DOI: 10.7251/JTTTP2201026T
UDC: 629.3:621.43

REVIEW

New Phase of Motor Vehicle Development

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Received: December 22, 2021
Accepted: June 5, 2022

Abstract: Development of motor vehicles has gone through several technological phases and today we are definitely in a new era that is primarily related to steering autonomy and vehicle propulsion systems. Although electric vehicles have become an absolute priority in some countries, their global expansion is happening and it is to be expected that they will become a near future in these regions as well. Today, special attention is drawn to advances in the development of autonomous driving systems, which will cause many changes in design, regulations and the environment. For the coming wave of change, we need to be adequately prepared and take part in global processes. In addition, it should be noted that the futuristic versions of vehicles capable of moving in multiple environments, on land, on or in water and in the air, are being widely promoted, and the EU is introducing mandatory application of some active and passive safety systems.

Key words: vehicle development, electric vehicles, automated driving.

INTRODUCTION

Until the advent of the mobile phone, the car was the most commonly owned item. Today, it is estimated that there are about 1.5 billion vehicles in use on Earth, which means that every fifth inhabitant owns a vehicle. The development of cars was conditioned by development of technology, materials, energy, legislation, etc. The result of this is that almost every manufacturer has vehicles on the market in every segment. The period of the development cycle of the new type is decreasing and the number of manufactured vehicles is increasing. Although the vehicles look alike, out of 100 vehicles of the same type and model, only 5 completely identical vehicles will come off the production line. The new generation of luxury models has up to 70 different computers that control the operation of vehicles or serve for assistance purposes. This diversity indicates that many vehicle functions are related to modern information technology and computers. The role of the driver will become less and less important and driving comfort becomes greater. The autopilot has long shown its superiority over the professional driver. Already today in the serial offer we have vehicles with automated driving systems, so the question arises when the vehicle will definitely become self-driving in mass use. Models of vehicles that have the ability to move on the roads and in the air are exhibited at the fairs. What lies ahead in near future? Shall we, soon, only remember, with sadness, vehicles with conventional mode of operation and driving?

FROM THE FIRST CAR UNTIL TODAY

The first car is associated with Karl Benz and his construction of the first functional type of vehicle, which had all the basic construction systems as well as today's vehicles: body, drivetrain, engine, steering system, braking system and light signaling devices.

It is interesting to recall some important dates from the automotive industry and the dynamics of development of individual devices:

- 1828 Electric motor
- 1832 First electric car
- 1878 Gasoline internal combustion engine
- 1886 First car with gasoline engine
- 1897 Diesel internal combustion engine
- 1895 First tire
- 1918 Electric starter
- 1924 Integral body
- 1924 Hydraulic brake
- 1928 Synchronous transmission
- 1939 Automatic transmission
- 1947 Radial tire
- 1953 Disc brakes
- 1950-60 Fuel Cells
- 1974 Anti-lock- braking (ABS) system
- 1980 The reduction of exhaust emissions
- 1990 Start with application of computers in the automotive industry
- 1997 Hybrid vehicles

Time will tell in which direction the development of the vehicle is heading, in terms of propulsion energy, assistance system, automatic control and combination of modes of transport, and this paper will present some forecasts of the future development of vehicles and their systems.

DEVELOPMENT OF ENGINES

Exacerbated problems of environmental pollution, the greenhouse effect, uncertainty regarding oil reserves and the development of innovative technologies have contributed to the fact that today very intensive work is being done on improving existing engines and developing alternative motor vehicle propulsions.

Conventional propulsion

Internal combustion engines have experienced absolute dominance as a propulsion system for motor vehicles after resolving "children's diseases" and after the discovery of oil. Although the basics of internal combustion engine construction are based on solutions that are over a hundred years old, various innovations are still very successfully applied to them, which enable higher specific power, lower mass, better traction and speed characteristics, etc. The period of their domination lasted from the first vehicle until today, but alternative modes of propulsion are rapidly developing, which could soon suppress internal combustion engines, especially as the basic variant of motor vehicle propulsion.

Hybrid propulsion

Hybrid propulsion involves a combination of several types of propulsions. Until recently, such vehicles were produced only for military purposes, but today we have a wide range of very successful solutions of combined types of propulsion on the market. For now, the internal combustion engine and the liquefied petroleum gas are most often combined, and more recently the electric motor, in various variants and versions. The combination of internal combustion engines and electric motors utilizes the best characteristics of both drives, reduces pollution, reduces noise, and makes driving cheaper and so on.

Electric vehicles

It is interesting to mention that the electric vehicle was made about 20 years before the first vehicle powered by an internal combustion engine, but a number of circumstances have contributed to their actual affirmation in the last twenty years. Today, all major manufacturers have serious plans and are allocating large funds for the development of electric vehicles. We already have an enviable offer of electric vehicles whose motor is powered by its own battery. It is considered that fuel cell vehicles are the vehicles of the future, but much remains to be done to improve the design, although we already have fuel cell vehicles in serial production. How fast the development of electric vehicles is progressing can be seen in the behavior of some manufacturers, who have already stopped producing vehicles with conventional propulsion.

DEVELOPMENT OF VEHICLE STABILITY SYSTEMS

With the advancement of science and technology, manufacturers place on the market vehicles with very respectable speed performance, which poses a very delicate task for designers, how to tame a vehicle in some situations and adapt it to the average driver. Development of Anti-lock braking system (ABS) has created a ground basis for the construction and application of other systems that have become mutually complementary.

Electronic Stability Program

Electronic Stability Program ESP is tasked to neutralize the influence of the centrifugal force that causes inclination of the vehicle when driving in a curve. It is also called the dynamic stability program because with targeted action on individual brakes, and engine mode, it maintains the dynamic stability of the vehicle. ESP includes two main functions DSP (dynamic stability system) and ROP (rollover protection). DSP takes care mainly of the vehicle's stability at a lower coefficient of adhesion (e.g. rain, snow, ice). As a rule, it is activated only when there is a significant difference between the driver's desired direction of travel and the actual movement of the vehicle. Roll over Prevention (ROP) reduces the risk of rolling over with a high coefficient of adhesion on dry road.

Anti-slip regulation (ASR) system

This system should prevent the drive wheels from slipping in conditions of reduced or uneven grip, such as wet surfaces, ice, gravel, etc. The system is regulated by acting on the individual brakes and the engine operating mode.

Electronic brake force distribution system

The role of this system is to prevent the rear wheels from braking too hard before the anti-lock brake system is activated or when it is out of order.

Electronic differential lock system

The electronic differential lock allows driving on different surfaces, i.e. under different traction conditions, by activating the brakes on wheels which are slipping.

Engine Braking Control System (EBC)

This system prevents the driven wheels from locking due to engine braking when the accelerator pedal is released suddenly or when vehicle is braking with any gear engaged.

THE DEVELOPMENT OF THE ASSISTANCE SYSTEMS

The development of electronics has made driving as comfortable and safe as possible. We are assisted in this by various driver assistance systems, which warn, restrict and help him/her perform certain actions while driving. To illustrate, a few commonly used ones will be mentioned.

Panoramic view monitor

The panoramic view monitor, which shows the vehicle from a bird's eye view, has been enhanced with a view that "sees" through objects. At the touch of a button, the driver switches between a bird's eye view and a see-through view, which allows the driver to see the vehicle's surroundings as if the vehicle itself were transparent. Compared to the bird's eye view, the see-through view makes it easier to spot obstacles, as they are more clearly displayed on the monitor.

Active parking assist system

The parking assist system facilitates parallel and lateral parking of the vehicle. Whether activated or not, the system measures potential parking spaces as you pass them at low speeds (up to 35 km/h) at a maximum distance of 1.5 m from the row of parked cars. When a large enough space is found, the driver turns on the turn signal and the auxiliary parking device takes control of the vehicle, while the driver takes care of speed, brake and transmission. The system gives instructions on the control monitor and acoustic signals during parking. More advanced parking systems can do parking without driver assistance.

Parking support

When leaving the parking space by driving backwards, you get support for continuous monitoring of the road behind the vehicle via a sensors in the rear bumper. The support system provides visual and acoustic warnings when obstacles such as pedestrians, other vehicles or obstacles occur. In an emergency, automatic brake control prevents a collision.

Reversing cameras

Rear cameras allow the driver to see the area behind the car while maneuvering or parking with assistance of the control monitor. Reversing cameras also improve visibility when reversing at lower speeds. Vehicle guidance lines and color-coded obstacles, which appear on the control monitor, show the driver whether the selected parking space is long and wide enough for the vehicle and makes parking easier. Ultrasonic sensors constantly measure the distance between the car and the obstacle and the acoustic signal warns of possible dangers and thus reduces the chances of damage when parking.

Cameras for driving in conditions of reduced visibility

These cameras provide drivers with an overview of the situation on the road, outside the limits of normal visibility to the eye, at night, driving in fog and in other situations when visibility is reduced.

The adaptive cruise control

Adaptive cruise control (ACC) automatically regulates vehicle speed and distance from the vehicle in front. Automatic cruise control automatically brakes prematurely, if necessary, and maintains a safe distance between vehicles. This prevents sudden braking, which can cause another vehicle to crash from behind. Radar cruise control, in addition to maintaining the distance between vehicles, when the vehicle in front accelerates or moves away, reacts and car accelerates again to the desired speed. In cooperation with the Stop & Go function, it also helps in traffic jams or in conditions of slow traffic, automatic stopping and starting the vehicle.

Start-Stop (Go & Stop) system

The task of the start/stop system is to automatically switch off the engine when the vehicle is stationary. The engine is switched off as soon as the foot is removed from the accelerator pedal and switched on with a next pressure on the accelerator pedal. In this manner, fuel is saved and environmental pollution is reduced.

Lane Keeping System

This system warns of lane departure by detecting lane lines and alerts the driver to accidental lane changes when the vehicle reaches a certain speed, via an audio signal or steering wheel vibration. The system will not activate if the lane change is intentional, when the driver activates the turn signal.

Traffic Signs Recognition System

A camera housed in the interior mirror registers traffic signs with speed limits and overtaking restrictions and displays them on the instrument panel display. In this way, the driver is more focused on driving than on remembering signs because he/she knows at all times how fast he/she is allowed to drive and whether overtaking is allowed.

Blind spot detection system

This is a device that monitors side and rear of the vehicle and warns driver with a light or sound signal of the vehicle which is in a blind spot. The system is especially useful when changing lanes or on roads where several vehicles are moving in parallel.

Brake Assist System (BAS)

It is an additional system to ABS which helps reduce vehicle stopping distance while sudden braking. This system recognizes a situation where sudden braking is required. In this case, the system is currently developing its maximum power and may include ABS adjustment.

Emergency Brake Assist (EBA)

The Emergency Brake Assist system (EBA) makes vehicles even safer and reduces the risk of accidents. The system combines information from radar sensors and cameras in the front of the vehicle, which enables faster detection of dangerous situations and timely activation of emergency braking. On this occasion, in addition to the brake lights, the Emergency Stopping Signal (ESS) is activated, which warns road users with flashing lights with increased blinking frequency to a critical situation, thus reducing the risk of collisions.

Hill-Hold Control

Hill-Hold-Control allows vehicle to start going uphill without reversing the vehicle and without applying the parking brake. Also, when the brake pedal is released after stopping on an uphill, the uphill support will maintain pressure in the brake system for 1 to 2 seconds, long enough to continue relaxed driving without rolling the vehicle wheels backwards.

Pedestrian alert system

Pedestrian alert system, with soft braking function, reacts to pedestrians and operates at speeds between 10 and 60 km/h and emits a warning in the event of imminent danger. In the event of a danger, the system initiates braking and thus reduces the speed at which a collision can occur. The system works in steps - the warning symbol appears first, then the symbol starts flashing and a beep sounds, and finally a slight braking occurs.

Automatic adjustment of headlights and wipers

Adaptive headlights are very sophisticated. They work by monitoring the position of the steering wheel, vehicle speed and its inclination, and based on that headlights direct the light beam in the direction of the road, and not directly, like classic headlights. Additional, somewhat less demanding technological device that helps in better visibility is the rain sensor connected to the windshield wipers. If moisture is detected, the sensor turns on the wipers, and at the same time, depending on the amount of moisture, determines the speed of wiping.

High beam assist

High beams are automatically switched from high to low beams and vice versa, depending on the traffic situation. When the system is active, a camera installed on the inside of the mirror monitors the traffic situation and assesses the brightness, i.e. determines when the high beams should be switched on. When the vehicle is approaching from the opposite direction or when the exterior is sufficiently well-lit, the system automatically switches off the high beams.

Intelligent Shock Absorbers

Continuous Damping Control (CDC) calculates the required shock absorber power each time, depending on vehicle load and road characteristics, when braking or slipping during driving in curves or on hills. The control unit continuously regulates the solenoid valve which determines the flow rate of oil in the shock absorber. Height and pressure sensors provide data for the calculation and the system also has information on driving speed, deceleration and acceleration, lateral acceleration and wheel speed. The CDC adjusts normal attenuation to new circumstances measured in milliseconds. By continuously recording data on wheel position, bodywork and shock absorber stroke, this system can react extremely quickly to sudden traffic situations. Thus, the vehicle adapts to the requirements of the road section and its own driving style by stabilizing damper and brake parameters.

Driver fatigue detection system

During long journeys, reduced concentration and driver fatigue have a negative effect on the handling of the steering wheel and the time it takes for the driver to react. Precise motor skills are deteriorating, steering wheel handling is no longer so accurate, and the driver has to manage the steering wheel more often. The fatigue recognition system algorithm analyzes the driver's handling of the steering wheel at the beginning of the ride and thus recognizes the changes that result from further driving and driver fatigue. This function calculates the fatigue index based on the frequency of such typical steering wheel corrections, but also other parameters such as driving time, use of turn signals and time of day.

Tire pressure sensor

The tire pressure sensor provides information on whether or not the tire pressure is adequate, which can affect wheel grip and brake system performance.

Emergency call system (E-call)

E-Call or emergency call system is a novelty that appeared in the car market and will be mandatory for all cars made after April 1, 2018. E-Call will work on the same infrastructure throughout Europe. The system itself will call the call center, where it will report key information about the accident (location, direction, type of vehicle and number of passengers in the vehicle), and at the same time will establish a telephone connection between the center and the vehicle. The system is expected to shorten the emergency response time.

The system for navigation

Modern navigation system offers drivers the design in full 3D, in combination with the innovative concept of interface and numerous functions for navigation, office and multimedia. Navigation systems support the quick start function, fast calculation and route selection, individual counseling to reduce fuel consumption, selection of alternative tours, detection of obstacles on the road, etc.

MODERN PHASE OF MOTOR VEHICLE DEVELOPMENT

If we look back at the development of cars through the development of car systems, we could see that the design of the first car had 100 years of development and improvement of basic systems that functioned mainly on the principles of mechanics.

The first use of electronics in motor vehicles, when the seat belt was electronically supported in the United States, laid the foundation for electronic systems that were then used to develop systems that regulate fuel injection, control pollution from exhaust emissions and later on many other systems.

The development and application of computers progress has definitely enabled in the development of all systems on the vehicle, which has contributed to greater comfort, greater safety, better speed and traction characteristics, reduced fuel consumption, reduced pollution, etc. Modern vehicles of high class, can have about 70 computers that perform various functions, perform process optimization, manage the vehicle, provide support to the driver through assistance systems, etc.

Due to the specifics that automated driving systems will bring when showing on scene in the last phase of the development of fully automated driving, this phase of development could be called a special, modern phase of vehicle development.

The phases of development could be classified as follows:

Phase I: Perfecting the basic systems on the vehicle
Phase II: Application of electronics in vehicles
Phase III: Application of computers in vehicles
Phase IV: Autonomous vehicles

Appreciating the importance of the development Phase IV, the development of this phase will be explained separately, from the aspect of technical requirements and legal regulations.

Development of automated driving systems

Among all the technological innovations, automated driving system has drawn special and great attention. Although some elements of this system are already available to drivers, through some forms of assistance, it is expected that this system will bring major changes in all spheres, because its full implementation will require adjustment of traffic infrastructure and especially legal regulations both internationally and nationally.

For many years, the term "Advanced driver-assistance systems" (ADAS) has been in use, which in general, performs its function by collecting and processing information received from the vehicle sensor, regarding the characteristics of the vehicle relevant for its behavior (stability, handling), as well as monitoring and detection in the environment of the vehicle itself, and evaluation and processing of collected information. This also includes the option to collect and evaluate information from the transport infrastructure, if available. The systems have been developed to support drivers in performing their driving tasks and improve traffic safety.

Recently, there have been very intensive activities on creating premises for the development and wider application of automated driving systems, i.e. systems capable of performing some or all of the driver's dynamic tasks. Full implementation of these systems is planned to take place in five steps. Table 1 will present the distribution of responsibilities between the driver and the system depending on the category of the automated driving system.

Vehicles in which the driver performs all dynamic driving tasks are, from the aspect of driving automation, **conventional vehicles** - vehicles without automated driving system.

The first group of automated driving systems will be those in which the perception of objects and events in the environment, and the response to them, will be the responsibility of the driver. Within this group, two categories of systems have been singled out.

The Category 1 automated driving system (Driver assistance) takes over part of the driver's dynamic tasks, whether controlling longitudinal (acceleration/deceleration) or transverse (turning) vehicle movement, but not both at the same time.

The Category 2 automated driving system (Partially automated driving), when activated within the designed operational area, should perform the tasks of controlling longitudinal and transverse movement of the vehicle. Category 1 and 2 systems are expected to have

Table 1. Automated driving systems

System Category	System Name	Longitudinal and transverse movement	Environment observation	Reserve option
0	Not automated driving	Driver	Driver	Driver
1	Driver assistance	Driver + System	Driver	Driver
2	Partially automated driving	System	Driver	Driver
3	Conditionally automated driving	System	System	Driver
4	Highly automated driving	System	system	System
5	Fully automated driving	System	System	System

limited ability to detect objects and events in the environment and respond to them. Therefore, in the case of vehicles equipped with systems of these categories, there will be expectations for the driver-person to constantly perform all dynamic driving tasks not performed by the system, to assess when it is appropriate for the system to be (de)activated, to monitor the environment, to monitor the system (execution of the driving tasks) and immediately intervene when necessary due to environmental events or system requirements, and, when necessary, immediately take over the execution of all dynamic driving tasks.

The second group includes automated driving systems in which the detection of objects and events in the environment, and the response to them, will be the responsibility of the system. Automated driving systems from this group will perform all dynamic driving tasks. Within this group, three different categories of automated driving systems will be singled out.

The Category 3 automated driving system (conditionally automated driving) will continuously perform all dynamic driving tasks within the projected operational area. In the event of a failure of a system relevant for performing dynamic driving tasks, or in the event of an imminent exit from the projected operational area, the system will request from the driver to take action and continue to perform dynamic driving tasks or put the vehicle at least risk. The driver has the role of a backup option, and must maintain his ability at a level where he can timely, reliably and adequately respond to this type of stimulus by automated driving systems and vehicle in general, including determining whether and how (if necessary) to bring the vehicle in a state of least risk.

The Category 4 automated driving system (highly automated driving) will continuously perform all dynamic driving tasks within the projected operational area, including a reserve option (redundancy) to perform those tasks. The system of this category does not expect the driver (user) to respond positively to the request to take over the execution of dynamic driving tasks or to bring the vehicle to a state of least risk. While the system is active, the user will not need to supervise the operation of this category of system, nor maintain their state at a level where he/she is able to respond in a timely manner to the system's request to take over the execution of driving tasks. A driver is not necessary within the projected operating area of the system. The driver, while the system is active, will be allowed to perform a wide range of other activities.

Category 5 automated driving systems (fully automated driving) will continuously perform all dynamic driving tasks including the reserve option (redundancy) to perform those tasks. For the systems of this category, the existence of predefined boundaries of the operational area is not envisaged. A system of this category will not expect the user to respond positively to a request to take over the execution of dynamic driving tasks. Therefore, the system will "drive" the vehicle in all traffic conditions in which it can objectively be controlled by the driver - without projected geographical restrictions, restrictions related to the type of road, speed regime, part of the day, weather conditions etc. A driver is not required during the entire ride. Therefore, the person sitting in the driver's seat does not have to perform driving tasks, i.e. is not in the role of a backup option of the system, he/she does not have to think whether or how to bring the vehicle in state of the least risk, etc.

Of course, the introduction of automated driving system must be accompanied by very intensive development of regulations at the international and national level, in order to: (i) establish the minimum technical requirements that must be met by newly developed systems (devices, equipment), and gradually and systematically (ii) remove the restrictions imposed by the existing regulations regarding the approval of equipping vehicles with such "novelties" and their use in traffic.

VEHICLES OF THE FUTURE

It is known that the European Commission has already adopted a package of measures that require the application of 11 systems on all new vehicles intended for the EU market from 2021. The said systems are as follows:

1. Autonomous braking system in critical situations,
2. Driver's alcohol detection,
3. Drowsiness detector and low driver concentration,
4. "Black box" of the vehicle
5. Stop light for critical situations,
6. Improved seat belt systems and passenger front protection system
7. Head protection zone for pedestrians and cyclists and safety glazing in the event of a collision
8. Intelligent assistance to the driver in terms of speed of movement
9. Assistance in Lane Keeping
10. Lateral protection of passengers
11. Reversing cameras or an adequate detection system.

If we add to this, that ABS, electronic stability controls and isofix connections are already mandatory in the EU, it is to be expected that in the foreseeable future the EU will be closer to achieving the *EU Vision Zero* goal. This means that a significant improvement in the field of safety is expected, without severely injured and killed traffic participants.

It is difficult to answer what the vehicles will look like in the future on the basis of current development trends, because the development of vehicles, systems and devices is happening both vertically and horizontally. Vertically, it is to be expected that new forms of vehicles will appear, which, according to their construction characteristics, will not fit into the existing definitions. Such vehicles could have multiple mobility options; by land, in or on water and in the air.

Horizontal development, in this context, means upgrading or developing new systems and devices that will further improve vehicle performance, increase safety, facilitate or take over driving, or make propulsion more environmentally friendly and cheaper.

CONCLUSION

A new phase in the development of motor vehicles can be considered the time since the conceptual notion of construction has changed, including new concepts outside the standard terminology and automotive dictionaries. Appreciating the legal regulations, technical and technological achievements, the readiness of the regulators and the expectations of the public, it is to be expected that major and rapid changes will occur in the construction and production of cars that will contribute to greater comfort and greater traffic safety.

Mandatory systems will be the "basic package" of vehicle equipment, while more demanding customers will be able to enjoy the support of a large number of driving assistance systems. Technologies that were once developed for the needs of the aviation industry have long been used in the automotive industry and today are representing basic technologies, and one could say mandatory equipment on vehicles. A similar thing will happen soon with technological achievements that are the privilege of space programs and underwater systems, and fuel cells can be quoted as an example.

Special attention is drawn to the development of autonomous driving systems, which will cause numerous changes in legislation and the environment. With their full application, we are approaching the "zero vision" when there will be lost lives in traffic accidents. The technological and normative revolution will enable the realization of the idea of autonomous vehicles even sooner than we expect it, although, for the time being, it seems foggy and distant.

Appreciating the scope and expansion of the changes brought by modern technologies, it is to be expected that major changes will take place in the construction and exploitation of vehicles. Maybe the near future is already here, with vehicles not being pollutants, the driver being replaced by automatic pilot, the movement of vehicles being enabled by combining driving and flying, vehicles becoming completely safe, and so on.

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