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DEGRADATION OF THE PERFORMANCE OF ROAD VEHICLE DRIVERS DUE TO DRIVER FATIGUE

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Abstract: *Unsuccessful driver performance can result in a traffic accident (TA) or avoidance. In this paper, the possible influence of the factors of driver fatigue on the performance of road vehicle drivers will be investigated. Deductive method, method of analysis and synthesis, and by compilation and comparing recent scientific and professional literature available new insights were made. Fatigue can degrade driver's performance by reducing the maximum possible driver's capability to perform (e.g., chronic fatigue that affected the driver before performance) or by degrading the driver's performance (passive fatigue due to monotonous fast road environment or dynamic fatigue due to traffic requirements from the environment). Driver fatigue is the factor that causes TA the most and it should be focused on more and mitigated with advanced driver assistance systems.*

Key words: *road traffic, driver's performance, fatigue, traffic accident, automation.*

1. INTRODUCTION

The performance of road vehicle drivers take place in a complex working and transport environment, and the performance is influenced by a lot of factors from the system human (driver) – the transport environment - vehicle and consequently safety. The driver's unsuccessful performance can end in a TA or avoidance of it for two reasons: the successful avoidance or intervention of an advanced driver assistance system for higher-level vehicles of automation. Factors from the group "human factor" according to all previous studies predominantly influence the occurrence of TA [1, 2], with an emphasis on the wrong reactions of drivers. While driving, several simultaneous factors may adversely affect the performance of the driver. The current psychophysical readiness of the driver is characterized by a performance that he does not approach with the maximum ability with which he theoretically has.

Experienced drivers are aware of their limitations and this problem cannot be solved without the application of advanced driver assistance systems. However, where is the limit of application of advanced systems and whether they have a detrimental effect on basic driving skills in the long run. Among the dominant factors of degradation of performance is fatigue.

More and more drivers are driving a vehicle after insufficient and substandard sleep. In recent years, there has been an intense increase in the proportion of TA that are thought to have been caused by driver fatigue. Scientists believe that this factor from the group of factors "human factor" causes up to 20 % of all TA [3, 4, 5, 6]. Driving under the influence of fatigue increases the likelihood of TA occurring by as much as three times [7]. The increased statistical risk for TA due to fatigue of road vehicle drivers is between 4 am and 6 am, from midnight to 2 am, and in the afternoon between 2 pm and 4 pm [3].

The consequences of such crash are the most common serious bodily injury or death as the reaction time of the driver is prolonged, or drivers do not undertake any maneuvers to avoid a collision [8]. With the development of advanced driver assistance systems and autonomous vehicles, the impact of them can be drastically reduced. From the second level of automation according to SAE, vehicles can control longitudinal and lateral control of vehicles and thus mentally and physically relieve the driver. The development of such systems is necessary to reduce TA and the

impact of fatigue factors on the performance of road vehicle drivers. Consequently, this paper will analyze and prove the hypothesis of how factors from the working and transport environment such as fatigue can adversely affect the performance of road vehicle drivers and consequently the safety of traffic processes measured by the number of traffic accidents.

2. THE IMPACT OF FATIGUE ON DRIVER PERFORMANCE

The factors of TA can be divided into three basic groups according to the usual methodology: the human factor, the traffic environment, and the vehicle. In the professional and scientific literature, and in general, it is considered that the dominant cause of the occurrence of TA are factors from the group 'human factor' [1, 9].

Fatigue is a daily phenomenon that describes the loss of work efficiency and the state of apathy. General fatigue can be caused by overload of part of the psychomotor system caused by repetitive work and continuous attention while driving. Fatigue manifests itself as a decline in the quality and quantity of work activity. The feeling of moodiness, fatigue, pain, exhaustion, irritability is irritated, and manifests itself as apathy and lack of interest in work [10].

The five main factors that cause fatigue in general and fatigue in drivers are [11]: lack of sleep or poor sleep, biological rhythm of sleep and wakefulness; time spent working; monotonous actions/jobs; individual characteristics (age, mental state, etc.) and health condition.

Driving requires different cognitive skills such as visual perception, attention, memory, executive function, and motor function [12]. Performance in these cognitive domains is related to driving performance and driving ability. Furthermore, psychophysiological aspects such as mental fatigue can influence cognitive processes involved in driving [13].

Driving under the influence of fatigue can cause a TA with severely physically injured participants and a fatal outcome, as fatigue causes a degradation of the driver's performance that manifests itself in [14, 15]: slower i.e., longer reaction times of the driver to complex cognitive-motor tasks while driving, reduced ability to maintain sufficient distance between vehicles depending on the speed, reduced steering abilities (speed control and course maintenance i.e. lateral position of the vehicle), and tendencies to mentally "alienate" from the task of driving a vehicle.

In research drafts, measuring performance in realistic or simulated conditions generally distinguishes between two types of fatigue [16]:

- Passive fatigue (it is associated with monotonous driving at night for a period between midnight and 5 am in a uniform traffic environment, most often on motorways);
- Dynamic fatigue (fatigue associated in literature with driving in urban environments in a dynamic traffic environment and it is more difficult to measure such fatigue as well as the impact of fatigue on performance in real circumstances).

Overall fatigue in drivers is not easy to measure. Some of the scientifically known methods of fatigue measurement and fatigue size indicators can be classified into six groups [10]: quality and quantity of performance, subjective feeling of fatigue, electroencephalography (EEG), critical fusion frequencies of visual stimuli, facial expression, psycho-motor, mental and behavioral tests.

The most common methods for measuring fatigue in drivers are self-assessment of fatigue, eye-tracking measures, and EEG measures. When comparing methods for fatigue assessment, EEG provides the most accurate assessment of the driver's mental state [17].

In addition, changes in EEG activity are considered biomarkers of mental fatigue [18]. Mental fatigue has influence on EEG activity spectral bands as increased theta and alpha activity. Enhanced alpha power is an indicator of cortical hypoactivity [19] and mental fatigue during driving [18]. Furthermore, the enhancement in alpha power correlates with driving errors during fatigue driving [18, 20]. Some studies suggest that enhanced alpha activity is related to a decline in memory performance [21]. On the other hand, increased theta activity is strongly associated with mental

fatigue during prolonged driving and cognitive tasks [18].

Furthermore, increased theta in the occipital region is associated with identifying and processing visual stimuli and controlling cognitive demands during driving [22, 23, 24].

In recent years, there has been an intense increase in the proportion of traffic accidents in the world, which is thought to have been caused by driver fatigue, as among other things an increasing number of drivers are driving a motor vehicle after insufficient and substandard sleep. The report on the number of seriously injured and/or killed participants in fatigue-related TA for 2008-16 for Western Australia recorded 532 fatal TA in which 583 participants died, where a percentage proportion of driver fatigue factors accounted for about 17% of all TA for the same period. From 2011 to 2015, a slight decrease in the number of participants killed was evident, while since 2015 there has been an increase of 32 %. During this period, fatigue along with alcohol was the second most common factor in the occurrence of TA [25].

Participants in such TA are often drivers under the age of 30 who are at greater risk of driving in a drowsy state on the grounds that they are more vulnerable to sleep deprivation before starting a ride on long sections of highways, which an individual badly needs to feel awake and alarmed [26]. In addition, one possible reason is the behavioral indicators of young drivers who often know how to overestimate their driving ability and thus themselves pose a risk to other road users [27, 28].

In a study by Connor et al. (2001) it has been demonstrated that drowsiness increases the risk of TA by 8.2 times, and that the amount of sleep up to 5 hours over a period of 24 hours before the onset of TA and driving between 2 am and 5 am is the main risk factors of the TA [29].

In a case study [30] conducted on 716 professional drivers from Iran using the questionnaire and interviewing method, the aim was to investigate the link between drowsiness and TA. The results showed that drowsiness and fatigue were the biggest reported cause of TA with a share of 35%, while in second place was inattention and lapses of other drivers with a share of 18.1 %.

3. ADVANCED DRIVER ASSISTANCE SYSTEMS AND LEVELS OF AUTOMATION

There are six levels of automation according to SAE [31]. In the natural milieu, the 2nd level of automation is the most prevalent. Automation level 2 vehicles are equipped with all advanced driver assistance technical systems necessary to maintain one and the same reduced distance between multiple followable vehicles at higher speeds (e.g., adaptive cruise control combined with an advanced automatic emergency braking system), without all such vehicles in the line being interconnected with each other.

The second level of automation, or partial automation of driving, implies a vehicle containing a combination of automated functions such as: speed control (longitudinal control), steering control (lateral control). Namely, with the second partial level of automation, the driver still must be engaged during the entire time of the operation of the vehicle due to the supervision: elements essential for the operation of the vehicle, always monitoring the traffic environment.

The second level of automation can enable the driver to physically (but not cognitively) separate himself from the task of driving the vehicle and take on the role of controlling the road and vehicles, i.e., other road users [32].

However, table 1 shows that the management activities of traffic environmental monitoring at level 2 automation are still performed by man, while at level 3 of automation the same takes over the system, and that is why the authors consider the third level of automation the most dangerous in the segment of maintaining the necessary attention when the driver is cognitively and physically out of performance.

Table 1

Comparing the executor of the control activity in the car between level 2 and 3 automations.

Management Activities	**Who's doing them? System/driver**	
	L2 automation	L3 automation
Activate the accelerator/brake pedal	System	System
Rotate the steering wheel	System	System

Monitoring the traffic environment	Driver	System
System Activation/Deactivation	Driver	Driver
Taking control of the vehicle after the automation stops working	Driver	Driver

According to the authors Tadashi et al. (2019) [33] with the arrival of vehicles of different levels of automation, drivers will be responsible not only for driving but also for monitoring the traffic environment. For this reason, the driver status monitoring system is very important to ensure that the driver remains in a driving condition that allows him to react in a timely manner to sudden changes in the traffic environment. Authors [33] have proposed new criteria for measuring the concentration level for driving that will allow drivers to be monitored in real time. Innovation is one key aspect of the proposed approach and that is because of the impact on labor productivity [34, 35].

The criteria for estimating the level of concentration of the driver are gaze orientation, driver readiness and proper sitting. The first criterion of gaze orientation refers to checking whether the driver follows the trajectory of the vehicle (road in front of him). Driver readiness refers to whether the driver is affected by fatigue, distraction, or any other unwanted condition. The last criteria relate to the position of the body in the seat. This criterion is defined because there is a possibility that with the increase in vehicle automation, driver engagement in traffic environmental control will gradually deteriorate, and their participation in these processes will become more important than before [33].

According to the information collected so far, the criteria for determining the level of concentration of drivers will vary for different levels of vehicle automation as well as the time of driver monitoring. Vehicles of the 1. and 2. level of automation should detect in real time undesirable conditions of drivers such as fatigue, drowsiness, distraction, carelessness, and the like. Third level of automation allows the driver to actively engage in secondary distraction tasks since the system performs traffic environmental monitoring, which is not the case in level 2 of automation. Accordingly, it is necessary to provide partial monitoring of the driver immediately before issuing a system shutdown warning due to its limitations to check in time the driver's concentrations and ability to react appropriately.

A similar situation is with level 4 automation where the vehicle can perform all the control functions, but there are spatial limitations where such a system cannot function. Vehicles 5. level of automation will no longer have drivers, which will allow passengers to have greater comfort in the vehicle, which requires monitoring of the position of passengers in the seat so that in the event of an unavoidable collision, the safety systems of the vehicle can react validly in the event of an unavoidable collision.

4. DISCUSSION AND CONCLUSION

This paper has proven the hypothesis of how factors from the working and transport environment such as fatigue can adversely affect the performance of road vehicle drivers. Fatigue in TA is difficult to measure, and often drivers do not want to plead guilty.

The proportion of such TA is on the rise and the consequences are the most common serious bodily injury or death of the as the vehicle most often drive off the road and hits the object at or next to the road. The negative consequences of the impact of fatigue on the performance of the driver are a decrease in the reaction time of the driver to environmental stimuli and consequently reducing the level of driver performance.

To prevent the occurrence of TA, it is necessary to continue to develop driver monitoring systems that can detect unwanted conditions of the driver in real time and alert him in a time or depending on the level of automation of the vehicle also allow the system to decide and take action to avoid an TA. Generally it is necessary to develop integrated ADAS for road vehicles that will compensate for the driver's defects or lack of driver ability or completely replace the driver while driving (depending on the level of automation).

The above applies to situations when the driver cannot intervene with a satisfactory level of performance in view of the required level of

safety (due to currently reduced psychophysical readiness he does not use its maximum theoretically available ability) or is unable to intervene (because the current difficulty of the task in a particular traffic emergency is too high in relation to driver available ability). According to the Council of the European Union decision of 2019, all new vehicles will be obliged to introduce advanced driver assistance systems whose vision is to reduce the number of TA and consequently reduce the consequences such as serious bodily injury or death.

It is obvious that all vehicles with higher levels of automation will have to be networked in real time to achieve as high a level of safety as possible and to achieve a synergistic effect in terms of traffic parameters (such as the lowest possible and maintained distance between multiple vehicles in sequence at higher speeds). This implies a special dedicated lane only for highly automated vehicles, since in mixed traffic the advantages of vehicles with high degrees of automation (traffic benefits and higher safety) will not fully come to the fore.

This review paper can serve young researchers as an introduction to the field of research, i.e., driver fatigue, and will be very useful for designing driving simulator scenarios, for the purpose of measuring the impact of driver fatigue on driver performance.

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Degradarea performanței șoferilor de vehicule rutiere cauzată de oboseală

Rezumat: Performața scăzută a șoferilor poate cauza un accident rutier. În această lucrare, se va investiga potențiala influență a obosealii asupra performanței șoferilor de vehicule rutiere. S-a aplicat metoda deductivă, metoda analizei și sintezei și compilarea și comparația surselor bibliografice recente. Oboseala poate degrada performanța șoferului prin reducerea capacității sale maxime de a conduce (de exemplu, oboseala cronică acumulată înainte de a conduce) sau prin degradarea performanței șoferului (oboseala pasivă cauzată de mediul rutier monoton sau oboseală dinamică produsă de solicitările din trafic și din aprtea mediului extern). De cele mai multe ori oboseala șoferului este factorul care cauzează accidentul rutier și ar trebui să existe o preocupare mai intensă asupra reducerii sale prin utilizarea de sisteme de asistență avansată a conducătorului auto.

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