DOI: 10.7251/JTTTP1901005D
UDC: 656.08:352.07]:621.313.2

ORIGINAL SCIENTIFIC PAPER

Application of a new Model for Fatigue Identification of Commercial Vehicles Drivers

Jelica Davidović
M.Sc. University of Belgrade, Faculty of Transport and Traffic Engineering, Belgrade, Serbia, jelicadavidovic@sf.bg.ac.rs
Dalibor Pešić
Ph.D. University of Belgrade, Faculty of Transport and Traffic Engineering, Belgrade, Serbia, d.pesic@sf.bg.ac.rs
Boris Antić
Ph.D., University of Belgrade, Faculty of Transport and Traffic Engineering, Belgrade, Serbia, b.antic@sf.bg.ac.rs

Received: January 30, 2019
Accepted: April 14, 2019

Abstract: For decades, around the world is developing a fatigue detection system to alert drivers when they reach the state of fatigue that threatens them in traffic. Most of the research on the impact of fatigue on drivers based on driving simulators mainly because it is a controlled environment, cheap and safe approach. Since the nineties of the last century, many surveys were conducted in which the survey method was applied, while examining the subjective attitudes of drivers about the impact of fatigue on traffic safety. The beginning of the 21st century is characterized by the development of a fatigue detection system based on modern technologies, and a number of experiments were conducted. However, it not yet in use tools that can be easily detected drivers fatigue, in order to respond quickly and prevent them from operating the vehicle in such condition.

The aim of this paper is to demonstrate the importance and implementation of a new fatigue identification model for commercial vehicle drivers in selected transport companies. Based on the results of this research, it is possible to determine which company is the safest from the aspect of fatigue, which is least safe. Also, the analysis of the results can determine which influencing factor is "the weakest link" among the drivers in the transport company, or where to direct measures in order to improve the road safety of the company, and therefore the local community.

The study included five transport companies in Serbia, three of which are engaged in the carriage of passengers, and two transport goods. The survey used the survey method, the face face model, and 265 drivers of commercial vehicles participated, 16.6% of whom were found fatigued before the start of the shift.

Keywords: road safety, fatigue, model for fatigue identification, commercial vehicle drivers.

INTRODUCTION

In order to identify driver fatigue, several methodologies are applied depending on whether a preventive approach is used - identification of fatigue prior to the occurrence of a traffic accident or analysis of traffic accidents, or determining the factors that led to sleep during driving. Analyzing a number of world experiences (for example see 1-19), fatigue can be identified using the following methods:

1) analysis of a database of traffic accidents;
2) a system for the detection of fatigue;
3) driving simulator (tests of psychomotor alertness, consumption of energy drinks, coffee, etc.);
4) analysis of attitudes and self-reported behavior of drivers.

Identification of fatigue by analyzing the database of traffic accidents is not an acceptable method because the analysis starts only after a traffic accident occurs. This method can be used to analyze impact factors and define measures for improving traffic safety.

Driver Detection Systems, which have been developed so far, are based on a variety of principles, such as fatigue detection based on the speed and frequency of closing eyelids, based on tracking the position of the vehicle in the traffic lane, based on headlining and movement, in relation to the dividing line, on the basis of the face line, etc.

Gupta and Garima (20) indicated that methods for fatigue detention based on modern technologies are divided into intrusive and non-intrusive. Intelligent methods include methods in which electrodes that must be in direct contact with the driver's body are used to determine its physiological state and according to him, detected drowsiness. The disadvantage of this technique is that it requires physical contact with the driver.

Other methods, which fall into unobtrusive, include a system that does not interfere with the driver during his driving. The system measures the level of alertness of the driver following the movements of the steering wheel, braking patterns, the view of the traffic lane in which the vehicle is located, facial movements. Accordingly, the driver will be alerted via video or audio signals, without any physical contact. An unobtrusive system based on visual data collection has been developed to locate eye and mouth positions, and to detect drowsiness with the driver. During the driver's supervision, the system is able to detect when the eyes are closed and the mouth is open simultaneously, for a long time interval, and then alert the driver to the danger with the help of sound and text signals. Also, the system will warn the driver if the driver closes his eyes for a long period of time, which may mean that he has fallen asleep while driving. Namely, the human face is dynamic and has a high degree of variability. Face Detection is the first step in the analysis of facial movements. Today, a large number of different methods of face detection using computer software are in use. One of the essential facial features for identifying and analyzing facial movements is the eyes. When the eyes are detected, using their location can be determined the position of other characteristic facial features, such as the mouth and nose. Therefore, the main objective of this technique represents an analysis of the above mentioned features.

With the help of a variety of driving simulators, numerous laboratory studies have been carried out over the past decades, which have shown that due to limited sleeping, there is accumulation of daily performance deficits that affect the ability to monitor traffic, reaction time and alertness (21) for the occurrence of a traffic accident is increasing.

An analysis of attitudes and self-reported behaviors is a method that has been used for many years to collect data from a large number of respondents in various fields, as well as to determine fatigue and its influence factors. Tools have been developed to help determine the tendency to tired, the level of daily drowsiness, and the like. This method is suitable for rapid data collection, only issues need to be carefully selected in order to avoid giving socially desirable answers.

The aim of this paper is to demonstrate the importance and the possibility of applying a new model for identifying fatigue in the drivers of commercial vehicles in selected transport companies based on the analysis of attitudes and self-reported behavior. The model is formed on the basis of weight factors of influence factors and as an output gives information whether the driver is tired or not.

Based on the results of this research, it is possible to determine which company is the safest from the aspect of fatigue, which is least safe. By analyzing the results, one can determine which of the influencing factors is "the weakest link" among drivers in the transport company, or where to direct measures in order to improve the safety of the company's traffic, and hence the local communities.

METHODOLOGY

The application of a new model for identifying fatigue in commercial vehicle drivers consists of collecting new data set by a face-to-face model, entering data in a specially formed database based on the programmed code for the application of such models, and processing and analyzing the data collected.

The research was conducted in the period from April to July 2018, in five transport companies in the Republic of Serbia, two dealing with transport of goods and three for transporting passengers (Table 1). A total of 265 drivers were surveyed, 84 of them were truck drivers. Prior to taking the driving order, or before the start of the shift, drivers were asked to select the subcategory for the 11 relevant indicators that best describes them. The application of a new model for identifying fatigue in commercial vehicle drivers consists of collecting data by a face-to-face model, entering data in a specially formed database based on the programmed code for the application of such models, and processing and analyzing the data collected. Drivers did not have an insight into the weight coefficients of the subcategories they chose. They did not know the value of their responses used for the model, so they did not have an overview of what the outcome depends most on. The survey was carried out by a person employed in a transport company that did not have a slight insight into the value of the weight coefficients of the offered responses, nor information on the layout of the model.

Table 1. Overview of the respondents to the company and the type of transport engaged

Company	Type of transport engaged	number of drivers
TC1	passengers	59
TC2	passengers	56
TC3	passengers	66
TC4	goods	42
TC5	goods	42

Table 2. The ranking of indicators related to the fatigue of commercial vehicle drivers (22)

Group	Influential factor	Value
1	Sleep quality	14.909
	The amount of sleep	14.455
2	Daily driving time	10.545
	Driving time (by visibility)	10.455
	Daily rest of the driver	9.364
3	Weekly driving time	7.909
	Age	7.727
	The measures used to eliminate sleepiness	7.364
	Two-week driving time	6.545
4	Monthly mileage	5.636
	The type of vehicle it manages	5.091

The drivers responded to 11 questions, which are defined according to the most important factors influencing the onset of fatigue in the driver of commercial vehicles, which were previously defined by Davidović and Antić (22), are shown in Table 2. Davidović and Antić (22) have shown that using the method of expert judgment, it was found that the most influential indicator of fatigue is the quality of sleep, which has a 2.92 times greater impact than the least influential indicator, that is, the type of vehicle that the driver manages.

RESULTS

In order to identify the fatigue due to commercial vehicle drivers, the five observed transport companies analysed all 11 influential factors: the amount of sleep, sleep quality, daily, weekly and two-week driving time, daily rest, driving time (by visibility), as well as the types of vehicles that drives, the driver's age and distance traveled.

In the continuation of the analysis type of vehicles, not particularly analyzed, given that the companies, TK1-TK3 passenger transportation by bus, and in TK4 and TK5 goods, heavy cargo vehicles. Also, not really analyzed monthly distance travelled because it is approximately equal in all transportation companies where more than 80% of drivers travel more than 1600 km monthly. In addition, the age of the driver as an influential factor is something included in the model, but not particularly analysed according to the transport companies, because the sample was not stratified by this criterion. As a result of the analysis of the four observed age categories it was found that 23.5% of the drivers aged 36-45 years identified fatigue, then 17.5% of the drivers 26-35 years, at 9.1% of drivers over 45 years of age and 4.5% among drivers up to 25 years.

The analysis of the eight road safety indicators, which, due to the commercial vehicle drivers' fatigue, can determine which company has the most driver fatigue, at the time of testing, and that these are " weakest link" for any company in terms of these indicators.

Table 3. Values of analysed fatigue indicators for transport companies

TC	% of drivers who drive more than 1.600 km a month	% of drivers who slept less than 6 hours last night	% of drivers who have poor sleep quality	% of drivers who drive over 70% at night	% of drivers who exceeded the daily driving time	% of drivers who exceeded the weekly driving time	% of drivers who have exceeded the two-week driving time	% of drivers who had at least 11 hours of daily rest	% of tired drivers
TC1	98	25	1,7	5,1	1,7	52,5	59,0	42	5
TC2	93	71	3,6	3,6	19,6	16,1	25,0	29	7
TC3	86	45	25,7	15,1	19,7	25,7	35,0	42	35
TC4	81	69	16,7	7,1	16,7	1,6	1,6	33	17
TC5	86	69	16,7	7,1	11,9	7,1	12,0	36	17

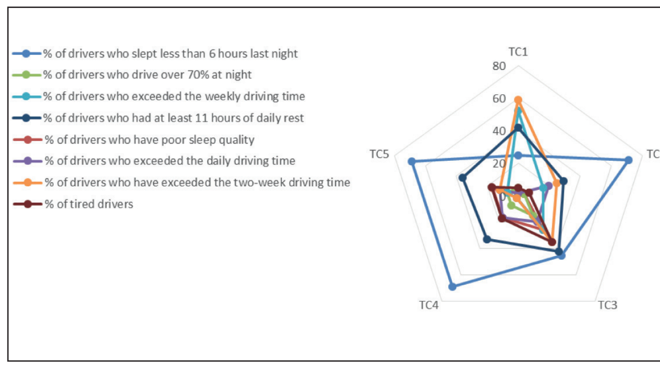

Figure 1. Values of analysed indicators for transport companies

In the company, which is designated as TK1 the worst value has indicator "% of drivers who have exceeded the law defined driving time for two consecutive weeks", which is 90 hours, even 59% of drivers. In the other four analyzed transport companies indicator with the worst results is "% of drivers who slept less than 6 hours of the night." On the basis of the presented results, it can be concluded that on the issue of fatigue due to drivers of commercial vehicles in TK1, the most important indicator is from the group of indicators related to the transport company, while in other companies the biggest problem is the amount of sleep, i.e. the indicator that is in connection with the driver. The second place is the indicator related to the transport company, that is, the daily rest of the driver is shorter than 11 hours.

The application of a new model for the identification of fatigue, which is based on the weighting of influential factors has been found that the most tired drivers in a company is engaged in the transport of passengers marked with TK3, even 35%, then 17% in companies that are engaged in the transport of goods (Fig. 2-left).

According to Davidović and Antić (22), the most influential factors are the quality and quantity of sleep. A comparative analysis of the results of the models and indicators «% of drivers who have poor sleep quality» and» % of drivers who have slept less than 6 hours of the night « observed that companies with a high value of drivers who have poor sleep quality, have a higher driver fatigue index. On the other hand, the amount of sleep has a different distribution, that is, at least sleep have the drivers in the company of TK2, after which the truck drivers (Fig. 2-right).

A comparative analysis of the percentage of drivers whose last day›s rest was less than 11 hours and the percentage of driver fatigue observed that a larger percentage of driver fatigue in companies in which more drivers have been reduced daily rest (Fig. 3-left). Similarly, a study shows that companies where drivers are more likely to drive at night have a higher percentage of driver fatigue (Fig. 3-right).

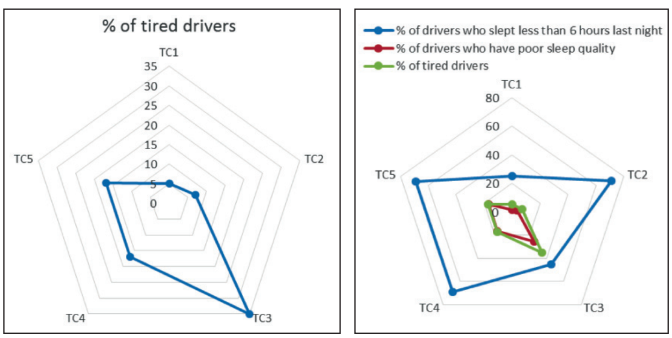

Figure 2. Percentage of tired drivers (left) and comparative analysis of indicators related to sleep and determined fatigue by transport companies (right)

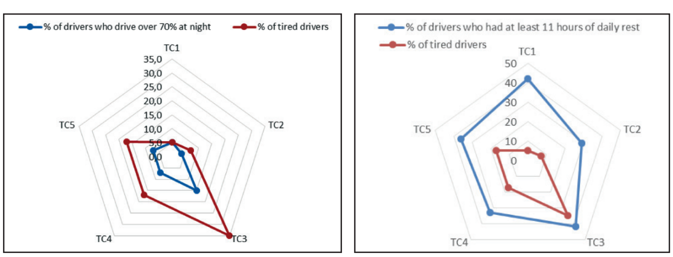

Figure 3. Comparative analysis of daily rest and % of tired drivers (left); % of drivers driving more than 70% at night and % of tired drivers (right)

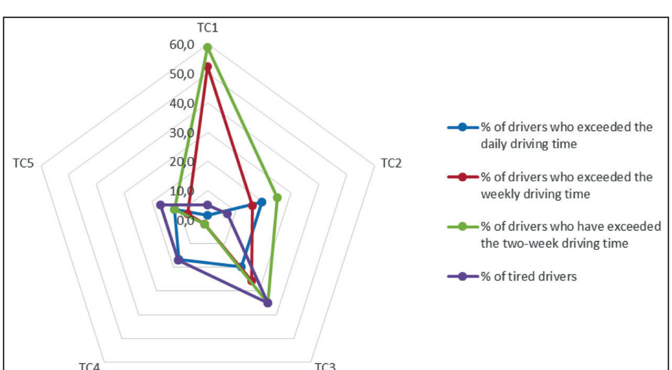

Figure 4. Comparative analysis of driving time and % of tired drivers

As a result of the analysis of road safety indicators in relation to driver fatigue of commercial vehicles become destructive data, so that in the analyzed transport companies, the percentage of drivers who were in the previous day exceeded by law limited driving time ranges from 1.7% to 19.7%. During the week, driving time and driving time for two consecutive weeks exceed 1.6% of drivers in TK4 to 52.5%, i.e. 59% of drivers in TK1 (table 3, figure 4).

A comprehensive analysis of the studies concludes that the largest excess of the legal limit of driving time in TK1, and the smallest in TK4, the largest percentage of drivers who had a reduced daily rest in TK1 and TK3. On the other hand, drivers in TK1 have better values of indicators that relate to the amount and quality of sleep. Bus drivers have significantly better performance values that relate to the quality and amount of sleep than a truck driver, but have more common exceeding legal driving time limits.

DISCUSSION

Model for the identification of fatigue due to commercial vehicle drivers, in which the application is shown in this paper, provide detailed and comprehensive analysis of the state of road safety on the issue of drivers fatigue, regardless of whether it is the transport of goods or the transport of passengers.

The model allows:

- to prevent driving under the influence of fatigue
- identify the main indicators of road safety, related to fatigue due to the drivers of commercial vehicles
- rank transport companies according to the level of road safety in terms of fatigue
- identify the "weakest link" within the transport company when it comes to indicators that relate to driver fatigue
- highlight the best companies at the local community level that will be subsidized and rewarded.

The advantages of this model compared to the still developed models are:

- apply quickly-the driver needs no more than 3 minutes
- easy to apply-the driver answers 3 questions and the responsible person reads the information for another 8 items from the valid documents
- reliable-out of 11 questions, 8 are obtained by reading documents, only 3 questions are based on self-reported behavior (quantity and quality of sleep, application of measures to eliminate drowsiness)
- does not require additional material resources (cameras, electrodes, devices for monitoring brain waves, sensors, etc.)
- does not require drivers to be connected to any

devices that distract them while driving
- it acts proactively-the driver does not put in motion, if it is found that tired, ie without endangering any passengers or cargo, or the driver
- not spatially limited – does not bind to one vehicle, which is installed, can be applied anywhere
- not timed-previous fatigue detection systems usually have trouble identifying in the event of darkness or if the driver is using sunglasses, so at night and on hot summer days is not suitable.

The main disadventage of this model is that it does not include all the influential factors, for example. Can not determine whether the driver during the day rest rested or had some extra work, can not control himself, whether the driver was 6 hours of sleep, and even if he had frequent sleep breaks, or sleep was quality. These deficiencies can be addressed by further research, i.e. identification of factors that can be controlled and are directly related to these deficiencies.

CONCLUSION

This paper shows the procedure for applying new, simple and reliable models to identify fatigue in commercial vehicle drivers. The model shown takes a step further compared to the models that have been used so far because it does not require additional resources in the form of a camera, a device for recording brain waves, electrodes, sensors, etc.., does not require special training, is applied simply, not spatially limited application and gives an overall picture of the status of important road safety indicators that are based on fatigue in commercial vehicle drivers.

The importance of applying a new model for identifying fatigue in the drivers of commercial vehicles for the local community is that local communities and transport companies within local communities can be monitored and ranked in terms of fatigue. As shown in the paper, the model shows in which company the most tired drivers are, whether the company is a problem of safety indicators of traffic related to fatigue related to drivers or related to the transport company. The significance of the local community is also reflected in the possibility of ranking transport companies in this aspect of traffic safety and easier choice of carriers, for example, for organized transportation of pupils, for organized excursions, etc.

REFERENCES

[1] Hockey, G.R.J., Wastell, D.G., Sauer, J. Effects of sleep deprivation and user interface on complex performance: a multilevel analysis of compensatory control. Human Factors 40 (2), 1998, pp. 233–253.

[2] Horne, J., Reyner, L. Falling asleep at the wheel, Report TRL 168. Transport Research Laboratory, Crowthorne, 1995.

[3] Horne, J., Reyner, L. Sleep-related vehicle accidents: some guides for road safety policies. Transport Research Part F, 4, 2001, pp. 63-74.

[4] Houser, A., Murray, D., Shackelford, S., Kreeb, R., Dunn, T. Analysis of benefits and costs of lane departure warning systems for the trucking industry. Washington, D.C.: Department of Transportation, Federal Motor Carrier Safety Administration, 2009.

[5] Jackson, M. L., Croftc, R.J., Kennedy, G.A., Owens, K., Howard, M.E. Cognitive components of simulated driving performance: Sleep loss effects and predictors. Accident Analysis and Prevention 50, 2013, pp. 438–444.

[6] Jo, J., Lee, S.J., Ryoung Park, K., Kim, I.J., Kim, J. Detecting driver drowsiness using feature-level fusion and user-specific classification. Expert Systems with Applications 41, 2014, pp. 1139–1152.

[7] Johns, M. W. Sleep physiologist's view of the drowsy driver. Transportation research part F Traffic Psychology and Behaviour, 3, 2000, pp. 241-249.

[8] Jung, S., Shin, H., Chung, W. Driver fatigue and drowsiness monitoring system with embedded electrocardiogram sensor on steering wheel. IET Intelligent Transport Systems, Vol. 8, Iss. 1, 2012, pp. 43-50.

[9] Klauer, S., Dingus, T., Neale, V. The effects of fatigue on driver performance for single and team long – haul truck drivers, Proceedings of the Second International Driving Symposium on Human Factors in Driver Assessment. Training and Vehicle Design, 2003, pp.143-147.

[10] Lal, S.K., Craig, A.A. A critical review of the psychophysiology of driver fatigue. Biological psychology 55, 3, 2001, 173-194.

[11] May, J., Baldwin, C. Driver fatigue: The importance of identifying causal factors of fatigue when considering detection and countermeasure technologies. Transportation Research Part F 12, 2009, pp 218–224.

[12] Mohamed, N., Mohammad-Fadhli, M., Othman, I., Zulkipli,Z., Rasid Osman,M., Shaw Voon, W. Fatigue-related crashes involving express buses in Malaysia: Will the proposed policy of banning the early-hour operation reduce fatigue-related crashes and benefit overall road safety? Accident Analysis and Prevention 45S, 2012, pp. 45– 49.

[13] Monique AJ, Ketzer S, Blom K, Maartje H, van Gerven, van Willigenburg G, Olivier B, Verster C. (2011). Positive effects of Red Bull® Energy Drink on driving performance during prolonged driving. Psychopharma, 2011, pp. 737–745.

[14] Morris, D.M., Pilcher J.J., Switzer III F. Lane heading difference: An innovative model for drowsy driving detection using retrospective analysis around curves Accident Analysis and Prevention 80, 2015, pp. 117–124.

[15] Obst, P., Armstrong, K., Smith, S., Banks, T. Age and gender comparisons of driving while sleepy: behaviours and risk perceptions. Transportation Research Part F: Traffic Psychology and Behaviour, 14(6), 2011, pp. 539-542.

[16] Williamson, A., Friswell, R. The effect of external non-driving factors, payment type and waiting and queuing on fatigue in long distance trucking. Accident Analysis and Prevention 58, 2013, pp. 26–34.

[17] Wu, J.D.; Chen, T.R. Development of a drowsiness warning system based on the fuzzy logic images analzsis, Expert Systems with Applications 34, 2008, pp. 1556-1561.

[18] Pešić, D., Antić, B., Brčić, D., Davidović, J. Driver's attitudes about the impact of caffeine and energy drinks on road traffic safety, Promet, accepted for publication, ISSN: 1848-4069, 2015.

[19] Davidović, J., Pešić, D., Antić, B. Professional drivers' fatigue as a problem of the modern era, Transportation Research Part F 55, 2018, pp. 199–209, https://doi.org/10.1016/j.trf.2018.03.010.

[20] Gupta, S., Garima, E. Road Accident Prevention System Using Driver's Drowsiness Detection by Combining Eye Closure and Yawning. International Journal of Research (IJR) 1 (6), 2014, pp. 839-842, ISSN 2348-6848.

[21] Williamson, A., Lombardi, D., Folkard, S., Statts, J., Courtney, T., Connor, J. The link between fatigue and safety. Accident Analysis and Prevention 43, 2011, pp. 498–515.

[22] Davidović, J., Antić, B. The most important indicators of fatigue due to commercial vehicle drivers. XIII International Conference Road Safety in the Local Community, Proceedings, Book 2, 2018, p. 1-10, ISBN 978-86-81230-01-5, Kopaonik.