of motorsport worldwide) has been followed by the automotive industry, where the differences are like day and night.

Since we entered the 21st century, the concern with the environment has dramatically increased and so, the automotive industry has been obliged to cut down on CO_2 emissions. Moreover, as time goes by and with the increase of the oil price, cars have developed the continuous necessity to be more fuel efficient and new types of fuel have been researched. Among the fuel alternatives there are bio fuels, hydrogen and electricity. This is where motorsport enters, by innovating with new technologies to make engines more powerful, and to make cars more efficient and easier to drive.

The improvements discovered under motorsport necessity can be used by "regular" automakers to adapt and use in their cars in order to make them more easily fulfil emission regulations and making car companies save huge amounts of money that would be spent in R&D.

The purpose of this dissertation is to explain how motorsport is leading and guiding the path the automotive industry is taking; to explain this, I will make an approach to what innovation is and how it has affected the world as whole, and specifically, the automotive industry. Furthermore, engineering is also following the path of motorsports, even though, in different extremes of the evolution process. For example, new breakthroughs in motorsport performance may inspire engineers or even engineering students to innovate in a certain way; on the other hand, that same breakthrough may afterwards be implemented in road cars, improving their performance in some way.

To help me find information, I recurred to a number of articles and some videos, taken from engineering and motorsport magazines, from scientific publications and some informative websites. After gathering information, I analysed some technologies that brought innovation to the automotive industry, some of which adapted from motorsports and that changed the way automobiles are. In the end, at the Methodology, I studied the progress of Tesla Motors, which is at the moment considered The Most Innovative Company in the automotive industry by Forbes magazine. At that study, I highlighted the strategy taken and how the company got to this successful moment, as well as the CEO's – Elon Musk – vision.

The following dissertation is at first composed by the Literature Review, where examples of two technologies brought from motorsport are given and further explained, followed by two examples of technologies introduced in the automotive industry without recurrence to motorsports. To complete the Literature Review, there is an insight on two technologies that are at the moment being introduced in the automotive industry. After that, in the Methodology, there is an analysis to the path taking by Tesla Motors, an example of what innovation is in the automotive industry, which is revolutionizing the way the electric car is looked at. At the end, there is the discussion of what these technologies and this company added to the industry in question.

2. Literature Review:

2.1. Technologies brought from motorsport:

With the necessity of on-going evolution and innovation, sometimes the automotive is not capable of testing every new technology in a new concept car or prototype. To fill this necessity some Original Equipment Manufacturers (OEMs) sometimes invest in having motorsport teams so that continuing testing can take place. After those tests, some innovating technologies are eventually used in road cars. Due to the necessities in cars' performance and new concerns, sometimes the transition from motorsport to road cars with takes bigger time differences. The following technologies were introduced in road cars so that the much discussed fuel efficiency and consequent gas emission meet regulations and make cars more environmental friendly.

2.1.1. KERS – Kinetic Energy Recovery System

As Newton's First Law of Motion states, "Everybody remains at rest or in motion in a straight line at constant speed unless acted on by an unbalanced force" which is of course applied to cars. So, for a car to stop some force needs to be applied and, apart from frictional force that is exercised at all moments on Earth, it is in friction brakes that that force is most applied to slow or stop the car.

Braking is basically reducing the kinetic energy of the car, which is created usually by an Internal Combustion Engine (ICE), and that reduction happens due to the use of the friction brakes. When the friction brakes are used, the kinetic energy applied is dissipated in heat, and so, that same energy is no longer possibly recovered (Boretti *et al*, 2016). In order to prevent the loss of this energy, an energy recovering system was invented, and as the energy recovered is kinetic, it is referred to as KERS, or Kinetic Energy Recovery System. This makes even more sense at present day, as fuel consumption is something that OEMs are trying to reduce as most as possible, so it makes perfect sense to use all the energy produced by the engine in a way the car can move using energy otherwise just simply dispersed in the air. There are many ways the KERS can store energy, which is either hydraulically, mechanically or electrically.

Considering hybrid and electric vehicles becoming more and more common, as is the R&D in the auto making area, storing energy electrically when braking is the most popular way of recovering kinetic energy in cars. This type of technology is already well-known and spread across numerous motor racing categories and is becoming more and more common in everyday cars.

Even though recovering the energy that results from the heat produced when braking, there are other ways to recover kinetic energy. For instance, an electric assisted turbocharger can recover energy differently compared with the KERS braking system. The energy wasted at the exhaust system can be recovered in order to mitigate the turbo lag effect, by using the gases exiting the exhaust. The mentioned gases can even be used in an electric water pump (used to control the engine temperature), in order to fight the inertia of the cooling system, providing a faster warm-up and allowing better fuel efficiency.

Hybrid technology has been around in top notch motorsport championships since 2009, when Formula 1 introduced the KERS system. Despite not being compulsory, teams were allowed to create a system that recovered the energy created when breaking (heat) and to store either as electricity in a battery, or mechanically in a flywheel. This was allowed to aid the 2.8 litre V8 petrol powered engines with up to 80 hp for 6 seconds per lap. Three years after, in 2012, Audi started having electric powered engines in 2012 24 Hours of Le Mans in the R18 e-tron Quattro LMP1 prototype aiding its diesel propelled ICE (see Figure 2). The difference compared with previous F1 cars was that the energy could be used limitlessly with restrictions only at where energy could be recovered. At this first attempt, the car was already a success, taking the 24-hour marathon by storm and winning at its first appearance being the first ever hybrid car to win the mythical race.

Fig. 2: The 2012 Audi R18 e-tron Quattro LMP1, the first ever hybrid car to win the 24 Hous of Le Mans

Source: Audi MediaCenter; https://www.audi-mediacenter.com/en/press-releases/the-audi-r18-e-tron-quattro-803

Two years after Audi's hybrid car debut in Le Mans, it was time for Formula 1 to use hybrid technology similarly, when all regulations changed and the power system became more complex. In 2014 the power unit was hybrid and was composed by a 1.6 litre turbocharged V6 Internal Combustion Engine (ICE), an Energy Store (ES), where electric energy is stored instead of being wasted. Adding to the two mentioned components, there are two Motor-Generator Units (MGU): the MGU-K, that recovers energy when braking, which is stored in the ES and when necessary used by boosting the ICE while accelerating; and the MGU-H, which recovers the energy not being used at the turbocharger to the ES and then takes it back to the turbocharger for assistance when accelerating (see Figure 3). This new power unit has itself made ground breaking innovations even in the F1 field, taking the power levels to something around 600 hp with a 1.6 litre engine, not to mention the additional 180 hp available at times coming from the Energy Recovery Systems.

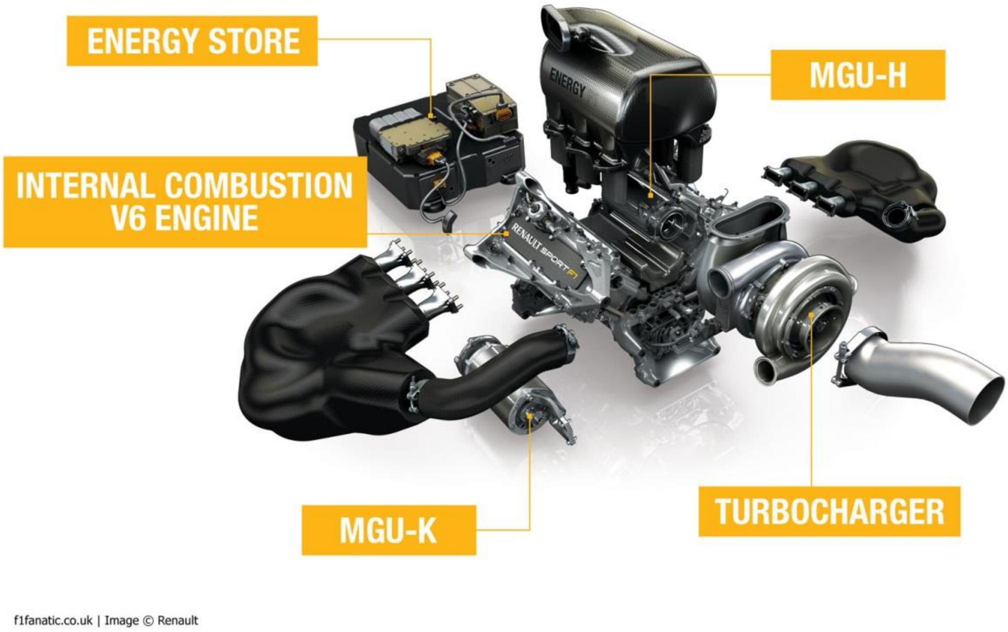

Fig. 3: The Power Unit of a F1 car since the 2014 season, including the KERS

Source:F1 Fanatic; http://www.f1fanatic.co.uk/2015/01/29/f1-fanatic-round-up-2901/eclate_moteur_gb/

These two championships, which have the most advanced engineering applied, resulting in outstanding performances and cars capable of breaking records almost every season have made the motorsport industry overcome itself and bringing huge innovations. The automotive industry has already started taking these huge advances to every day road cars, making hybrid and electric vehicles more efficient. With this, we can easily find a car in the market that already uses this technology; even if the examples made before are outstanding, the road cars available do not have such recovery capacity. It is impossible to harvest as much energy as F1 and LMP1 cars does because road cars do not cruise at similar speed, so the breaks do not take a similar effort, therefore not producing so much heat through energy.

2.1.2. Turbochargers

Turbochargers have been around since the beginning of the last century, and in the 1980s they were adopted at a large scale in the motorsports field. The main purpose of a turbocharger is to inject air “faster” when the combustion takes place in the engine, which happens by pressurizing the air. Despite that, like Kirby concurs in 2014, most car makers stopped using this technology regularly, not only in some family saloon cars, but also in sports cars and in motorsports series, like F1, this happened as well.

Even though turbocharged engines in F1 ceased to be approved roughly a decade after they were introduced, they made the 1980’s decade an unforgettable one in F1 history. Despite having the automotive industry started producing turbocharged engines in the early 1960s, in F1 the first turbocharged engine appeared only in 1977, when Renault risked to add a turbine to improve the engine’s power. As the technology was something of a novelty, in 2016 Matt concluded the company thought of using the introduction to make its engineers more eager to develop it, while publicizing the brand itself. This was the beginning of the “Turbocharge Era” in F1, where the most powerful cars that ever raced in the series competed, with engines producing around 1000 hp. Due to evolutions in engine turbocharging not being followed by the evolution of circuits and tyre technology, it became completely overruled in 1989. Oppositely to F1, the WRC continued using turbocharged engines for a long time, as they do at the moment; curiously, F1 adopted turbocharged engines in the 2014 season, which have been racing in the present day.

Countering the tendencies, by the turning of the century, turbochargers started having their space back in the automotive sector. One of the reasons turbochargers were overlooked in the first place was the lag made by the time between the air injection of the charger and the effective power release of the engine. But as mentioned, in the upcoming years, there have appeared noticeable innovations in the turbocharger field, and with these innovations, the turbo lag has been overcome.

One of them is the Variable Geometry Turbocharge, analysed by Kusztelan *et al* in 2011, where the turbo itself has the ability to let more or less air in the turbine with some internal vanes, enabling it to work more effectively; despite this, in petrol engines the temperature of the gases is so high that the vanes need to be made with exotic materials to withstand such temperatures. Still, we can conclude that this type of turbocharger is perfectly able to solution the turbo lag problem for diesel engine cars without a significant cost increase.

In terms of petrol engines, the most effective solution (mainly in terms of costs) is the Twin-Scroll Turbo, which, unlike Single Scroll Turbochargers, has two scrolls, dividing exhaust pulses. This system brings benefit by separating the power strokes between the cylinders, preventing each power strokes from interfering with each other. Despite this, Ward in 2010 stated that turbocharged engines would become more common both in racing and in everyday road cars. Due to the emission legislations and the rise of fuel prices, turbocharged cars show a number of advantages when compared to naturally aspirated cars, mainly in terms of efficiency.

After analysing what we can call “regular” turbochargers, which use solely the air in different ways to make the combustion process more efficient and powerful, there is another type of turbocharger that deserves to be highlighted: the electric turbocharger. Introduced in F1 in 2014, the electric turbocharger is nothing short of ground breaking in terms of innovation, mainly considering the one in F1 cars, which is quite complex. The car’s turbocharged 1.6 litre V6 engine has a motor generator unit (MGU) which reuses heat energy from the exhaust system (Kirby, 2014), this type of turbo could be further adopted in other racing series, as some other racing cars are “closer” in terms of technology to every day cars. The process would mean other racing series introducing hybrid technologies and would serve as a gateway change, as other racing series have cars “technologically closer” to those we see every day on the roads. The referred MGU is the one working with heat energy, with the code name MGU-H and its technology could be used by the automotive industry with the introduction of a hybrid turbocharger. This type of turbocharger would be able to assist not only high, but also medium and low performance cars improving the turbocharger performance and efficiency, also helping recharging batteries with energy that is usually not used at its most.

The electric turbocharger is something that can be used coupled with the previous described technology, the KERS. The use of both systems could be the considered almost a perfect symbiosis which could take hybrid cars to another level, not only in terms of performance and efficiency, but also in terms of awareness for customers, who would most likely take into account this type of vehicles if they were more common and widely developed.

After the introduction of the electric turbocharger in F1, some teams have started divisions in their road car divisions where this type of technology is used in the development of road cars, which resulted in what we know nowadays as hyper cars. The McLaren P1- one of the most powerful and technologically advanced car available in the market was developed by McLaren Technology Group, a branch of McLaren working closely with McLaren F1 Team, like Ferrari did with the Ferrari La Ferrari.

Even though high performance cars use turbochargers, so that their engines produce more power, every day regular cars have started having turbocharged engines as well. This has happened due to the worldwide focus on greenhouse gases emissions, like CO2 and others, and a solution to those emissions is to have low cylinder capacity engines with turbochargers, so that, even consuming less, the engines can produce more power when necessary (Lee *et al*, 2016). This process is often referred to as Engine Downsizing and is taking place throughout the whole automotive industry. At the moment, even high-end OEMs are planning on leaving the production of naturally aspirated engines, meaning in a few years, there is the possibility of all supercars on sale have turbocharged engines.

These two technologies were used in motorsports and both have similar responsibilities: to make the engine in a more efficient way. Despite having this focus, there are two separate objectives than are put into account when using these technologies:

-Performance: The reason why KERS and Turbochargers were adopted in motorsports is simply to, with the engine restrictions there are, make the car go as fast as possible. This is what happens with OEMs when building supercars and even medium level sports cars, but rather concerning about the taxes customers will afterwards pay after acquiring their car, trying to make them more powerful without augmenting cylinder capacity.

-Fuel Efficiency: Cars with KERS and cars with a Turbocharger can aid the main engine into making the car go without the necessity for the engine to make such an effort. This means that a “small” turbocharged engine may produce the same horsepower as a bigger one that is naturally aspirated. With the turbocharger, the engine can make low fuel consumption in regular use, but still have some “extra” power when necessary. The case with the KERS is a bit different, because it can, just when braking or lifting the foot from the throttle, produce energy that can later fuel the car by itself.

2.2. Technologies Previously Introduced

With the automotive industry’s continuous necessity to innovate, sometimes new breakthroughs need to be done without recurring to motorsports. The following innovations happened at first in other “transportation” industries and were only afterwards adopted by the automotive industry. For instance, diesel powered engines were not easy to manufacture when the car started being more popular in the first place, as diesel engines require a much higher injection pressure of the fuel when compared with petrol engines. The way fuels are mixed with air and how combustion happens is also something that has had several innovations, and they have changed and keep changing the way ICEs work. Also, aligned with most other developments, fuel injection has taken such a path that engines are becoming more fuel efficient.

2.2.1. Impact from Diesel Implementation and Introduction of Electric Engines

When the invention of the automobile took place, in the end of the 19th century, automobiles used at first steam-powered engine in its primordial beginnings and later that century and in the beginning of the 20th century the use of electric engines was the most common despite the competition between electric, steam-power and internal combustion (petrol and diesel powered) engines. At this point, it became clear that the recently invented and developed internal combustion engines were a cheaper, simpler way to propel automobiles and became the most used alternative around the 1910s.

At the beginning, petrol powered engines were used widely, and more than diesel powered ones, due to its less complex process of combustion which involves, in the diesel case, a much higher fuel injection pressure than petrol. Throughout the century, diesel combustion was better understood and started being used as much as petrol, as the combustion process was better understood and simplified. Even though the complexity in the combustion process in diesel engines, it involves lower exhaust gas temperatures among other details and so, the maintenance of diesel engines is less expensive, making cars more durable and easy to keep for more time/miles. Besides the maintenance, diesel engines have usually lower fuel consumptions when compared with petrol engines.

After all the previous conclusions, the first type of cars using diesel powered engines more widely were transport vans and, later, lorries. This also happened because diesel has a lower cost when compared with petrol at the time, and still does almost everywhere worldwide even though there are discrepancies in the difference of prices from country to country, mainly due to political regulations.

According to ACEA – European Automobile Manufacturers Association, in 2014, 53% of passenger cars newly registered in the EU were petrol powered and 44,3% were diesel powered (2,7% were powered with different fuels). This means that throughout the years, diesel and petrol have become the most used sorts of fuel. Over the years, the diesel engine has had the most notorious evolution, despite that, there are more petrol powered engines globally, making Europe an exception.

Like in road cars, in motorsports petrol powered engines are more widely used and have dominated the top classes and most enigmatic races. Despite this, diesel engines have already won mighty races like Paris-Dakar and 24 Hours of Le Mans (curiously, both by VAG companies at first).

Despite all this, some conclusions can be made about these two different ICE fuels. To start with, petrol engine cars are usually cheaper when compared with the same car with an equivalent diesel powered engine. On the other hand, diesel is cheaper than petrol, and the maintenance of a diesel powered car is also cheaper than petrol powered one, so the best deal to the buyer is result of an analysis of all these factors. After this whole analysis, there are other issues that should not be overlooked, for instance, even modern diesel powered engines have high nitrogen oxide as well as soot emissions (Baumgarten, 2006), which are not that high petrol powered engines. Nonetheless, diesel powered engines are more fuel efficient than petrol ones, this happens because, as diesel is a good lubricant, it can be injected into cylinders with high pressures, making it easier to start combustion.

2.2.2. Fuel Injection

Since its early ages, internal combustion engines have had the necessity to mix air with fuel. As mentioned earlier, petrol was the first widely used fuel for cars, and to mix it with air in order to have the correct fuel to air ratio, carburettors were used. This kind of technology was introduced still in the 19th century and lasted until the mid-1980 as the most used way to mix fuel with air in high volume production cars.

Despite the use of the carburettor until the 80’s decade, in 1954 another technology was introduced which is the one we see in everyday cars nowadays, it was fuel injection. This technology was first used in aviation, but it was first introduced in a racing car by Mercedes-Benz in the W196 F1, and later that year it also introduced fuel injection in production cars, with the Mercedes-Benz 300SL.

Since the 1950s and the introduction of fuel injection there has been quite an evolution of the system, and innovations are constantly appearing. Through the years, many methods have been studied in order to make the combustion process more efficient, not only in petrol engines but also in diesel. In order to achieve so, processes were developed and different ways of injecting fuel have been found, therefore, a further description of then is done.

2.2.2.1. Petrol engines:

By reason of being the first fuel largely used in Internal Combustion Engines, petrol engines are the ones in which there have been more innovations throughout time. At first, carburettors were used to make the air-fuel mix for the combustion but, eventually, fuel injection was finally introduced and became fully used around the 1980s and is nowadays the way all petrol fuelled engines work. Despite that, ways of making the combustion through injection process more fuel efficient have been found, resulting also in lower emissions.

After researching the work of Baumgarten in 2006 in it was concluded that in this type of engines there are two types of injection system: Port Fuel Injection and Direct injection.

Port Fuel injection has two separate systems:

-Single-point injection system and it basically replaces the carburettor with a central injection unit. As the air is mixed with the fuel, it flows through the manifold to the cylinders, meaning fuel droplets, fuel vapour and air are delivered to the manifold, and the question is that the mixture is not homogeneous so to speak. In this type of injection, the mixture prepared centrally has to be distributed between the cylinders by the manifold. As it goes through the manifold, some of the mixture forms a liquid film in the wall that does not get to the cylinders at the same time as the mixture steam. This process makes the mixture that gets in the cylinders vary constantly, not only in terms of quantity, but also in terms of quality; concluding, there is no possibility of achieving a uniform distribution of the mixture due to the manifold's variable geometry.

-Multi-point injection is a more complex system when compared with the single point injection one. In this system there is one injector for each cylinder injects the fuel at the necessary moment, this makes the fuel distribution be more uniform in contrast to single point injection, allied to that is the fact that the air is what mostly fills the induction system. Even though there is still formation of the liquid film as well as some fuel drops they affect the air-fuel mixture much less because the temperature near the inlet valve is higher its surface having small wettable area.

Direct Injection system stands up to Port Fuel Injection mainly when CO2 emissions reduction and fuel saving is concerned. As the amount of time available to disintegrate the spray and to form the mixture inside the cylinder, common-rail injection systems are used and the pressure of the injection is quite intensified, so that the highly dispersed sprays are available. In Direct Injection systems there is the necessity to have fuel injectors to spray the fuel into the cylinder and there are three types of nozzle injectors that will be explained and further discussed in terms of advantages between each other. The nozzles analysed will be the multi-hole, the inwardly opening pressure swirl and the outwardly opening nozzles.

-The multi-hole nozzle has several holes injecting fuel, spraying it with rather large penetration producing big sized droplets (see figure 4). With that said, the fuel in the cylinder is not injected homogeneously which may result in various burning velocities and also soot and nitric oxides emissions. Still, this type of nozzle has an upside to it which is, independently of the backpressure, the spray structure and cone angle does not change, not to mention the advantage of the possibility of easily influencing the spray shape by adapting the position and number of holes.

The other two types of nozzles, unlike the multi-hole nozzle, produce a hollow-cone spray in contrast with the solid-cone spray. The hollow-cone spray is nothing but a thin liquid sheet of fuel, and it permits a high area-to-volume ratio, allowing the necessary atomization level without the requirement of large penetration, as the droplet size is smaller compared with the multi-hole injector.

-The inwardly opening pressure swirl nozzle (see figure 4) makes the fuel be sprayed in a rotational motion, which happens due to the tangentially arranged swirl ports where the fuel passes through. The previously mentioned hollow air cone is formed by the centrifugal motion of the fluid, and due to the nozzle reduction of the swirl chamber, the rotation motion itself is increased. After the cone formation inside the combustion chamber, it thins due to conservation of mass and leaves the nozzle, and turns into droplets afterwards.

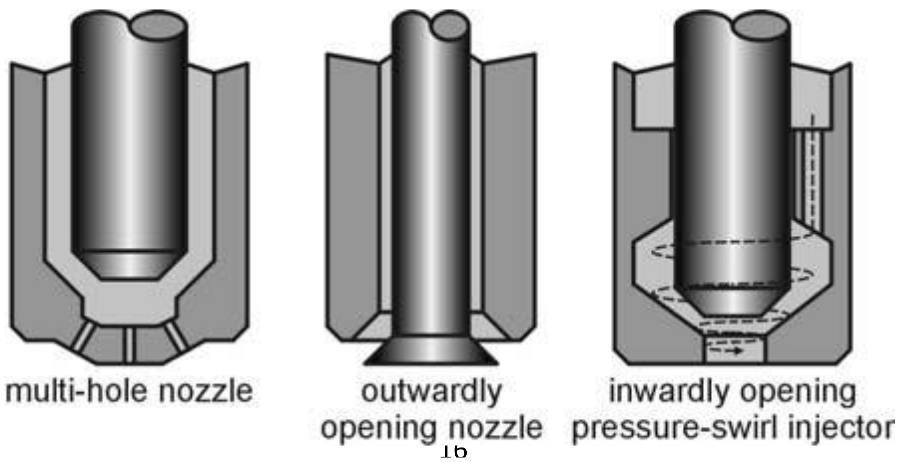

Fig. 4: Different type of injection nozzles

Source: Baumgarten, C. (2006). Mixture Formation in Internal Combustion Engines. EBook. https://doi.org/10.1007/3-540-30836-9

-The outwardly opening nozzle a slight difference compared to the inwardly opening pressure swirl one (see figure 4), which is not having any pre-spray and not collapsing at higher backpressures. This is just a slight difference, but it is also a huge advantage, and it will most likely be the most used nozzle system in direct injection, making fuel consumptions go down.

2.2.2.2. Diesel Engines:

As it is studied and analysed by Merker *et al* in 2014, in Diesel Engines, unlike petrol engines, there is no necessity of a spark to ignite the mixture and ignite the combustion; instead, the fuel is injected under high pressure towards the end of compression. During the pressurized injection the fuel spray evaporates and mixes itself with compressed hot air, igniting itself. Therefore, the higher the fuel pressure, the easier the combustion takes place, leaving no residues in terms of droplets and soot, improving fuel consumption and lowering gas emissions. Nowadays, direct injection is used in diesel engines almost exclusively; this happens because this method allows smaller fuel consumption comparing to indirect injection methods. The downside to direct injection is the higher noise level and the necessity to have really high injection pressures. Diesel engines have several injection systems, which can be separated between cam-operated systems, unit pumps, unit injectors and the common rail injection system, which is the most recent one.

-In Cam-operated systems, the metering of fuel and the increase in pressure and connected mechanically. Here, the cam compresses the fuel volume by moving the injector pump’s tappet; from this process, the rising pressure opens a valve that releases the feeding pipe for the injection nozzle. A trimming edge opens the return line, making the fuel pressure drop forcing the valve to close consequently ending the injection.

-With the Distributor Injection Pump system there is only one pump unit for all cylinders in the engine. In the most used type of engine (4-stroke) the DIP makes half as many strokes as the cylinders in the engine per engine revolution, then the fuel is added to the single injection pipes with the rotation of the distributor head. This system is more cost efficient for smaller engines compared to some others, representing the evolution of conventional injection system technology. (800-1000 bar)

-The Unit Pump system is quite a straightforward injection system, it consists of an injection pump, a small high pressure pipe and an injector-nozzle combination. Each cylinder measures injection start and injection amount with a solenoid valve, which by opening a quick pressure decline is caused, leading to a closing of the nozzle.

-In the Unit Injector system the injection nozzle and pump compose a unit, and one is installed in each cylinder by itself. There is an electronic module where an electronic control unit is placed; the control unit sends a shift signal that operates the solenoid valve which manages the injection start and finish. High pressures up to 2000 bar are withstood with this system, conceding low fuel consumption and emission levels.

-Common Rail (CR) Injection System, unlike the injection systems mentioned above, completely separates pressure raising and quantity regulation. Here, the electronically controlled common rail leads the fuel at a high pressure (1200-2000 bar), and from there, the fuel is led to the cylinders. Even though CR injection systems allow the representation of about any injection system, it is only better when solenoid/piezo valve injectors are replaced by directly activating, electronically controlled piezo common rail injectors. Meyer et al (2002) As the engine speed has no obligation to be solidly connected to high pressure pump operating speed, higher fuel injection pressures are possible (over 2000 bar), making improvements in emission behaviour. With this possibility, this injection system should become the most successful at a wide basis.

Through the last decades cars have become pretty much unrecognizable, mostly when talking about the mechanics inside and one of the most parts of the car that has suffered more innovation has been the engine. The introductions previously mentioned were, in the first case a whole new kind of engines and technologies as well as catalyser to ICE development in cars as petrol was no linger the hegemonic fuel in the automotive industry; in the second case, all the mentioned methods and components bring something new to the combustion process making it more efficient, making cars break records in every technical chapter year by year.

2.3. On-going Introductions

The following technologies are quite revolutionary, but may be considered to be still at an introductory stage. Due to being in such a stage, they are still not massively present in cars we see every day, but will certainly be utilized at a wider level when more Research and Development are put into by interested parts of the automotive industry. Nonetheless, at the extent these on-going introductions have been used already, they have already made a stand for themselves and have already proved further development is worthy.

2.3.1. Electric Engines

As mentioned above, when the automobile was first invented, there were electric powered engines, which is quite odd when we consider that fully electricity powered cars have only appeared in the recent years. Despite that, when considering the European car fleet registered in 2015, only a tiny percentage of cars are electricity powered or plug-in hybrid (see Figure 5). At the moment, there is not a huge sale of this type of car due to its still blossoming development, affecting the cars in terms of battery range, lasting only around 150 to 200 kilometres. In addition to the battery range, there are not many charging stations for EVs, despite the investment made from some countries in order to encourage the purchase of these cars.

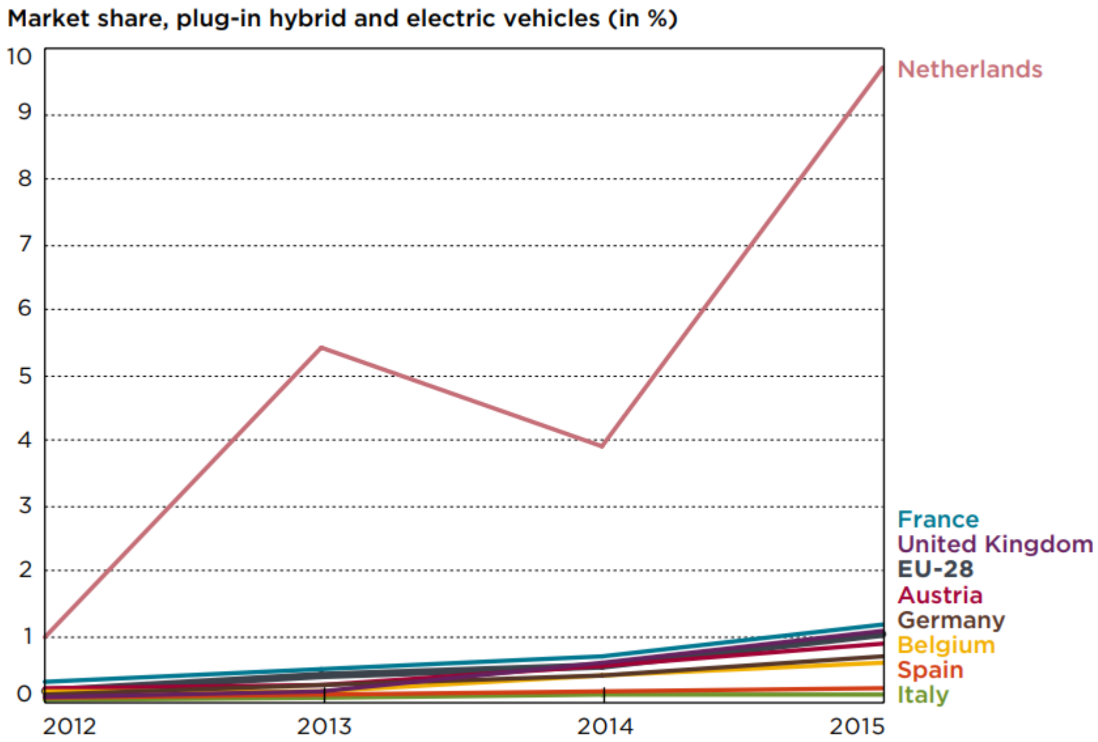

Fig. 5: The evolution of the market share of plug-in hybrid and electric vehicles (in %) in the designated areas

Source: EUROPEAN VEHICLE MARKET STATISTCS – Pocketbook 2016/17 by The ICTT: International Council on Clean Transportation

Due to the issues mentioned, an electric car is a good option for everyday short distances, making the owner save a lot in fuel and being allowed to drive in cities creating laws to prohibit fossil fuel powered cars, but it is still not useful to have an EV to make long distance travels.

In terms of motorsport, electric cars are something we can consider a novelty. The first well known competition with fully-electric cars was the Andros Trophy, a circuit race that takes place in a snow/ice surface every year in the French Alps. In 2010, for the first time, there was a category exclusively with fully electric powered cars in the French event as seen in Figure 6.

Fig. 6: Electric category race in Andros Trophy 2017, in Val Thorens, France

Source: Trophée Andros website; http://www.tropheeandros.com/index.php/photos/les-photos-de-la-saison-2016-2017/photos-val-thorens/100-photos2017/2355-photos-2017-valthorens-tae.html

Despite that complete category, there have been previous attempts to make impacts with electric cars in motorsport, and some racing competitions make it easier for electric cars than others. For instance, hill climbing makes electric cars' handicap- limited range between lengthy charges- unnoticed (Bingley, 2016). The constant altitude increase also represents a "weakness" of internal combustion engines, as oxygen, an utterly necessary compound for the combustion to occur, becomes lower when altitude increases. The altitude increase allied with the eradication of the electric cars' handicap makes hill climbing the perfect motorsport model for electric cars to make a stand for themselves.

To support this, we can see Pikes Peak results and conclude that combustion ICE powered cars took almost 60 years to shorten the finishing time from 15 to less than 10 minutes, while electric vehicles (EVs) took only 11 years to accomplish that milestone. This represents the possibility of evolution for EVs which, with the technology available nowadays, can take a huge leap in the years to come.

Fig. 7: Drive eO PP03, the first Electric Vehicle to win the Pikes Peak Hill Climb in 2015

Source: Bingley, L. (2016). Silent Revolution. PMW Magazine, 52–56.

Even though there have been efforts from many drivers, manufacturers and racing teams, EVs usually have had a low impact on motorsports until a completely new format was created: Formula E. Formula E is a single-seater racing series under the governance of the FIA (Fédération Internationale de l'Automobile) where cars are electric powered exclusively. The series has debuted in 2014 in Beijing and unlike most motorsport categories, it has a schedule more similar to those of other sports, beginning in September and ending in July of the following year. The grid is limited to 10 teams, each with 2 racing cars with different drivers; each car takes 3 seconds in 0-100 kph and goes as fast as 225 kph with a peak power of 200 kW, or 270 hp (Tyson *et al*, 2016). Despite being quite state of the art technology, it is still not possible for a single battery to complete a whole race, so drivers need to stop at the middle of the race in the box and change cars, meaning each team, composed by 2 drivers, has necessarily to have 4 cars that fulfil racing conditions. This problem is intended to be solved by 2019, where battery supply will stop being exclusive from Williams Advanced Technology and batteries will be lighter and more powerful, not to mention the additional competitiveness brought by having different battery suppliers (Bingley, 2016). All these innovations will be adapted to everyday cars in just a few years, so we can conclude Formula E is taking steps forward for the automotive industry right now, and we can consider the fuel cells evolution in batteries, the composites used that are fire proof and that withstand electric power while being super lightweight materials.

Fig. 8: Great action at the 5th race of the 2016/2017 Formula E Championship, Monaco ePrix

Source: FIA; https://www.fia.com/multimedia/image-gallery/formula-e-2017-monaco-eprix

Even though racing series with EVs are making the path of automotive technology for years to come, we know that hybrid cars have been around for over a decade, but they have had quite an evolution through these years. The first hybrid car everyone should remember is the Toyota Prius and it was quite a revolutionary novelty in the automotive world, since there were no cars with internal combustion engines aided by electric power. Despite that, if we compare the Toyota Prius with the Porsche 918, the Ferrari LaFerrari or the McLaren P1 (see in Figure 9), there are outstanding differences in what those cars are and represent. While the Prius represents the first hybrid car generation, the first with electric motors aiding the combustion engine, the 918, the LaFerrari and the P1 represent the state of the art cars of utmost performance with ground breaking engineering innovations, which cannot be considered supercars, but hypercars due to their outstanding performance, technology and price as well. The connection between the point in time when these hypercars are "born" and the F1 revolution in 2014 cannot be overlooked, as we can easily conclude that these manufacturers used technology from F1 to develop the mentioned road cars. Moreover, two of the three manufacturers are directly involved in the sport, with Ferrari even being a power unit manufacturer;

Fig. 9: The McLaren P1, Ferrari LaFerrari and Porsche 918: the most advanced cars at the moment, the Hypercar Trinity

Source: JBR Capital; https://jbrcapital.com/blog/the-holy-trinity-mclaren-porsche-and-ferrari-hypercars-take-a-grand-tour/

with this, there is obvious evidence motorsport helped these Original Equipment Manufacturers (OEMs) take leaps in terms of engineering and innovation.

2.3.2. Composites

With the on-going innovation both motorsport and automotive industry require, there are breakthroughs almost at a daily basis, and "inside" mechanical issues are no longer the only focus of racing teams and car manufacturers. What we can notice is that since the car was invented, there have been numerous materials used, some better than others, some more expensive and others that even became obsolete eventually. For instance, at the early ages of the automobile, wood was used in the body frames and cars were mostly made with iron and steel as observed by Mangino *et al* in 2007.

Steel is still the most used material in body and chassis of cars as it has been for decades, but as Wilhelm mentioned in 1993, automobile materials are constantly improved and steel is obviously no exception. Earlier, in the beginning of the 20th century, steel was the most used material as it is nowadays as mentions Singh in 2017; this happens due to its cost, lightweight, versatility, among other characteristics. Even being considered the best material, all things considered, it was not as reliable and "diverse" as the steel used in present day. According to Singh, "Automotive steels can be classified in several different ways." Which are low strength steels (that will be referred as mild steels), High Strength Steels (HSS) and Advanced High Strength Steels (AHSS). [Difference between HSS and AHSS] According to Singh, in North America between 1975 and 2015, there have been big changes in Light Vehicle Material Content in North America, for instance, the use of Mild Steel has dropped around 40%, while HSS has had an increase in usage of 125% and finally AHSS (with data available only between 2005 and 2015) registered a growth of over 260%.

Material	1975	2005	2007	2015	Change from 1975 to 2015(lbs)
Mild Steel	2180	1751	1748	1314	Down 866
HSS	140	324	334	315	Up 175
AHSS	-	111	149	403	Up 403
Other Steels	65	76	76	77	Up 12
Iron	585	290	284	244	Down 341
Aluminium	84	307	327	374	Up 290
Magnesium	-	9	9	22	Up 22
Other metals	120	150	149	145	Up 25
Plastics/ Composites	180	335	340	364	Up 184
Other Materials	546	629	634	650	Up 104
Total Pounds	3900	3982	4050	3908	Up 8

Table 1: North American Light Vehicle Material Content

Source: Application of Steel in Automotive Industry. International Journal of Emerging Technology and Advanced Engineering Website

While steel is a material that has been used for so many years in the automobile industry, there are also materials that have "appeared" in the industry more recently. Many different metallic materials have appeared and most are only used in some car segments, due to their cost, properties that define its moulding and rarity sometimes; aluminium is one example of these different metals used in car manufacturing. Considering all innovations, cars materials evolution has culminated, after the evolution of steel itself and the introduction of some other metals, in the use of new materials.

These new materials are called composites, and even though they have been used more often as motorsport and the automotive industry innovate, they have been used since the 1950s (Mangino *et al*, 2007), but obviously not to the extent they are used now. Composites, according to Cambridge Dictionary are "materials made up of more than one substance that is used for building things". Furthermore, the composite material has characteristics in the chemical and physical order different from the component materials.

Composites are used in the automotive industry for various reasons, but there still is a long way to go before these materials are used in everyday cars, that is to say in a large scale due to the costs of producing these components. These materials are mostly used in motorsports and carbon fibre, one of the most popular and most widely used, is used mainly due to its durability, lightweight, easier moulding and other specific characteristics, for example, carbon fibre is over 4 times lighter than steel.

As years go by, motorsports and the automotive have constantly "walked" (and evolved) side by side, and are beginning to help each other innovating, with motorsport being the main influencer. Due to climate changes, emissions are one of the automotive industry's biggest concerns, with fuel efficiency being highly involved. In motorsport, every split of a second counts, and so, cars must run at max performance and maximum speed meaning that a lighter car should be faster than a heavier one. So, Original Equipment Manufacturers (OEMs) that have always invested in motorsports have used some technologies in road cars, like composites that compose the whole body of some racing cars, which is gradually being used in more and more road cars. At the beginning, only top end supercars could afford such exotic materials, but OEMs are becoming aware that it pays off to innovate in this matter. With regulations penalizing high CO2 emissions, manufacturers will produce cars as light as they possibly can, while making the material cost viable to selling the car at its "fair price".

For instance, since the early 2000's BMW has been researching Carbon Fibre Reinforced Plastics (CFRP) and about 15 years ago started applying it in M models (like the M3 and the M6) but this could still not be considered mass production as only the roof or bumper of the car was made with CFRP (Jacob, 2010). But, in order to make the use of the composite more viable, BMW made a big investment in order to make a joint venture with a carbon fibre manufacturer in the USA in 2010. In 2014 they invested 200 million dollars (twice as much as in 2010) in order to triple the 3000 tons a year production by 2015. The intention of this was to make the electric vehicles, the

”Megacity Vehicle” light in order to have high battery range, so the car’s passenger compartment is made of carbon fibre and the body is made of a plastic material. Although BMW invested hugely in carbon fibre production, it is still not viable to overlook the use of steel in manufacturing the more produced models and like Mangino et al. mentioned in 2007, despite being easy to be optimistic about the use of composites in the future, their substitution of metals will not happen automatically, and probably never completely.

To sum up, these technologies are taking their first steps in the automotive industry, with still a large progression margin that can be attained in years to come. If we look at a car from 25 years ago we do not see a car any similar to the ones we have nowadays, so it makes perfect sense that in 25 years the automotive will be completely different and cars will be nothing like we are used to. With the help of the massive use of engines powered by electricity, and cars built with composite materials, evolution will certainly take place and energy efficiency will be something at a whole new level.

3. A Case of Successful Innovation - Tesla Motors

Tesla Motors is a company that completely shook the whole technologic world, mainly in the automotive industry. In a time when the automotive industry is pointed at as one of the biggest contributors to all environmental problems, Tesla took a route different from the competition. Being the one OEM that has genuinely invested only in electric powered cars, it has had an implementation strategy different from every competitor, which can be referred to as Disruptive Innovation (Hardman *et al*, 2015). Daneels in 2004 defined a disruptive innovation as “A Technology that changes the bases of competition, changing the performance metrics along which firms compete.” (…)

3.1. Market implementation strategy

The strategy adopted by Tesla to get introduced in the market was probably what made such a success. As electric cars were not common in 2002, the costs would be quite high, not only in R&D but also in manufacturing and implementing such cars in the market. In order to penetrate the market Tesla’s CEO, Elon Musk decided to divide the introduction of the brand in three separate phases:

Phase 1: Develop a high ($100.000) price low volume vehicle: The Roadster

Phase 2: Develop a mid-price ($75.000) mid volume vehicle: The Model S and Model X

Phase 3: Develop a low price ($35.000) high volume vehicle: The Model 3

The Roadster would fit into the high end sports car segment, of which buyers do not care much about price, but more about the performance (see Figure 10). In this way Tesla would be able to fund all the research even if selling a small number of cars when comparing with its competitors, making way to the second phase.

Fig. 10: The first Tesla ever made: The Roadster

Source: Car Magazine; http://www.carmagazine.co.uk/car-reviews/tesla/tesla-roadster-2008-electric-review/

With the awareness raise of the brand, more cars could eventually be sold, but now at a lower price and in larger quantities, at first with Model S and later with Model X; these two would not compete with supercars, but with family sedans or SUVs. As this phase is achieved, the market is already penetrated as are the previously mentioned segments have huge weight in the car park worldwide.

As the brand is established, a lower cost car can be produced; the Model 3, and further it can be sold at a high volume, making the company thoroughly grow. With this we can conclude that Tesla's policy intends to compensate costs with volume, keeping a steady inflow and making the electric car available for any person, despite of the income.

Fig. 11: The three Tesla models for sale at the moment (from left to right): The Model S, Model X and Model 3

Source: Motor Trend; http://www.motortrend.com/news/tesla-model-3-photos-analysis/

As it is widely known, the biggest handicap in EVs is the range, as well as the charging time and charger availability, mostly if we compare with ICE cars, for which there are petrol stations everywhere and takes only some minutes to fill the tank. So, according to Hardman *et al* in 2015, apart from the electric cars sale and manufacture, Tesla invested in some infrastructures required by these vehicles and started building them. Tesla created a network of electric chargers for the cars, named the Supercharger network; the Superchargers are electric chargers that are capable of charging the cars' batteries quicker than a regular charger, being able to charge 50% of the battery of a Tesla Model S in 30 min. This network is available in North America, Europe, the UAE, Asia and also in Australia and New Zealand, and is compound of 934 stations with over 6000 Superchargers.

The Superchargers are placed strategically in long course roads in order to enable Tesla drivers to make long trips without having to make detours to keep the intended route. The intention is to try to mitigate as much as possible the disadvantage of users having to wait for electric cars to be charged, when compared to the time filling a petrol tank takes. To fulfil the mentioned goal, Tesla makes partnerships with companies where people tend to spend some time, like restaurants, hotels and shopping centres, making the wait not felt in the same way as it would be somewhere where there is not much people can do for the mentioned amount of time.

3.2. CEO – Elon Musk's Vision

This whole process was thought so that success was achieved in the long terms. The policy of Tesla follows its CEO's ideology: to make the world better, step by step. The idea of Elon Musk has been put into practice in every one of the companies is has been into: to change the world and make it a more pleasant place.

After graduating from University of Pennsylvania, Musk believed there were 3 things that would affect humanity's future the most that he wanted to be involved in: the internet, sustainable energy, and space exploration (Welsh, 2015). He made the impact regarding the internet with his first company, Zip2 and some years later with PayPal with the intention to enable people to make financial transactions through the internet. Considering sustainable energy, Elon is making it with Tesla, by producing ground breaking revolutionary EVs and using the batteries for domestic use, the Powerwall and Powepack; and he even is the Chairman of Solar City, created by his cousins, in which solar panels are the core business. When it comes to space exploration, Elon founded Space X in 2002, and has already become the first private company to send a spacecraft to orbit successfully and to send one to the International Space Station, after signing a billion dollar contract with NASA.

3.3. Cooperation while competing - Coopetition

Apart from most companies in the industry, Tesla opted for having partnerships with other enterprises with more experience in the area, making the establishment process easier and less lengthy. This is the same as cooperating with competitors, so that all take benefits from the situation, this is referred to as Coopetition. In Infopedia, the definition of Coopetition is "the act of cooperation between competing companies; businesses that engage in both competition and cooperation are said to be in coopetition"

The first and most noticeable partnership was with Lotus, at the time the Roadster was launched. At the time, Tesla was just a company with an idea, so, to make itself noticed the goal was to launch a 100.000 dollar sports car powered only by electricity and with a range way above average, with a policy of brand awareness first and profits later. With the idea coming in 2003, the goal was to make the launch of the car as soon as possible, and that meant not spending too long designing and engineering the car.

Instead of trying to make everything themselves, Tesla's engineers partnered with those in Lotus, basing the bodywork of the Roadster based on the already proven Lotus Elise. In that way, Tesla did not have to worry about certain details that creating a car involves, and could gain expertise from experienced manufacturers; also, they were able to use some components from the Elise, saving time from the whole design and testing. Moreover, with Lotus' connexions, Tesla would benefit from the partnerships to negotiate components with Lotus' suppliers; and with its infrastructures, Tesla could have the assembly of the Roadster in Lotus facilities. This whole partnership enabled Tesla to manufacture 2.500 Roadsters in 4 years and to move to the following phase; apart from this, it made Tesla's notoriety improve and enabled the company to make other huge partnerships like Daimler and Panasonic.

With Daimler the partnership consisted at first with supplying drivetrains for Smart cars, which happened after Elon Musk's acceptance of a challenge made by the company (Stringham *et al*, 2015). Daimler wanted to enter de EV market, so it accepted partnering with Tesla if they were able to manufacture the batteries and drivetrain for the Smart car. This was a big challenge to Tesla, as Smart cars are not sold in the USA and due to the reduced amount of space available in the car to fit the desired long range batteries, all in roughly a month's time. After success, Daimler approved the partnership, buying the drivetrains and furthermore investing in the company itself.

Panasonic, the Japanese over a century old technology giant partnered with Tesla, something both take benefit from. While Tesla can use the Japanese's know-how in battery making, enabling Tesla to make better, more reliable batteries without making all R&D themselves, Panasonic can enter an everyday growing market which is Electric Vehicles.

3.4. The Goal to Make the World Cleaner – Free Patents & The Gigafactory

With Tesla's concern about energy sustainability and the way we "power" everything, from cars to houses, so the main priority is to establish the transition from internal combustion engines to electric powered ones. The effort is to make roads cleaner, more silent and better to spend time in, while, at the same time, EVs and ICE powered cars are as comfortable and practical. In Elon Musk's words, the main goal is to make this transition by bringing "transition to electric mobility by bringing a full range of increasingly affordable electric cars to market."

Having the intention to make the transition take place as soon as possible, Tesla did something considered impractical by some: make all the patents the company owns free, enabling other companies to work using their technology. Throughout history, there have been examples of such decisions that only made the innovation of the technology grow and at a better pace. From Elon Musk's point of view, the competition that should be fought is the OEMs producing fossil fuel powered cars and not the companies which, like Tesla, want to make electric cars appealing. As a result of this, Tesla's masterminds believe that the evolution EVs will take place at a much better pace, and new innovations are quite likely to take place, believing that, in a way, the transition from fossil fuels can more rapidly take place.

With ICE powered cars, the power is formed the momentary combustion, transforming the fuel into energy, the only necessity in these cars are for fuel tanks; in EVs this process is not so simple. In an EV, the power is stored in a battery, usually with lithium ions; the power is discharged when ions stored in the positive electrode to the negative one, and charged by plugging it to electricity, making ions do the inverse path. While looking simple, this is quite a complex procedure, and it is even more complicated when we take into account the fact that a battery needs to enable the car to have a good range, have a good life span, be resistant to high and low temperatures without compromising its performance too much, and still needs not to be too expensive.

In order to revolutionize the world, concerning the battery industry, Tesla intends to make a big factory to make huge amounts of batteries. Considering the pre-requisites of batteries mentioned above, Tesla can accomplish all but the cost issue and so, Elon

Musk's idea in 2015 was: "So it's either build a whole bunch of little factories or one big factory. And a whole bunch of little factories sounds like quite a bother. Why not just have one big one and maximize your economies of scale?" This is what justified the "Gigafactory" project, a 5 billion dollar plant in Reno, Nevada, which is intended to make the world's supply of lithium-ion batteries double until the next decade. The climate conditions in that place are ideal, due to the necessity to minimum humidity to manufacture batteries; and that allied with the area's low wages and cheap energy makes the location ideal.

To conclude, Tesla Motors is one of the most innovative companies at the moment, and that is step by step changing the world; this is justified by being second in Forbes' "The World's Most Innovative Companies" ranking, being the best considering the automotive industry. It is definitely a case of success in what changing the way we see automobiles is concerned, and, being such a "young" company, it is only the beginning.

4. Conclusion

4.1. Research Contributions

Considering the existing literature with reference to the innovation in the automotive industry and the technologies chosen as examples, a quite relevant insight was taken. All the information enabled us to get some conclusions and to validate an answer to the question "What can motorsports help the automotive with?" as several of the technologies mentioned were either brought from motorsport or improved through it. Despite motorsports being mostly focused on sheer performance, enhancing technologies can be used in road cars to make them more efficient, safe and even more comfortable.

As it is easily noticed, the innovation in the automotive industry is constant and at an ever growing pace. Just by looking at cars in the last 50 years we can see huge differences even on the outside, in what design is concerned; but the biggest differences happened out of sight, under the bodywork. In the 20th century most innovations can be considered mechanic ones, considering new technologies being applied at the mechanic parts of the cars. In the end of the last century and at the 21st electronics have kicked in and enabled innovation to develop at an exponentially quicker rate.

The introduction of electronics to a certain extent in the automotive industry enabled certain technologies to appear that could not be used to the degree they are when aided electronically. What is more, the whole electric innovation that is taking place is happening due to this electronic evolution in automotive.

After analysing the technologies approached in the literature review, the influence of motorsport in the automotive industry is utterly outstanding. When it comes to developing some component, there is absolutely no doubt that in motorsports the development takes place quite faster, saving time and money for the OEMs, not having to test technologies by themselves. Due to the competing nature in motorsports, racing cars are always taken to their limits, making the perfect scenario for innovations to take place and step up to previous technologies.

4.2. Motorsports influence over the time

Motorsport has associations that regulate it and the FIA is the organ that governs and administers the top level world motorsport championships, and therefore takes care of the path those championships follow. After being created, the biggest objective of motorsport was to improve the way cars behaved, by making them faster and more powerful. At some time, the power was too much, and during the 20th century, the FIA had to step in and make some changes in regulations. The mandatory use of the seatbelt is an example of this, but not only at safety did the FIA take action. In some championships, like F1, innovation is at its prime, and sometimes team engineers come up with technologies that take away the competitiveness of the sport, making the regulating body out rule some of those, for the sake of competition being maintained and innovation happening at a homogeneous pace.

In the 1980's the most popular motorsports championships- F1 and WRC- were at unprecedented levels in terms of sheer engine power due to a no-limitation policy. In F1 turbocharged engines were allowed and in WRC there were no regulations for the power unit in the at the time recent created Group B. The problem of the astronomic innovations were that the cars became unsafe both for drivers and for fans watching the races, which ended dictating the end of what many fans call "The Golden Age" of motorsport. During this period everything was "pure" due to the difficulty of driving such cars with little or no electronics to aid the process.

If we look to the past decade, we can see regulator's influence in a different way. As there have been more concerns about global warming and air pollution, the automotive industry has had to deal with certain regulations in terms of emissions and fuel consumption. To make motorsport more "green", the Federation has taken measures in these terms, making racing cars be as competitive while making less harm to the environment. From this, not only the environment but also road car manufacturers benefit, as the mentioned innovations can be utilized when adapted.

As mentioned above, technologies like KERS and the use of composites in road cars took place after motorsports enhanced its use, or started using such things at the first place. This happens due to the necessity of lighter cars and the efficiency improvement in energy terms that are necessary in racing. These two things can make road cars lighter, making them have better fuel consumptions and recover energy when braking, enabling them to use energy (only in hybrid or plug-in hybrid cars) to make the car move.

The creation of a racing series fully electric powered by the FIA made its support of electric powered cars noticeable. It also shows that the organization wants to show fans and the motorsports community that races can be held at hectic city centres without disturbing urban life with noise and pollution. This all happened with the creation of Formula-e, in which all races are held in city circuits, also to allow an approach to city inhabitants.

4.3. Tesla

The case of Tesla was an obvious example of what innovation can be at the automotive industry. After risking in investing in making an electric sports car with an above average range but with a cost above $100.000, the American brand stretched for success. With a peculiar market penetration strategy, Tesla opted for launching new models, with lower prices but with the intention to sell in larger volume.

The role of Tesla in the automotive is still not at its full potential. Despite having already come up with revolutionizing electric cars, there is a lot in the administrators mind to be done, so this can be considered just the beginning. With years going by and with the innovation process continuing, Tesla will certainly innovate in their cars and improve the flaws they have at the moment.

These were the contributions so far to the automotive industry, but Tesla’s goal is not to be a huge presence only at the automotive industry. Tesla has the intention to revolutionize the world in terms of energy supply, so that energy can be “cleanly” produced, without recurring to fossil fuels. This is why the batteries used in the cars are already being used to store energy caught in solar panels, so that households can be powered with this energy.

4.4. Limitations and further research

Every investigation has intrinsic difficulties when information availability is concerned, and this was no exception. At the beginning, there was some difficulty in finding the appropriate bibliography online, so some research was made in several magazines specifically dedicated to motorsport engineering and the motorsport professional world. Despite all this, the necessary information was found and eventually all examples and needed references were found.

Furthermore, some research could be done in this area, concerning automotive innovation allied with motorsport. For instance, autonomous car driving is something certainly worth investigating. As a matter of fact, a new racing championship called Roboracing has been idealized, in which electric driverless cars run automously in racing circuits. This evolution has been mentioned as the natural development after Formula E by one of the participating teams, Mahindra, by the chief engineer Vinit Patel in 2016. Considering Tesla's autopilot technology being developed at the moment even if not yet available at all cars and permitted legally the path to "driverless cars" is already started.

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