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## DRIVING TIREDNESS – THE END ENEMY OF THE DRIVER

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**Abstract.** In modern society, little or no sleep at all has become a habit, almost a good tradition. Fulfilled sleep is one of the key factors of a healthy lifestyle and longevity, along with proper nutrition, physical activity and that one is fighting stress. Driver fatigue reduces the level of traffic safety, having a negative impact on all psychophysical qualities. Fatigue at the wheel, like driving under the influence of alcohol, is a major factor in road accidents and should not be neglected, regardless of the experience of the driver, the car driven or, the road he travels. A moment of inattention at the wheel can turn the driver, passengers or other innocent people into a simple statistics of road accidents. The article describes the signs and causes of fatigue, measures to prevent and restore the driver's work capacity, as well as warning systems introduced by several manufacturers on keeping the car on the lane, monitoring the driver's fatigue etc.

**Keywords:** *driving fatigue, fatigue, road accidents, traffic accidents, drowsiness, car safety systems.*

**Rezumat:** În societatea modernă, a dormi puțin sau a dormi insuficient a devenit un obicei, aproape o tradiție bună. Somnul împlinit este unul dintre factorii cheie ai unui stil de viață sănătos și longevitate de trai, împreună cu o alimentație adecvată, activitate fizică și luptă cu stresul. Oboseala conducătorului auto reduce nivelul de siguranță a traficului, având un impact negativ asupra tuturor calităților psihofizice. Oboseala la volan, ca și conducerea sub influența alcoolului, este un factor major în producerea accidentelor rutiere și nu trebuie neglijată, indiferent de experiența pe care o are conducătorul auto, de automobilul condus sau de drumul pe care se deplasează. O clipă de neatenție la volan îl poate transforma pe conducător, pe pasageri sau pe alți oameni nevinovați într-o simplă statistică a accidentelor rutiere. În articol sunt descrise semnele și cauzele stării de oboseală, măsurile de prevenire și restabilire a capacității de muncă a conducătorului, precum și sistemele de avertizare introduse de mai mulți constructori privind menținerea automobilului pe banda de circulație, de monitorizare a stării de oboseală a conducătorului etc.

**Cuvinte cheie:** *oboseala la volan, stare de oboseală, accidente rutiere, accidente de circulație, stare de somnolență, sisteme de siguranță a automobilului.*

## 1. Introduction

There is no clear definition of the term „*fatigue*”. The term defines different meanings: *physical* – the result of hard physical or mental work, *neurobiological* – determined by the rhythm of sleep-wake cycles and *mental/psychological* – lack of energy needed to do something alternatively, demotivating the continuation of an action.

Fatigue also has many direct and indirect causes [1]. It is often directly associated with the period of time in which a person performs certain activities. Fatigue is also due to lack of sleep, which can be chronic or acute. Fatigue or drowsiness can occur without sleep. This type of fatigue is usually related to the daily cycle of sleep, or biorhythm, meaning that within 24 hours, the human body needs sleep several times. It takes place in the prolonged mornings, approximately between midnight and four o'clock in the morning or after 12 hours later, between 14<sup>00</sup>-16<sup>00</sup>.

Among the factors with indirect influence on fatigue can be considered the following: age, physical condition, habit of consuming alcohol, drugs, medications or external factors, such as: temperature, noise, vibration, routine of work. For example, driving alone on a boring road for a long time does not cause fatigue or drowsiness, but can lead to the rapid manifestation of their effects. Fatigue [2, 3] is the natural process of temporary reduction of work capacity, which occurs as a result of human activity. The work capacity of the driver depends on the condition of the central nervous system. As a result of overwork of the brain, disorders occur in the evolution of mental processes, perception, attention, thinking and memory are affected. Moreover, it reduces the acuity of vision, narrows the visual field, worsens stereoscopic vision, confuses the precision of movement coordination, reduces the degree of automatism, intensifies the pulse, increases blood pressure and reaction time, disappears the sensation of speed, apathy and asthenia appear, so that the ability to react quickly to unexpected and unusual changes in traffic situations is lost.

Vision fatigue is directly dependent on the duration of the driver's work. It was found that, after eight hours of uninterrupted work, the driver can visually perceive the road sign not from a distance of 100 m, but only from 80 m [2]. Visual fatigue has a negative effect on the driver's activity. Even experienced drivers, being tired, reduce the radius of visibility; direct the view in front of the vehicle and on the side of the road, which makes it difficult to forecast traffic situations. Only simple skills chiseled to the level of automatism are maintained in a state of fatigue, which gives possibilities to act only in known, standard situations. All these mentioned considerably reduce the reliability of the driver; contribute to the commission of errors and road accidents.

The tired driver involuntarily changes his working position: an improper seat is noticed, that makes it difficult to use the steering wheel, pedals and on-board devices, as well as worsens visibility. The driver with obvious signs of fatigue often loses the accuracy of driving actions, more often than usual he turns the steering wheel from side to side. Fatigue worsens with increasing energy consumption, as a result, serious errors begin to occur.

Signs of characteristic fatigue are noticed at drivers after 4...5 hours of driving, become clearly visible after 6...8 hours of driving, and after 9 hours, strong efforts must be made to drive the vehicle safely [4]. After 9 hours, the risk of a car accident increases. Sad practice shows that more than half of road accidents are caused by tired drivers. The tired driver may not feel tired under the influence of strong psycho-emotional arousal or danger.

The driver, who is beginning to feel tired, may initially drive the vehicle safely, but not for long. Falling asleep or drowsiness usually occurs instantly and unexpectedly, creating a

very dangerous situation on the road. Therefore, you do not have to fight drowsiness, but it is recommended to stop and sleep, or to do some exercise. The most effective way is to get out of the car for a few minutes and relax your muscles.

It is known that the aromas of coffee, lemon, mint and cinnamon remove fatigue, have a beneficial effect on the brain and bring the human body into an active state. Air flavors and lollipops with such flavors are beneficial. It also helps remove drowsiness, music, audio books and conversations with passengers. The open window of the cab allows fresh and cold air to enter, which invigorates the driver.

Every driver should know that driving a tired vehicle is one of the main causes, leading to road accidents from simple bumps to serious and particularly serious ones. Statistics show [2] that drivers who drive a vehicle without breaks for 7...12 hours as a result of drowsiness, are involved in road accidents approximately twice as often, and if the duration of driving exceeds 12 hours, the frequency of driving in road accidents increases 9 times. The driver must rest at least 8 hours before the working day, as drivers who sleep only 6 hours at the end of the working day have less than 2,5 times less attention. Also, according to statistics, 60% of overworked drivers are already asleep at the wheel after 3...4 hours of work.

## 2. Statistical data on the driver's fatigue

In order to better assess the effects of drowsy driving, some statistical data are presented below [5]:

- if the duration of sleep for 24 hours is less than 6 hours, the risk of drowsiness, which can lead to a car accident, increases 3 times;
- 18 hours of wakefulness in a row leads to a condition comparable to alcohol intoxication;
- \$ 12,5 billion – this is the annual loss of *US* money due to road accidents, caused by drowsiness while driving;
- 37% of drivers said that they fell asleep at least once while driving;
- it is estimated that 1550 deaths each year are caused by road accidents caused by drowsy drivers;
- 15% of serious road accidents involving trucks are attributed to driver fatigue;
- 55% of road accidents resulted of fatigue are caused by drivers up to the age of 25.

The mentioned figures refer to the *USA*, but they can also be successfully included in the sad statistics of road accidents in the *Republic of Moldova*.

Driver fatigue leads to a much higher number of road accidents than it previously was believed. The risk group included young people aged 18-20: they often go to bed late at night, but have to wake up early in the morning. In this category of drivers, signs of fatigue are more common during the day than at night.

According to the study conducted by specialists from the *Polytechnic Institute of Transportation in Virginia, USA* [6], the number of road accidents caused by driver fatigue is close to 20% of the total number, so it does not constitute 2-3%, as previously established other studies and surveys on similar topics. The study, called the „100-car naturalistic study”, was conducted over two years with the participation of the *State Department of Transportation and the US National Road Safety Administration*. The study allowed close monitoring of leaders without direct involvement in their lives.

The study involved 100 car owners from *Virginia* and *Washington*: five cameras were installed on their cars, collision warning systems in the front and rear of the car, several

accelerometers, belt traffic monitoring systems and a network sensor. For the research, the Institute's specialists tried to attract as many drivers up to the age of 25 as possible, as well as motorists whose annual journey is higher than the national average.

With the help of the study, it was possible for the first time to follow the behavior of drivers before the accident. In 20% of all road accidents and in 16% of all situations close to the accident, drivers showed obvious signs of fatigue: closed eyes, „nibbling” with the nose, „disconnection” of facial muscles, as well as moments of microsleep, when the driver's eyes close slowly, and open immediately.

During the study, experts analyzed 110000 situations in which drivers were involved. Of these, 10500 cases were particularly important, when drivers were involved in a car accident (82 times) or managed to avoid a car accident (761 times), as well as emergencies (8200 times) and other potentially dangerous situations – for example, the driver did not stop at the „no-stop crossing” sign (1400 times).

The *European Commission*, together with the *International Road Transport Union (IRU)*, has conducted a unique scientific study of the causes of road accidents. The aim of this study was to identify the main causes of road accidents with the involvement of trucks. To this end, teams of experts were involved in the study of over 600 road accidents in 7 European countries (*France, Germany, Italy, Hungary, the Netherlands, Slovenia and Spain*) [7].

Of the 624 road accidents investigated in 6% of cases, driver fatigue was the main cause of the road accident. 37% of such road accidents had a fatal end. In 68% of the situations, in which fatigue is the main cause of the road accident, the truck and another vehicle were involved in the accident, and in 29% of the cases, only the truck.

Regarding the time of day, when an accident occurred due to the driver's fatigue, two critical periods of time were identified. Most accidents occurred between 2<sup>00</sup> and 3<sup>00</sup> at night – the time when the driver's biorhythm is at its lowest point, as well as between 15<sup>00</sup> and 16<sup>00</sup> – almost at the end of the working day. Almost 90% of all road accidents caused by driver fatigue occurred on highways or roads between localities. In localities, road accidents due to the driver's fatigue are extremely rare.

Most drivers overestimate themselves when it comes to long driving distances, often ignoring fatigue. Many fatal accidents occur a few kilometers from the destination, due to the fact that the driver is confident that he will resist. A study conducted in the *UK* showed that many drivers drive tired, but very few of them resort to measures to protect them from that critical level, which puts them in great danger [8]. The study shows that 70% of drivers prefer to open a window and drive on, while 69% take short breaks to refresh them. 54% of leaders listen to music to stay awake and only 21% stop for a few minutes of sleep, 43% resort to various caffeinated beverages. Of those who stop for refreshment, 39% resort to short walks and only 21% fall asleep for a few minutes.

### **3. Signs of driver fatigue and circumstances of accelerated fatigue**

One of the most important issues regarding road safety is to reduce and avoid driver fatigue. Of great practical importance, it is of concern to many renowned scientists around the world. The more tired the man, the lower his production rates and the higher the probability of serious road accidents.

In such cases, from the point of view of medicine, the events take place according to a certain scheme [9]. About halfway through, the driver feels very tired and begins to fall asleep. Due to the tense pursuit of the road, eye pain occurs, the eyelids become heavy as

lead. Coffee or tea served before departure has no stimulating effect, does not help the sound of the radio or conversations with passengers. The reaction becomes slowed down to the rapid changes of the situation, the pulse rate decreases and for a few fractions of a second a euphoric sleep appears. After the blows, the consciousness clears for a few moments, then drowsiness reappears, but now for a longer period of time. This is the cause of the tragedy. The only way to avoid this tragedy is to stop and fall asleep for a while or give up driving.

Recognition of signs of fatigue is manifested by [3, 10]: difficulties in concentrating attention, keeping eyes open or head up, daydreams and the appearance of random thoughts, the tendency to have hallucinations, especially at night, the sensation of sand in the eyes, and their repeated need to rub, the need to blink more often, and the tears of the eyes, the weakening of coordination between movements, the attenuation of the ability to operate commands, the sensation of weight in hands, feet and eyelids, prolonged and frequent yawning, driving in zigzag and omission of road signs or indicators, anxiety or irritation, etc. Among other manifestations of fatigue: headaches, feeling of lethargy and weakness throughout the body, yawning, unwillingness to communicate with someone.

Although the movements necessary to drive the vehicle are easily performed as a result of accumulated skills and physical effort, without difficulty covered by the driver's energy resources, driving activity, carried out with tension and continuous attention, tires the nervous system of the subject, the fatigue process being accelerated of a number of circumstances. Among these are [3, 9-11] *external causes*: the monotony of some roads and the landscape, the known character of the itinerary, the intense rhythm of the traffic, the driving in the evening and especially at night with intense traffic in the opposite direction way etc.; *causes depending on the vehicle*: uncomfortable or inadequate seats, awkward position while driving, uniform engine noise, rocking motion of the vehicle, heat in the cab, inadequate or incomplete ventilation of the passenger compartment, penetration of harmful gases by technical ventilation or ventilation etc.; *causes that depend on the driver*: the activity submitted before driving, driving under the influence of low alcohol consumption, the influence of drug use contraindicated for driving, prolonged driving time (every fifth car accident occurs after eight hours of driving), psychological state before going on the road, immobility of the driver's position, feeling hungry, excessive smoking while driving, driving with unjustified low speeds, the existence of diseases etc.

All these circumstances often cause sleep, which is why short stops are recommended when leaving the driving position and exercising, proper ventilation of the cabin, having a snack or eating sweets etc., all having an effect disconnecting. Among the signs that precede sleep may be: a pleasant state of lethargy; drowsiness for a short time, during this time the eyes are open and the gaze is fixed forward, but does not perceive anything; the waking state is completely annihilated; the muscles of the hands and feet relax; the trajectory of the vehicle becomes unpredictable, etc. These signs appear in the early hours of the morning or at the end of the program, when the state of fatigue reaches maximum values.

Driving fatigue during driving is manifested by dispersed attention, abnormal reactions to external stimuli, decreased ability to coordinate movements, accuracy and speed of reactions, increased reaction time. The driver who is tired makes an effort to be careful and focused. He notices that he no longer clearly observes the signs, the markings, and he perceives the traffic situations late. To concentrate, the driver consumes the last reserves of physical and mental energy.

Fatigue is a natural process of temporary decrease in work capacity, caused by long or

great effort, but this condition disappears after a good rest, when work capacity is fully restored. Dangerous is the state of over fatigue, over fatigue, i.e. the accumulation of fatigue, which can suddenly manifest itself in a sick state.

Over fatigue is harmful and must be prevented. At the same time, moderate fatigue increases work capacity. If the man is tired at work to the right extent, then he has a good appetite and a good night's sleep. Therefore, it is necessary to know and forecast the functional possibilities, the time of onset of fatigue.

It should be noted that, under road law [12], it is forbidden to drive in an advanced state of fatigue, which affects the driving ability of the vehicle.

At the same time, it is necessary to take into account the experience of driving, keeping in mind that if you have not driven for a long time, then the first trips are accompanied by excessive physical and emotional stress. These emotions are manifested by tightening the steering wheel, following the road carefully and, as a result, static tension, which leads to rapid fatigue. These actions are also characteristic to novice drivers. In parallel with physical tasks, the human information request must be dosed. Lying down all day, doing nothing, for people with strong, mobile nervous system (blood) can be much harder than intense muscle activity. Both monotony and excess of information lead to fatigue. The monotony of the task causes the permanent tension of some and the same centers of the nervous system and this the nervous fatigue develops. The same legitimacies are noticed when poor information request. During the movement on the highway and in the conditions of an information deficit, the situation appears when the driver's eye fulfills one and the same thing – it follows the road. In this case, the same visual centers of the brain are permanently included in the activity and the uniformity of visual perception causes the development of fatigue in the centers of the brain, and the appearance of the inhibition state of some groups of nerve cells causes drowsiness. The lack of information can also be the cause of falling asleep at the wheel.

Fatigue and psychological stress are more pronounced at night, especially if the driver is blinded by car lights, moving in the opposite direction. Roads on which there are trees or poles placed at regular intervals also amplify this aspect. In addition to the feeling of monotony, the driver may enter a state in which sight and hearing are slightly reduced, or at least not as effective as normal. At night, fatigue can turn into a state of drowsiness, this being a very dangerous phase, both for drivers and passengers. This condition can be exacerbated due to situations where uneven surfaces are present on the road. Driving a car at night on a less crowded road, where there are no traffic signs, can also have a negative impact on the driver. A feeling of loneliness may set in, and the driver will be tempted to accelerate to a seemingly safer place. As a result, with acceleration, there is a high risk of losing control of the steering wheel or getting involved in a collision with another vehicle.

It is recommended to drive a car with a companion or to share driving hours with another driver, when it comes to very long roads and especially at night. Of course, the person on the right does not have to sleep, as this is contagious. Autopilot (*Adaptive Cruise Control*) is perhaps the worst choice when the driver is drowsy. It significantly reduces the interaction with the car, thus further accentuating the state of drowsiness.

Roads covered with snow or ice, water or wet can also cause difficulties, as the driver is subject to increased energy consumption. The arrhythmic movements of the wipers, the poor lighting of the headlights can also increase fatigue and reduce the level of attention while driving. The same weakening effect can be produced by billboards of different colors arranged on the side of the road.

#### 4. Measures to prevent and reduce driver fatigue

Fatigue prevention is possible by optimal planning of the race or trip, correct and proportionate staging of the trip, observing time schedules, ensuring the supply of physical and mental energy until the end of the trip, taking breaks to relax, ventilating the passenger compartment of the car, etc. Smoking is not recommended while driving, because polluted air in the cabin accelerates the onset of fatigue, due to the fixation of carbon monoxide on hemoglobin, which reduces the oxygenation capacity of the circulatory system.

In order to reduce fatigue [3, 9, 13], it is recommended to pay attention to the work and rest regime, the duration of the car driving process. Thus, for example, before leaving a long distance, especially if you are going to drive at night, the driver must rest. Several studies have shown that sleeping for about an hour, the body regains its energy level and is rested enough to stay awake all night. The struggle with fatigue and procrastination to save time is not justified, it is much more important for the driver and his passengers to reach their destination healthy and sound.

Immediately before departure, it is recommended to consume 30...50 g of lemon or 1–2 ascorbic acid pills [9]. Pay close attention to medications consumed, some of which can cause severe drowsiness and are not recommended while driving. Even if the driver has eaten well before setting off, he will take a few healthy snacks with him. The fast foods found along the way are convenient and comfortable, but are full of fat, salt and sugar that make you feel tired. Foods that give more energy and provide long-lasting resistance are made up of complex carbohydrates and proteins. Consumption of energy drinks can help in this case, but it is not the safest method. They can increase the level of alertness, but not for long, and then fatigue can occur even more strongly. Sugar-containing drinks are not recommended, as they can also create a greater state of fatigue later, even if for the moment they make us feel good.

During the trip, every 2 hours until noon and 1,5...2 hours after lunch, interruptions of 10...15 min must be made, during which it is recommended to perform the simplest gymnastic exercises, also recommended for passengers. During the warm period of the year, it is recommended to wash your face with cold water. However, when you feel the first signs of drowsiness, you must refresh yourself with fresh air while driving, opening the side window. It works very well if it is hot in the car and cold outside. Cold air gives the body a temporary shock and makes it more alert. The conversation with the passengers also helps, if it does not distract, and in their absence we can open the radio or the tape recorder, but the music must be rhythmic, lively, light and not noisy. It is recommended that the leader himself sing. It is not recommended to listen to radio reports from sports competitions, they distract.

If these easily acceptable measures do not help, then it is necessary to stop the movement, because it is known that the most effective remedy for fatigue is rest. In case of pronounced manifestation of fatigue and drowsiness, a short rest of 30...40 min in the places indicated for this purpose helps to get out of the state of inhibition. Many drivers, fighting fatigue, drink coffee. It really stimulates the body, but for a very short time, after which there is an even more pronounced fatigue.

When the body is about to give in to sleep, on the border with reality you can meet hallucinations (hypnogenic). These are practically fragments of dreams, detached from the immediate reality. Under these conditions you can get to what specialists call microsleep. It is a state of sleep, which sets in for a period of 2...10 seconds, often followed by a shock on waking. Then the brain is „*overwhelmed*” by the situation and involuntary reactions occur, such as the sudden steering wheel or brake, which leads to destabilization and loss of control

of the car. During this time, the driver has his eyes open, sees the road, but in a state of blurring of reality. The reflexes are very slowed down, and the driver misses any maneuver to avoid an obstacle.

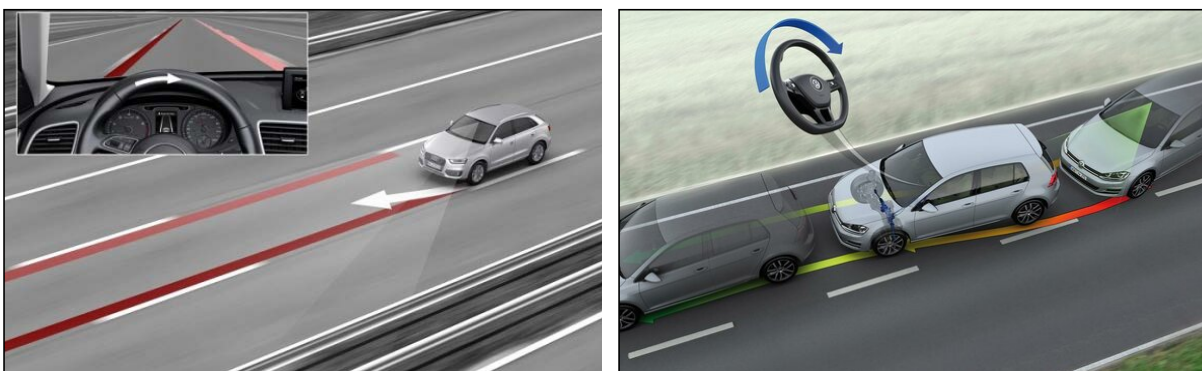
## 5. Car safety systems

This state of microsleep, in which the hesitations of maintaining the tread, are the basis of the warning and prevention systems introduced by several car manufacturers. They produce alarm signals, vibrations in the steering wheel and seat, when the driver crosses the lane marking line without signaling. Lane restraint systems could help to avoid many road accidents caused by the driver's fatigue.

The *lane-keeping assistance system* (lane keeping system) helps the driver to keep his or her chosen lane, thus preventing accidents. The system is efficient when driving on highways and national roads, because the quality road marking is drawn on them. There are two types of lane departure assistance systems: passive and active. The passive system warns the driver about the deviation from the chosen traffic lane, the active system, together with the warning, corrects the traffic trajectory.

At different car manufacturers the lane keeping system has its trade name, but all the proposed systems have practically a similar construction [14, 15]:

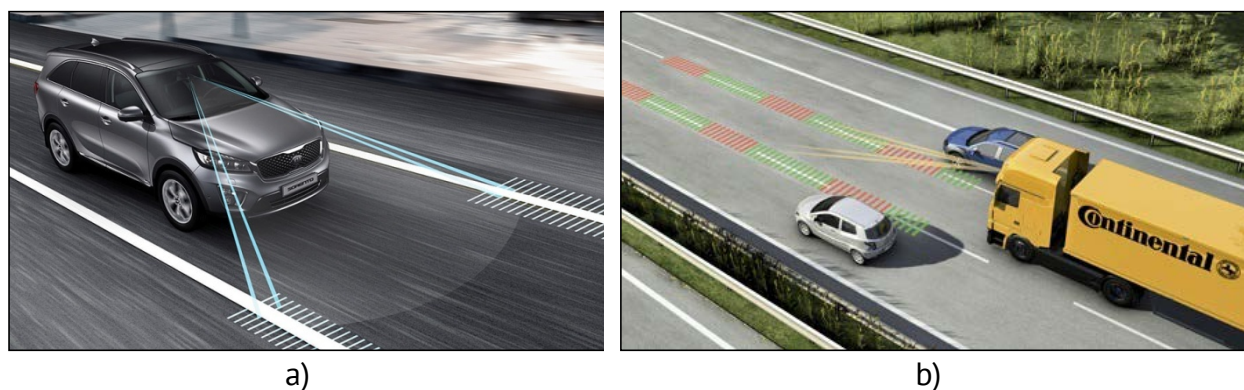
- *Lane Assist* from Audi, Volkswagen, Seat (figure 1);
- *Lane Departure Warning System* from BMW, Citroen, Kia, General Motors, Opel, Volvo (figure 2, a);
- *Lane Departure Warning* from Continental Teves AG (figure 2, b);
- *Lane Departure Prevention* from Infiniti;
- *Lane Keep Assist System* from Honda, Fiat;
- *Lane Keeping Aid* from Ford;
- *Lane Keeping Assist* from Mercedes-Benz;
- *Lane Keeping Support System* from Nissan;
- *Lane Keeping System* from Continental Teves AG (figure 3, a);
- *Lane Monitoring System* from Toyota.



**Figure 1.** Lane Assist system LA.

The Lane Assist system is an electronic system and includes the control button, a video camera, the control unit and the actuators. By means of the control button, the system is activated. System operation information is displayed on the instrument panel as a control lamp. The driver's warning is given by the vibration of the steering wheel or seat, as well as by the visual light and sound signals. The vibrations are generated by a vibrating motor integrated in the steering wheel or seat.



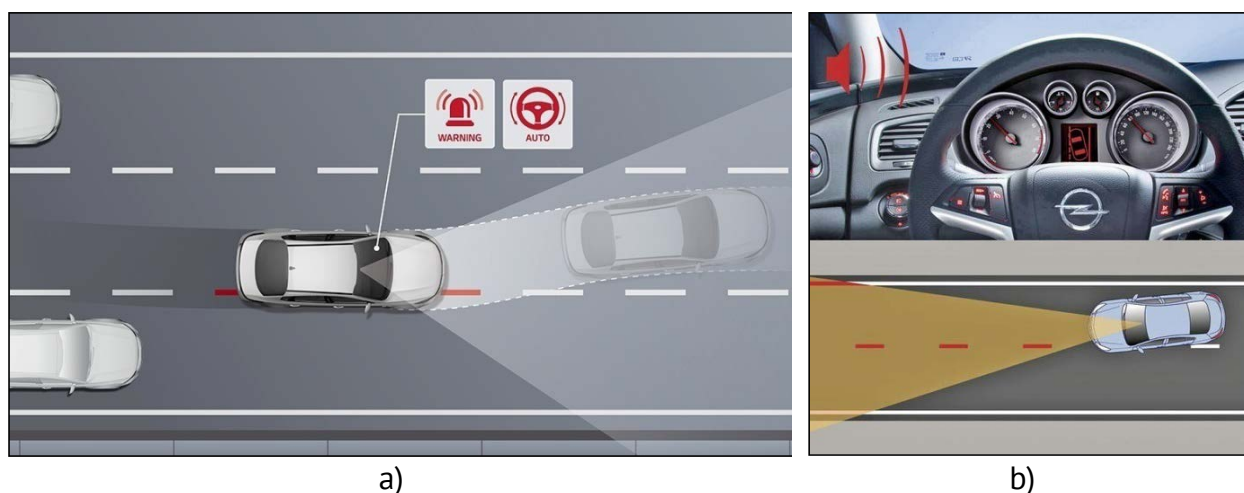


**Figure 2.** Lane Departure Warning systems: a) Lane Departure Warning system *LDWS*;  
b) Lane Departure Warning *LDW*.

Correction of the travel trajectory is achieved by forced steering of the steering system using an electromechanical amplifier (most systems) or by braking the wheels of a part of the car (*Lane Departure Prevention system*). The control unit operation algorithm determines the position of the lane marking lines, evaluates the quality of the mark recognition, assesses the width of the lane and its curvature and determines the position of the vehicle on the lane. Based on the calculations, a control action is taken on the steering system or the braking system, and if the necessary effect of keeping the car on the lane is not achieved, the driver is warned by the vibration of the steering wheel, seat, audible and light signals.

It should be noted that the value of the torque, applied to the steering mechanism or the braking force on two wheels of a part of the car, is small and can be exceeded by the driver at any time.

When the traffic lane is premeditated, the turn signal must be switched on, otherwise the system opposes the maneuver. In case of unfavorable conditions (lack of one of the lines or the entire road marking, dirty or snow-covered roadway, narrow traffic lane, non-standard marking on the road sections under repair, short-radius curve), the system is deactivated, thus with no help for the driver.

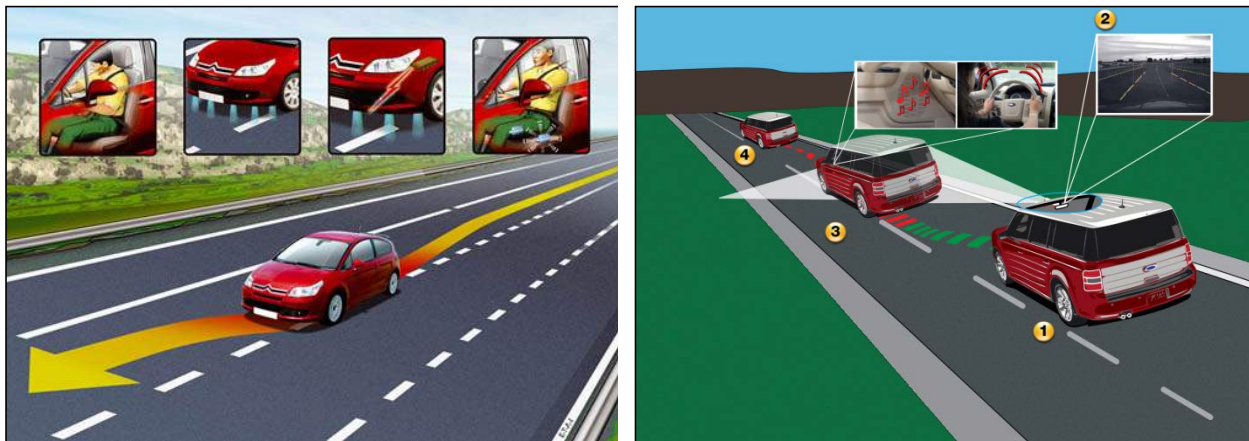


**Figure 3.** Lane Keep systems: a) Lane Keeping system *LKS*; b) *Opel Eye* system.

The *Opel Eye* system (*figure 3, b*) is designed to prevent the car from leaving the lane automatically. The effectiveness of the system on narrow roads with local destination is especially emphasized: it helps to prevent accidents related to the exit on the opposite lane. If this system were installed on all European cars, it would help save 5000 lives and avoid

serious trauma for 20000 people. The doubling of road speed limit signs makes it possible to avoid overtaking it in dangerous areas.

A similar system [15, 16] is also *Alerte de Franchissement Involontaire de Ligne* (warning system for involuntary intersection of road markings), which starts operating at speeds of 80 km/h and determines with the help of transducers the intersection of road markings without connecting turn signal. The system (*figure 4*) prevents the tired or careless driver from vibrating in the seat cushion on one side, which corresponds to the intersecting road marking, so that he can react in time.



**Figure 4.** Warning at unintentional intersection of road markings AFIL.

Road accident statistics show that the cause of a large number of accidents is the physical condition of the driver. A large number of car manufacturers are actively working on the creation of various driver monitoring systems, designed at least to announce the occurrence of a dangerous condition of the driver and, at most, to intervene in driving and prevent accidents. The work is carried out in several directions, including monitoring fatigue, assessing physical stress, establishing the state of tension of the driver [15, 17].

*Volkswagen* is installing the emergency system on cars, which is an extension of the lane keeping assistance system. If the driver is unable to drive the car (loses consciousness, falls asleep), the *Emergency Assist* system takes control and stops the car, also warns other road users of a dangerous situation. If the driver does not use the steering system for a certain period of time, the *Emergency Assist* system warns him with visual and audible signals, brakes the car. If there is no reaction from the driver, the system determines that he is not able to drive the car. The lane-keeping assistance system ensures the car's movement within the boundaries of the busy lane, and the adaptive cruising speed system prevents collisions with the car in front. To warn other drivers, the damage signal is triggered, the car starts to move sinusoidally within the lane and finally stops.

Another direction in the development of driver status monitoring systems is the equipment of cars with biometric sensors, with the help of which important health indicators (pulse, respiration rate, skin conductance etc.) can be monitored. These systems are promising and must be installed on mass-produced cars. The closest to solving the problem is *Ford*, which proposes a system for assessing the driver's load (strain), designed to reduce distractions and excessive stress. The physical stress of the driver is estimated by processing several parameters:

- vehicle traffic (*speed, longitudinal and transverse acceleration, speed of rotation*);
- driver actions (*steering wheel rotation angle, accelerator pedal position and brake pedal*);

- road conditions (*traffic density, character of road pavement*);
- biometric indicators (*heart rate, respiratory rate, skin temperature*).

If the load on the driver is large enough, the system takes steps to reduce the tention, including automatically connecting the mobile phone lock function to incoming calls („do not disturb” function).

The following biometric sensors are used for the operation of the driver load assessment system:

- piezoelectric sensor in the seat belt for monitoring the respiratory rate;
- conductive conductors on the steering wheel for measuring the pulse;
- infrared sensors on the steering wheel for measuring the temperature of the palms;
- infrared sensor behind the wheel, which monitors the face temperature.



**Figure 5.** Driver Status Monitoring systems:

a) Driver Wellness Monitoring *DWM*; b) Mind Sense systems *MSS*.

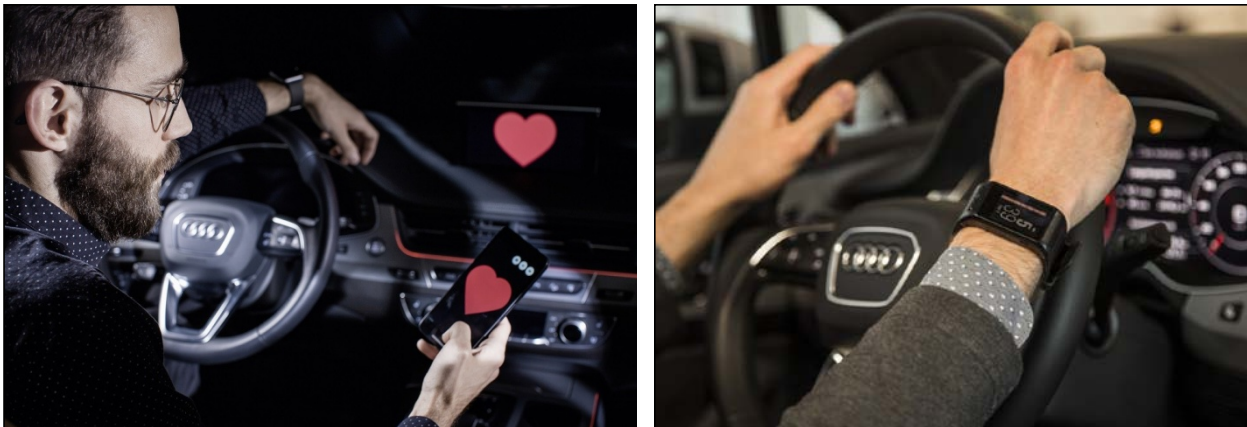
The *Jaguar Land Rover* company proposes to monitor the driver's condition with the help of biometric sensors, built into the driver's seat. The *Driver Wellness Monitoring* system (figure 5, a) uses breath and pulse rate sensors. If the system identifies serious health problems or excessive driver agitation, measures shall be taken to ensure traffic safety. In case of stress, internal cooling, audio system and air conditioning control are adjusted. In the event of a sudden and serious illness, an emergency call is made and the car stops automatically.

In 2016, *Audi* presented the *FitDriver* project (figure 6) under the motto „My Audi takes care of me”. Vital parameters of the leader, such as pulse and temperature, are monitored using mobile devices (*training bracelet or SmartSatch*). These data are supplemented by information on driving style, breathing frequency, weather and road conditions, provided by various car sensors. Taken together, the data obtained allow to determine the current state of the driver, including high fatigue or stress.

*Ferrari* has patented the technology, which assesses the driver's tention level after changing brain waves. The bioelectrical activity of the brain is measured using wireless sensors, built into the driver's headrest. Depending on the condition of the driver, there is a reduction in the fuel supply of the engine and automatic stabilization of the car.

The *Jaguar Land Rover* is also working in this direction. The *Mind Sense* system (figure 5, b) determines when the driver is distracted or falls asleep while driving through brain activity. It has been found that the human brain generates several brain impulses of different frequencies. By constantly measuring the impulses, one can estimate how focused the driver

is (hesitated, drowsy or distracted). The monitoring of brain waves is done with the help of sensors, built into the steering wheel.



**Figure 6.** The system FitDriver.

If the activity of the brain indicates drowsiness or low concentration of the driver, then the steering wheel or accelerator pedal begins to vibrate, drawing attention to driving. If the driver does not show any reaction, a visual and audible signal is given.

The fatigue monitoring system [15, 17] monitors the driver's physical condition and, if it detects certain deviations, warns the driver about the need to stop and rest. The system suggests a rest pause by means of a warning beep or a signal on the instrument panel „coffee cup” (figure 7, a). Depending on the method of assessing the driver's fatigue, there are three types of systems. The first are built on the control of the driver's actions, the second – the control of the car's movement, and the third – the control of the driver's eyes. Currently, the driver fatigue monitoring system is implemented on *Mercedes-Benz*, *Volvo*, *Lexus* cars.

Since 2011, *Mercedes-Benz* has been installing the *Attention Assist* system on its cars [15, 18], in which the control of the driver's actions is based on many factors: driving style, driving behavior, use of driving organs, character and driving conditions. and so on The control unit processes the input signals and determines:

- driving style (*analysis of speed, longitudinal and transverse acceleration for 30 minutes after starting the movement*);
- driving conditions (*analysis of the time of day, duration of the trip*);
- use of controls (*analysis of the use of brakes, switches under the steering column, buttons on the control panel*);
- the character of the steering wheel rotation (*speed, acceleration analysis*);
- road condition (*lateral acceleration analysis*);
- the character of the car's circulation (*analysis of longitudinal and transverse acceleration*).

As a result of the calculations, the deviations in the driver's actions and the driving trajectory of the car are established. A warning signal about the need for a pause is displayed on the control panel screen and an audible signal sounds. If, after signals, the driver does not stop and continues driving in a state of drowsiness, the system repeats the signals at intervals of 15 min. The system activates at a speed of 80 km/h.

Unlike the *Attention Assist* system, *Volvo's Driver Alert Control* system (figure 7, b) only sets the character of the car's movement on the road. The camcorder facing forward fixes the car's position on the lane. Deviation from the established traffic parameters is considered by the system as the beginning of the driver's fatigue. Depending on the driver's condition, the

system performs two levels of warning – „soft” and „hard”. The levels differ according to the intensity and tone of the sound signal. The *Driver Alert Control* system works together with the *Lane Departure Warning* system and is based on its constructive elements. The system activates at a speed of 60 km/h.

Eye control for driver fatigue assessment is introduced by *General Motors*. Based on the existing technique *Seeing Machines* (figure 7, c), which used in air, rail, quarry, commercial freight. A special unit controls the degree of opening of the eyes and the direction of the driver's gaze. When recognizing the driver's lack of attention, fatigue or drowsiness, the system warns of the need to stop.



**Figure 7.** Driver Fatigue Monitoring systems: a) Attention Assist system AA; b) Driver Alert Control system DAC; c) Seeing Machines systems SM.

The presence of resonant bands in the longitudinal direction is a measure that warns both audibly and sensitively the driver, if the car tends to go off the road or enter the opposite direction of traffic. The positive experience of using resonator tapes in different countries demonstrates the high efficiency of this technology for raising road safety. In the *US*, resonator tapes are used in 85% of countries [19], significantly reducing the number of deaths. On highways in *Japan*, the construction of roadside resonant lanes and the line separating opposite transport flows has reduced the number of collisions with oncoming traffic by up to 55%. In *Finland, Denmark and Sweden*, the use of resonator tapes has also led to a significant reduction in the frequency of accidents and is mandatory for new road construction.

Other safety features related to road infrastructure are sidewalks and off-road parking lots, that limit the consequences of a fatigue accident.

## 6. Conclusions

1. Based on what is described in the article, it can be concluded that fatigue has a negative effect on car driving skills and road safety, being the cause of many road accidents.
2. The problem of driving a car in an advanced state of fatigue will not lose its relevance as long as each driver will not be aware of the danger to which he is subjected.
3. Traffic fatigue is a problem not only for countries with well-developed road infrastructure or professional drivers, but for all drivers.
4. Driving in an advanced state of fatigue, which affects the driving ability of the vehicle is prohibited in most countries, including the *Republic of Moldova*. But statistics show that this restriction does not reduce the number of road accidents caused by driving fatigue.
5. There are many recommendations on how to reduce fatigue, but the most effective remedy is rest.

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