MCE 4787

Automobile Engineering

A Review of Modern Automotive Technologies

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Table of Contents

Abbreviations

- KDD – Koenigseg Direct Drive
- CVT- Continuously Variable Transmission
- EV- Electric Vehicles
- AEB- Automatic Emergency Braking
- CE- Combustion Engine
- ICE- Internal Combustion Engine
- ECU- Electrical Control Unit
- LIDAR- Light Detection and Ranging
- ACC- Adaptive Cruise Control
- BSM- Blind-Spot Monitoring
- HUD- Head-Up Display
- CO- Carbon Monoxide
- VOCs- Volatile Hydrocarbons
- NOx- Nitrogen Oxides

Modern Automotive Technologies

Koenigsegg Direct Drive (KDD): KDD replaces the traditional transmission system with the advantages of EV (Electric Vehicle) mode. This system rear axle is connected to the CE through a direct drive, eliminating the need for gear reduction and variable transmission. KDD is proved to be 50% more efficient than CVT or traditional transmissions [1].

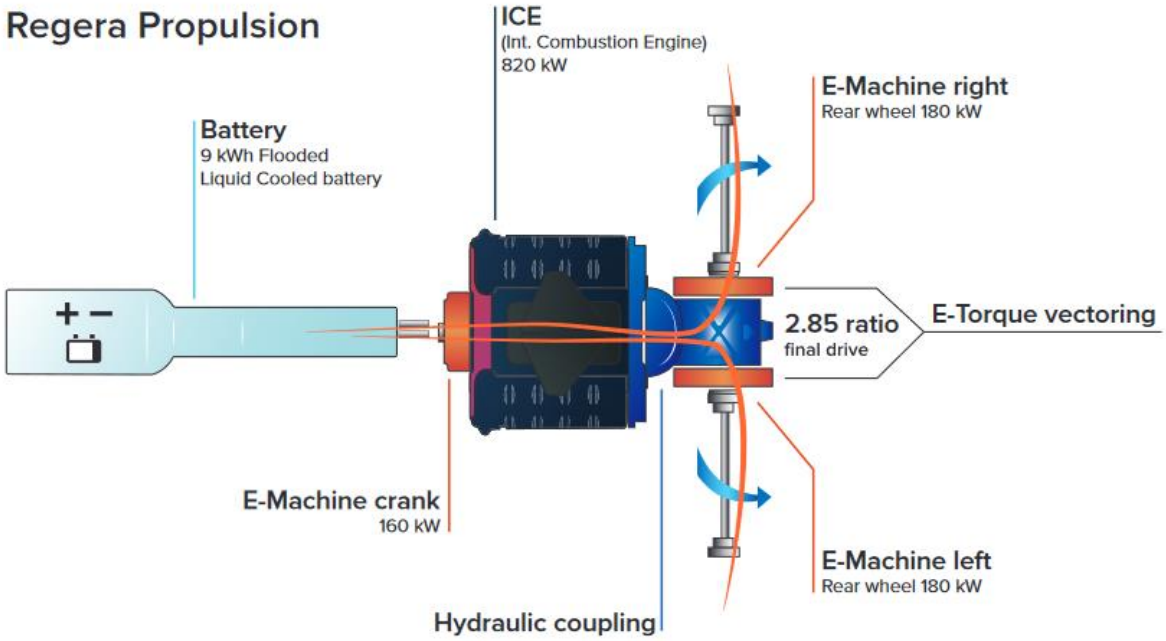

Figure 1: Schematic of KDD [1]

Cam-Less Engine (Free Valve): 'Freevalve' design excludes the camshaft's necessity to control the valves in the engine cylinders. Theoretically, it can be called variable valve control. In this system, the valves can be controlled individually using actuators (little pistons) above each tappet. It can be lifted whenever the car's brain (ECU) wants it to open, remain open as long as the brain says, and be raised anytime in the engine cycle. Also, the brain can order the valves to stay close throughout the cycle [2]. A certain amount of compressed air presses the piston to open the valve. When the air is released, spring forces the piston back to its original position. The piston can also be locked in the open position by pushing oil from the reservoir [2].

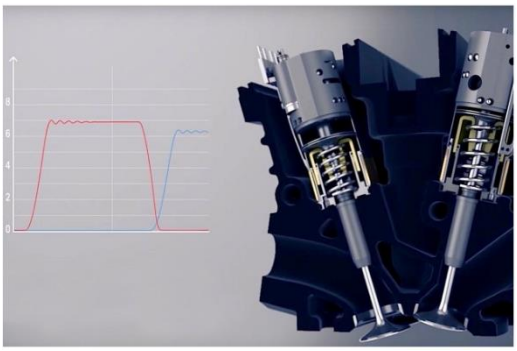

Figure 2: Freevalve Design [21]

LIDAR(Light Detection and Ranging): Although NASA developed it for space applications, it is becoming crucial for autonomous cars. LIDAR uses a laser to map (three-dimensional model) its surroundings quickly and precisely with less amount of time. Autonomous vehicles need accurate and reliable data of their environment to work properly. LIDAR can act as the eyes of cars. Cameras are being used in AVs, but the time required to process data from cameras is greater than LIDAR. Also, LIDAR is superior in terms of accuracy [3].

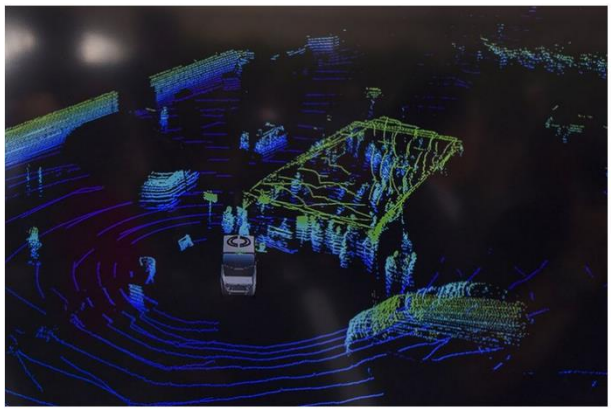

Figure 3: Mapping of LIDAR [3]

Challenges

As the technologies continue to evolve, vehicles are getting more and more efficient. At the same time, the cost of newer technologies is increasing at a higher pace. Thus, most modern technologies are still out of reach of the general people and are limited to only a few percent.

Modern cars are becoming more and more data-driven [4]. To handle this enormous amount of data and complex problems are hassles. Also, rules and regulations make it difficult for the industry to tackle the issues.

Today's vehicles use a lot of electronic sensors, which help in the data-driven decision-making process. Still, superficial flaws of these sensors can lead to detrimental effects causing life-threatening situations for the passengers.

Future Recommendations

- Companies should test the new technologies rigorously before implementing them at the consumer level.
- The automobile industry should try to bring modern and efficient technologies to the general mass.
- Cost-effective solutions should be given priority.

Safety

Adaptive Cruise Control (ACC): ACC monitors roads, other cars, and objects and helps the driver keep the speed constant or steady [5]. The radar sensor allows ACC to watch all the factors [6]. ACC system is placed at the front of a car, and depending on the situation, it controls the

speed. If the system detects the road is clear, then it maintains the pace set by the driver. Again, if the system detects a slow vehicle in front, then ACC decelerates the car. If it detects accelerating vehicles or vehicles trying to change lanes, it will accelerate the vehicle [6]. There are different modes available in ACC which can be activated or deactivated by the driver.

Figure 4: Working of ACC [5]

Blind-Spot Monitoring (BSM): Drivers cannot see certain areas while driving a car, mostly changing lanes or turning into another direction. These areas are called blind spots and if there is another vehicle in the driver's blind spot accident is imminent. A series of ultrasonic sensors or radars are placed at the sides and rear of the car to detect other vehicles approaching or changing lanes and notify the driver [7]. A blind-spot monitoring system gives coverage of every corner and every side of the car, and drivers do not need to worry while driving. BSM can also activate the brake system and steering control to avoid collision when other vehicles or objects are nearby [7]. BSM gives a greater degree of freedom to the drivers and helps in a stress-free drive.

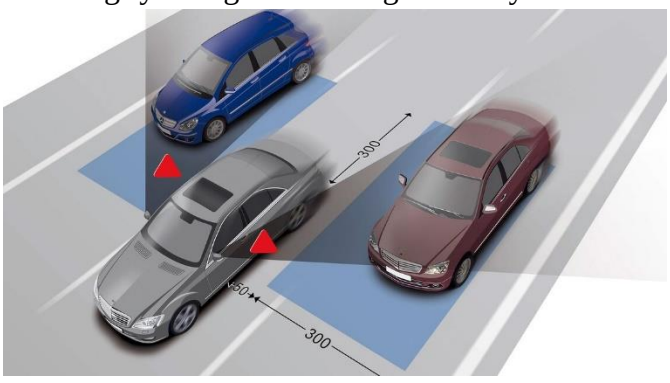

Figure 5: Blind-Spot Monitoring System [8]

Automatic Emergency Braking (AEB): Modern cars are often equipped with automatic emergency braking to reduce the risk of rear-end collisions and accidents while the vehicle runs in reverse gear. It also assists while turning across paths and crossing [9].

In the heart of the AEB system, radar sensors are placed in front and corners of the vehicle. The AEB system constantly monitors the distance between the cars/other vehicles in front. If the other vehicle is within a specific limit of the AEB system, it notifies the driver and starts braking, which gives the inattentive drivers some time to react. The AEB comes into play when the car is in reverse gear, and the driver does not look at the vehicle or other object right behind it. Thus the AEB automatically slows down the vehicle and reduces the risk of accidents [9].

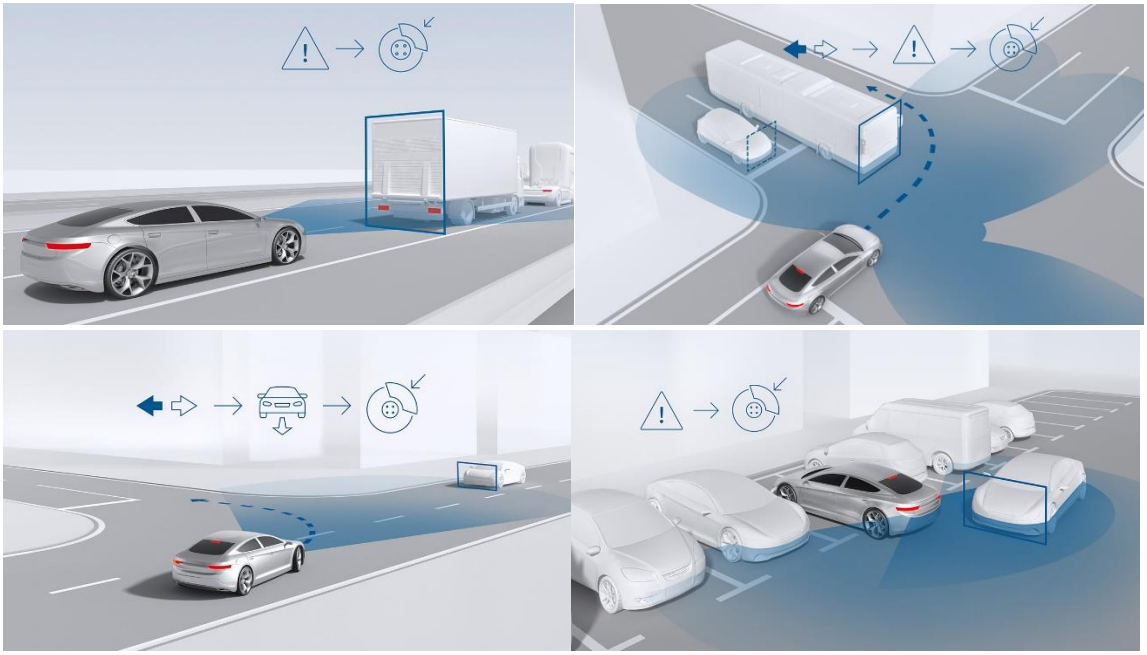

Figure 6: Working of AEB [9]

Head-Up Display (HUD): The drivers often need to look into the monitor (and need to head down for that purpose) for different information such as speed, fuel reserve for safe drives. However, here lies a potential flaw because the drivers need to take off their eyes from the road to the monitors, which can be dangerous in some cases and cause fatal accidents. To address this problem, manufacturers have developed a solution in which the giant windshield can be used as a transparent screen [10]. The necessary information is directly projected onto the screen and in line with the drivers' sight. Thus, the drivers do not need to head down to search for the info. This

solution eliminates the need to take off eyes from the road, and drivers and passengers can enjoy

safe journeys.

Figure 7: Head-Up Display [10]

Challenges

Though modern cars have come a long way in the case of safety, still there are lacking. Autonomous and semi-autonomous vehicles are becoming popular but still, there are safety issues. Bad weather makes it harder for cars to make accurate decisions because they encounter anomalies in data. Accurately mapping the environment in three dimensions is still challenging for autonomous vehicles.

The airbag is one of the most popular safety features of modern cars, which still lack precision. The actuation force of the airbag is pre-determined, but often, it is noticeable that the airbag fails to open in case of an emergency or accident.

Modern cars are increasingly dependent on the data gathered from the sensors. Even a simple flaw in the whole network can be detrimental for the passengers. Designing this complex system of sensors is getting more complicated every day. It has been seen that AEB or lane-keeping assistance is being triggered falsely because of the flaws in the sensory system.

Future Recommendations

- The testing system of the safety features should be rigorous. Without details of the test data, new technologies should not get clearance.
- Materials for making the cars should be chosen in such a way so that they can withstand certain damages.

- The concerning authorities must apply the safety regulations strictly.

Environmental Pollution

Modern automotive technologies always try to reduce pollution, especially air pollution. Some of the prominent technologies are discussed here.

Catalytic Converter: Catalytic converter helps convert dangerous pollutants into less harmful ones before leaving the exhaust system to the environment. The catalytic converter reduces the CO, VOCs, NOx from the exhaust gas. Modern vehicles have a 'three-way catalytic converter' installed in them which has three stages of reduction. They are reduction catalyst, oxidation catalyst, and feedback control system [11].

Reduction catalyst, consists of platinum and rhodium, controls the NOx emissions. The oxidation stage minimizes the CO and hydrocarbon emissions. The feedback control system includes sensors, monitors the exhaust gas, and sends information to the ECU. The ECU, in turn, controls the fuel injection to the engine and helps reduce the hazards of exhaust gas [11]. Different kinds of automobiles are being manufactured, such as electric vehicles, hydrogen-powered vehicles, hybrid cars, etc., to help reduce the environmental impact.

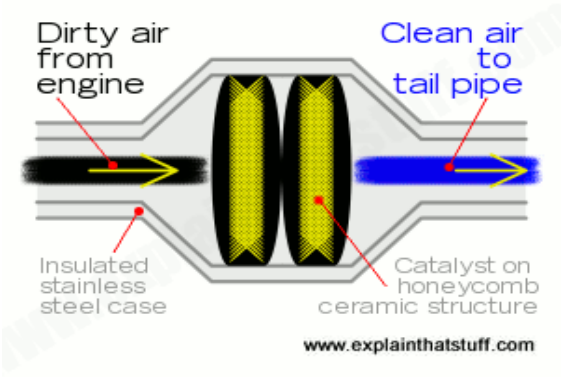

Figure 8: Catalytic Converter [12]

Electric vehicles do not have combustion engines; instead, they run on electric motors powered by lithium-ion batteries. EVs do not have emission problems like CEs and are considered clean. Nevertheless, the batteries do have environmental impacts.

Hydrogen-powered vehicles also do not have any pollution problems because they only emit H_2O as a by-product. Hydrogen is known to be the cleanest fuel. However, producing hydrogen mostly depends on fossil fuels and does have impacts on the environment.

Hybrid vehicles combine the combustion engine with battery packs and electric motors. They can operate on two modes, EV and normal mode. In normal mode, the car is powered by the combustion engine, while in EV, the car runs on electric power. Hybrids have considerably fewer emission problems than conventional CEs.

Modern cars also use particulate filters to mitigate environmental hazards.

Challenges

Though companies are making a significant effort to reduce the emission from combustion engines, there is an upper limit to reducing the emissions. Thus, they are trying to shift to electric vehicles, hydrogen-powered vehicles, and hybrids. However, these cars are costlier than conventional CEs. Here lies another problem, the more efficiently a car can handle emissions, it

becomes costly. High initial prices keep the public away from these efficient and advanced vehicles. Thus, it is more challenging to keep innovating and, at the same time, lowering the prices.

Future Recommendations

- More effort should be put into making the technology cheaper and available to the mass.
- The authorities should try to minimize the emissions gradually and at a steady rate. It would give more time to innovate and make the process easy to adopt.
- People should be educated about the green and clean environment to choose the alternative, which is better for the environment.
- Companies must work with the governments to establish themselves as green companies.
- Continuous innovations should be encouraged.

Fuel Economy

Turbocharger: Turbocharger uses the energy of otherwise wasted exhaust gas to suck in and compress fresh air and then supplies to the engine. It has a turbine and compressor connected through a common shaft. The exhaust gas, coming from the engine, goes into the turbine and losses its energy to the turbine and leaves. The turbine converts the energy to the rotational motion of the shaft, which, in turn, runs the compressor. The compressor sucks in fresh air from the environment, compresses it, and passes it to the intercooler. The intercooler cools down the hot compressed air and sends it to the engine's air intake manifold [13]. In this way, turbo helps to be more economical.

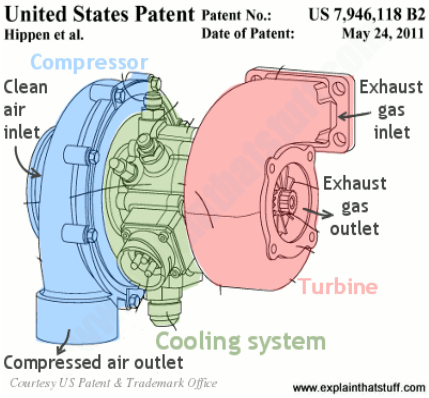

Figure 9: Turbocharger [13]

Continuously Variable Transmission (CVT): The CVT is more like automatic transmissions, but unlike them, it does not have a gearbox. Most basic CVT uses a pulley system, enabling an infinite number of gear ratios without shock between the two extreme gears. There are other CVTs known as 'Toroidal CVT,' 'Hydrostatic CVT [14]. It helps in fuel economy by enabling continuous alteration of engine speed and power transmission [15]. This alteration ensures that

Figure 10: Basic Pulley CVT [15]

only the right amount of fuel enters the engine. CVT offers 'stop-and-go in an easier way. CVT lessens the power loss and, at the same time, offers more control over the speed range [14]. As a result, it provides better fuel economy than other conventional transmissions.

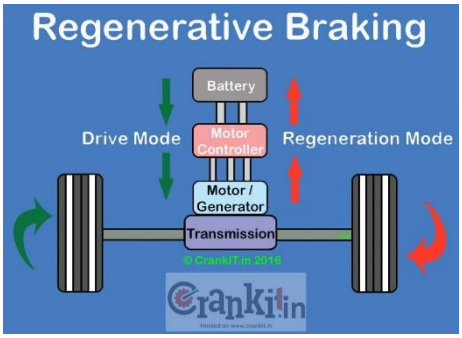

Figure 11: Energy flow in RB[22]

Regenerative Braking: Modern cars are equipped with the technology called 'regenerative braking.' The principle of this system is straightforward. When the driver brakes on a vehicle, the brake pads create friction to slow it down and generate heat. Thus, energy is wasted. Regenerative braking takes this wasted energy to charge a battery that powers a car's auxiliary electric systems, minimizing fuel consumption. Regenerative braking can be found in conventional combustion engines and electric and hybrid vehicles [16]. Regenerative braking helps improve fuel economy by utilizing the wasted energy of braking.

Challenges

There are a lot of technologies available to enhance the fuel economy of vehicles. Nevertheless, not all of them are perfect. Thus, there is a vast difference between theory and practical. Also, implementing new technologies is often challenging.

Future Recommendations

More effort should be given to the current technologies to make them perfect. Thus, helping in better fuel economy, better performance, and reducing loss.

Vehicle Regulations

Safety Regulations:

WHO sets several safety regulations, some of them are [17]:

- There must be standards of the car's frontal and side protective equipment to withstand damages at a specific speed.
- For the prevention of skidding and losing control, an electric stability controller should be there.
- Bumper and front-end modifications of cars are necessary to ensure pedestrian protection.
- ABS is a must-have for motorcycles.
- Manufacturers need to ensure child safety, and passengers need to use seat belts.

Emission Regulations: Most of the countries have their own set of emission laws for on-road vehicles. UK, USA, Canada, EU, India, etc., all have rules that must be met to run the cars on roads. Here is a figure of the European emission standards [18]:

European emission standards for passenger cars (Category M)*, g/km

Tier	Date (type approval)	Date (first registration)	CO	THC	VOC	NO_x	HC+NO_x	P	PN [#/km]
Diesel									
Euro 1†	July 1992	January 1993	2.72 (3.16)	-	-	-	0.97 (1.13)	0.14 (0.18)	-
Euro 2	January 1996	January 1997	1.0	-	-	-	0.7	0.08	-
Euro 3	January 2000	January 2001	0.66	-	-	0.50	0.56	0.05	-
Euro 4	January 2005	January 2006	0.50	-	-	0.25	0.30	0.025	-
Euro 5a	September 2009	January 2011	0.50	-	-	0.180	0.230	0.005	-
Euro 5b	September 2011	January 2013	0.50	-	-	0.180	0.230	0.0045	6×10^{11}
Euro 6b	September 2014	September 2015	0.50	-	-	0.080	0.170	0.0045	6×10^{11}
Euro 6c	-	September 2018	0.50	-	-	0.080	0.170	0.0045	6×10^{11}
Euro 6d-Temp	September 2017	September 2019	0.50	-	-	0.080	0.170	0.0045	6×10^{11}
Euro 6d	January 2020	January 2021	0.50	-	-	0.080	0.170	0.0045	6×10^{11}
Petrol (Gasoline)									
Euro 1†	July 1992	January 1993	2.72 (3.16)	-	-	-	0.97 (1.13)	-	-
Euro 2	January 1996	January 1997	2.2	-	-	-	0.5	-	-
Euro 3	January 2000	January 2001	2.3	0.20	-	0.15	-	-	-
Euro 4	January 2005	January 2006	1.0	0.10	-	0.08	-	-	-
Euro 5a	September 2009	January 2011	1.0	0.10	0.068	0.060	-	0.005**	-
Euro 5b	September 2011	January 2013	1.0	0.10	0.068	0.060	-	0.0045**	-
Euro 6b	September 2014	September 2015	1.0	0.10	0.068	0.060	-	0.0045**	6×10^{11}***
Euro 6c	-	September 2018	1.0	0.10	0.068	0.060	-	0.0045**	6×10^{11}
Euro 6d-Temp	September 2017	September 2019	1.0	0.10	0.068	0.060	-	0.0045**	6×10^{11}
Euro 6d	January 2020	January 2021	1.0	0.10	0.068	0.060	-	0.0045**	6×10^{11}
Petrol (gasoline) and diesel									
Euro 7[20](proposed)	2025[21]	2025[21]	0.1 to 0.3[22]			0.030[22]			

* Before Euro 5, passenger vehicles > 2500 kg were type approved as light commercial vehicles N_1 Class I
** Applies only to vehicles with direct injection engines
*** 6×10^{12}/km within first three years from Euro 6b effective dates
† Values in parentheses are conformity of production (COP) limits

Figure 16: European Emission Standards [18]

India set their emission laws in 2000 based on the European standard. Bangladesh has set 4.5% CO emissions from petrol-powered vehicles, 1200ppm for hydrocarbons, 3% CO emissions from CNG-powered vehicles, smoke opacity of 65 HSU and 72 HSU for diesel, and turbocharged diesel engines as standard [19].

Fuel Economy Regulations:

Nine countries, India, US, Brazil, Canada, China, Japan, EU, Mexico, KSA, have set their fuel economy rules [20]. All the vehicles must comply with the regulations. A chart from [20] is given below, which depicts the laws:

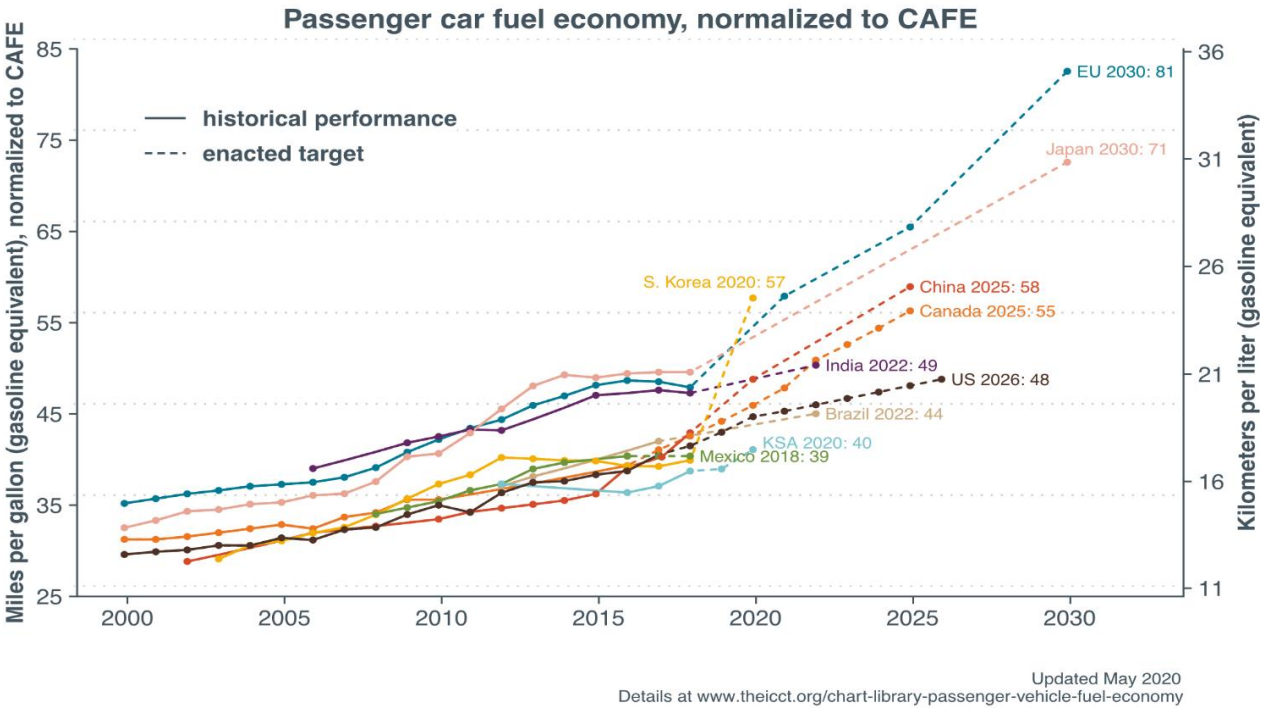

Figure 16: Fuel Economy Rates [20]

Challenges and Recommendations

- It is particularly challenging for the governments and authorities to apply the rules and regulations because of the unwillingness of the manufacturers to comply with them. However, authorities must be strict when it comes to safety, pollution, and fuel economy.
- There is another challenge. Technology is changing rapidly, and we often see that laws are not in harmony with newer technologies. For instance, rules and regulations from a decade ago will not comply with the current scenario because there were not as many electric/hybrid/autonomous cars as we see today.
- Rules and regulations must be updated regularly. They must keep pace with the ever-changing world of technology. With new technologies, different dimensional problems come up, and to tackle them, we need to adopt new rules and regulations all the time.

References

[1] R. Coppinger, "Direct drive," *Engineer*, vol. 292, no. 7634, p. 13, 2003.

[2] "Here's how the Koenigsegg Gemera's 600bhp camless engine works | Top Gear." https://www.topgear.com/car-news/future-tech/heres-how-koenigsegg-gemeras-600bhp-camless-engine-works (accessed Jul. 17, 2021).

[3] "What Lidar Is and Why It's Important for Autonomous Vehicles." https://www.autoweek.com/news/a36190274/what-lidar-is/ (accessed Jul. 17, 2021).

[4] "Top challenges automotive industry facing today." https://www.gminsights.com/blogs/todays-challenges-in-automotive-industry (accessed Jul. 17, 2021).

[5] "What is Adaptive Cruise Control? | TomTom Blog." https://www.tomtom.com/blog/automated-driving/what-is-adaptive-cruise-control/ (accessed Jul. 17, 2021).

[6] "Adaptive cruise control for passenger cars." https://www.bosch-mobility-solutions.com/en/solutions/assistance-systems/adaptive-cruise-control/ (accessed Jul. 17, 2021).

[7] "Another set of eyes: How does blind spot detection work?" https://www.hyundai.news/eu/articles/stories/another-set-of-eyes-how-does-blind-spot-detection-work.html (accessed Jul. 17, 2021).

[8] "Is Blind-Spot Monitoring Worth It? What Is It Exactly?" https://www.motortrend.com/features/blind-spot-monitoring/ (accessed Jul. 17, 2021).

[9] "Automatic emergency braking." https://www.bosch-mobility-solutions.com/en/solutions/assistance-systems/automatic-emergency-braking/ (accessed Jul. 17, 2021).

[10] "How does head-up display work?" https://www.hyundai.news/eu/articles/stories/how-does-head-up-display-work.html (accessed Jul. 17, 2021).

[11] "How Catalytic Converters Work | HowStuffWorks." https://auto.howstuffworks.com/catalytic-converter.htm (accessed Jul. 17, 2021).

[12] "How do catalytic converters work? - Explain that Stuff." https://www.explainthatstuff.com/catalyticconverters.html (accessed Jul. 18, 2021).

[13] "How do turbochargers work? | Who invented turbochargers?" https://www.explainthatstuff.com/how-turbochargers-work.html (accessed Jul. 18, 2021).

[14] "How CVTs Work | HowStuffWorks." https://auto.howstuffworks.com/cvt.htm (accessed Jul. 18, 2021).

[15] "Are CVTs The Fuel-Efficient Transmission Of The Future?" https://www.greencarreports.com/news/1078072_are-cvts-the-fuel-efficient-transmission-of-the-future (accessed Jul. 18, 2021).

[16] "Regenerative braking: what is it and how does it work? | Auto Express."

https://www.autoexpress.co.uk/tips-advice/353643/regenerative-braking-what-it-and-how-does-it-work (accessed Jul. 18, 2021).

[17] E. Desapriya, “Vehicle safety standards,” *Traffic Saf.*, pp. 201–222, 2011.

[18] “European emission standards - Wikipedia.” https://en.wikipedia.org/wiki/European_emission_standards (accessed Jul. 18, 2021).

[19] “Most motorcycles, buses, and trucks worsening air quality | Dhaka Tribune.” https://www.dhakatribune.com/bangladesh/dhaka/2020/03/01/most-motorcycles-buses-and-trucks-worsening-air-quality?__cf_chl_managed_tk__=pmd_7aad7201026b20b6f8074a7a544d0183ab86d410-1626620962-0-gqNtZGzNAyKjcnBszQgO (accessed Jul. 18, 2021).

[20] “Chart library: Passenger vehicle fuel economy | International Council on Clean Transportation.” https://theicct.org/chart-library-passenger-vehicle-fuel-economy (accessed Jul. 18, 2021).

[21] “Video: See How The Koenigsegg Camless Engine Works.” https://www.enginelabs.com/news/video-see-how-the-koenigsegg-camless-engine-works/ (accessed Jul. 17, 2021).

[22] “Regenerative Braking: What Is It & How Does It Work? - CarBikeTech.” https://carbiketech.com/regenerative-braking-working/ (accessed Jul. 18, 2021).