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How to Reduce Work-Related Road Deaths? Driver Fatigue Monitoring – Case Study

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ABSTRACT

Work-related road deaths are the leading cause of occupational death. These traffic accidents contribute to at least one quarter all work-related deaths. Key risk factors associated with driving for work are driver fatigue and speeding. Driver fatigue is the growing problem of the new era. Due to traffic exposure, commercial vehicles are identified as a particularly risky category. According to traffic accident data, depending on the country, the percentage of traffic accidents caused by driver fatigue ranges up to 40%. In this paper, we used a unique procedure for identifying fatigue based on eleven factors, using expert knowledge, budget allocation and the composite rank method. The case study was realised in the Republic of Serbia, which is a country with a huge professional drivers deficiency problem. The main objective of this paper is to present an approach to reducing work-related road deaths to reach vision zero, based on a model for identifying commercial vehicle driver fatigue before the drivers start their shift. The advantage of this model is that it does not distract the driver in any way while driving and is based on objective data. It does not require recording the driver with a camera or hooking up to an electrode to record heart or brain activity.

KEYWORDS

work related road deaths; fatigue; road safety; commercial vehicle drivers; road safety performance indicators; new fatigue identification model.

1. INTRODUCTION

Work-related road traffic deaths are the leading cause of occupational death. These traffic accidents contribute at least one quarter all work-related deaths [1–5]. Professional driving is a highly hazardous activity, involving risks far higher than those encountered in virtually any other occupation or most other activities of daily life [6].

Key risk factors associated with driving for work are driver fatigue and speeding [7] because they tend to drive while fatigued and under time-pressure to reach a destination all the while distracted by in-car tasks such as mobile phone conversations, eating and drinking [8].

A growing problem of the new era is driver fatigue [7, 9-16]. In the Republic of Serbia, about 3% of traffic accidents with fatalities occurred due to the influence of drivers' fatigue [17]. Accidents due to fatigue driving account for 25% freeway accidents in Germany [18], 21% fatal accidents in France [19] and 21% of the total number of road traffic accidents in China [20].

This paper aims to develop a new approach for reducing work related road deaths, which is based on the procedure for the creation and simple application of a new fatigue identification model for commercial vehicle drivers by transportation companies.

Previous studies have analysed the influence of fatigue and presented the development of a model for detecting fatigue while driving, which is installed in a vehicle based on tracking the movement of the steering wheel [21–22], monitoring the position of the vehicle in the traffic lane [23–25], tracking the driver's eyes and/or face [20, 26–33] and based on physiological indicators such as heart rate and brain activity [28, 34–39].

Therefore, in previous studies, fatigue detection systems have been developed, but no model has been developed that can detect fatigue immediately before the driving stars. The detection of fatigue while driving is already a risk zone, for example, it detects the fatigue of a bus driver who transports a full bus of passengers before dawn on a highway where there is no rest stop nearby.

The results of this approach enable preventing the drivers from starting the shift if they are found to be fatigued.

In this paper, we used a unique procedure for identifying fatigue based on eleven factors, using expert knowledge, budget allocation and the composite rank method. The case study was realised in the Republic of Serbia. The Republic of Serbia is a country with a huge professional drivers deficiency problem [9], due to lack of staff, drivers working overtime, resulting in fatigue while driving. This problem is expressed in other countries as well. According to the IRU [40], Europe has 105,000 unfilled bus and coach driver positions, which represents 10% of the total. The shortage of truck drivers in Europe is forecasted to remain high with 9% of driver positions in 2023, reaching at least 300,000 unfilled jobs [41].

All these findings contribute to achieving the global goal to reduce the incidence and risk of death and serious injury related to road traffic accidents which is embedded in the UN Global Plan for Road Safety and the UN Sustainable Development Goals and Vision Zero according to the ISO 39001 standard.

2. METHODOLOGY

2.1 Research area

The research was done on a sample of commercial vehicle drivers in Republic of Serbia. In the period from 1 January 2018 to 31 December 2022 in the Republic of Serbia, about 3% of traffic accidents with fatalities occurred due to the influence of fatigue on drivers according to the official statistics of the Ministry of Internal Affairs. However, if traffic accidents involving commercial vehicles are observed in the same period, it was found that this percentage is around 5% (http://bazabs.abs.gov.rs/smartPortal/saobNezgode). Considering the specificity of fatigue measurement, it is considered that this percentage is significantly higher than what the official statistics shows, because the data obtained in this way are not reliable enough since there is no device on the basis of which the level of fatigue in the driver can be measured, as is, for example, the device to measure the level of alcohol in the blood. The representation of commercial vehicles in the fleet in the Republic of Serbia varies depending on the municipality, and ranges from 7 to 14%.

The occupation of a professional driver comes in third place on the list of professions in which there is a shortage of workers. The Republic of Serbia currently lacks between 7 and 10 thousand professional drivers. The existing drivers are retiring, and there are no young ones to replace them. It is assumed that by 2026, 30% of drivers will retire. The influx of young staff is up to 7 times lower than that. All of this leads to professional drivers working overtime due to lack of staff, resulting in fatigue while driving [42].

2.2 Research design

An algorithm for designing a model is constituted of eight parts (*Figure 1*). The first step in defining an approach for fatigue identification in commercial vehicle drivers is analysing the previous experiences – scientific papers and professional studies related to the impact of fatigue on drivers conducted since the 1970s.

Based on results of the first step, the second step consists of defining a broader list of road traffic safety indicators related to commercial vehicle driver fatigue.

In this list, the indicators are classified in four groups on the basis of the first step, sleep indicators, work indicators, rest indicators and indicators of undertaken activities [12].

Next, from the broader list made by Davidović et al., [12] we defined a narrow list of indicators. In the narrow list, the indicators are classified into two groups: indicators related to the state of the transportation company and indicators related to drivers (individually). The objective manner of selecting key road safety performance indicators actually represents the application of appropriate techniques or methods whose aim is to determine the dependence, i.e. the strength of the correlation between the indicators and the number and consequences of traffic accidents.

However, when it comes to defining the fatigue related indicators, apart from statistical techniques, the objective methods should include the analysis of the tachometer [12].

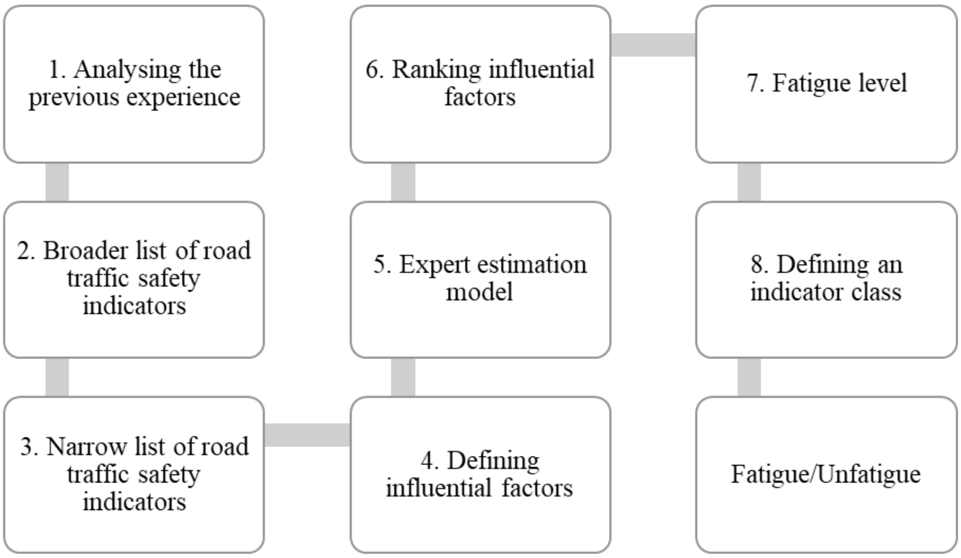

Figure 1 – Algorithm for designing a model

The fourth step is defining influential factors on driver fatigue. The influential factors were selected on the basis of previous experiences related to this topic worldwide according the criteria defined by Hermanns et al. [43] for selecting relevant key indicators: relevance, measurability, specificity, sensitivity, reliability and comparability. Objective indicators were used in defining the influential factors and subcategories of the influential factors: statistical method and tachometer analysis. The tachometer analysis provides an easy and reliable manner for determining the driver's daily, weekly and fortnightly driving time, as well as the driver's resting time. Several studies have investigated the factors that have contributed to the occurrence of accidents due to driver fatigue.

The influential factors were defined on the basis of reviewing the previous experiences, i.e. numerous studies conducted worldwide, with the application of various methods such as questionnaires, experiments and/or observation. The fatigue identification model consists of eleven influential factors based on the literature shown in *Table 1*.

Table 1 – The influential factors defined on the basis of reviewing the previous experiences

Influential factor	**Previous experience**
Sleep quality	[9, 14, 44–49]
Sleep quantity	[9, 14, 45, 50–52]
Driving time (daily driving time, vehicle operation time, weekly driving time, fortnightly driving time)	[9, 45, 51, 53–56]
Driver's daily rest	[44, 53, 57]
Measures used for preventing sleepiness	[9, 15, 45, 58–60]
Driver age	[15, 46-49, 51, 61]
Monthly covered mileage	[62]
Type of the vehicle they operated	[54, 62]

After determining the influential factors, the experts research was applied with the aim of assigning weights to indicators and subcategories. The research aimed to include 17 experts from the field of road traffic safety in several European countries and eleven experts participated in the research. An expert represents a university professor whose narrow scientific field is road traffic safety. The research was carried out electronically.

The experts applied the "budget allocation" model to the eleven relevant factors and allocated 100.000 euros; a higher value of money represented a higher importance of the indicator. Expert estimations of each participant had the same value. After allocating the budget according to the factors, for each factor they made an allocation for subcategories. For example, if the expert assessed that the amount of sleep is 20% influential, i.e. 20,000 euros, those 20,000 euros are divided into the subcategories of sufficient amount of sleep 10% (2,000 euros) and insufficient amount of sleep 90% (18,000 euros).

The sixth step in defining the model was ranking the indicators according to the experts' estimations. Following the definition of the influential factor list, the expert estimation method and composite rank method were used to perform the ranking of factors influencing commercial vehicle driver fatigue.

The application of the composite rank method resulted in the each indicator rank (CRi), which combines and integrates the ranks obtained by each expert's estimation, on the basis of the following expression:

$$CR_i = \frac{\sum_{j=0}^{n} R_{ij}}{n}, i = \overline{1,m} \quad (2.1)$$

where:

CR_i – the composite rank of the indicator *i*

R_{ij} – the rank of the indicator *i* allocated by the expert *j*

m– the number of indicators

n – the number of experts

This method implies combining the indicator ranks allocated by the experts; i.e. each of the experts *j* can define the indicator *i* according to a specific rank (R_{ij}). Based on the numerical value of the composite rank, the ranking list of indicators was formed (*Equation 2.1*).

Finally, the fatigue checking model, which refers to the driver *j*, is obtained by summing up the eleven weighting coefficients W_{si} which describe the current state of the driver *j* fatigue at the beginning of the shift. Based on the final value of the sum of the corresponding weighting coefficients, it is determined whether the driver is able to operate the vehicle safely.

$$F_j = \sum_{i=1}^{11} W_{si} \quad (2.2)$$

where:

$$W_s = \frac{\sum_{j=0}^{n} R_{ij} \cdot b_{sj}}{n \cdot 100.000} \cdot 100\%, s = \overline{1,l} \quad (2.3)$$

where:

F_j – fatigue level of the driver *j*

W_{si} – the weighting coefficient of the influential factor *i*

R_{ij} – the rank of the indicator *i* allocated by the expert *j*

b_{sj} – the weighting coefficient of the subcategory *s* by the expert *j*

n – the number of experts

i – the number of categories

s – the number of subcategories

After the ranking of each indicator was determined, the weight coefficients for each subcategory were determined. First, the weight coefficient for each subcategory was determined by each expert, and then, using the composite rank method, and according to the given *Equation 2.1*, the weight coefficient was calculated for each subcategory of the influencing factor (W_s) according to the *Equation 2.3*.

Defining the indicator classes implies defining the colours of the classes and their boundaries. Considering the characteristics of driver fatigue, it is not useful to define the number by which the driver is fatigued or not. In order to overcome this problem, we defined 5 equal classes of fatigue indicators. The upper limit of the class is calculated based on the following equation:

$$CLASS_i = minF + i \cdot C \quad (2.4)$$

where C is calculated based on *Equation 2.5*:

$$C = \frac{maxF - \min F}{5} \tag{2.5}$$

where:

max F – maximum fatigue level
min F – minimum fatigue level
i – the number of class
C – class coefficient

2.3 Data

Population included in this research are professional drivers (bus drivers and truck drivers) across the Republic of Serbia employed in transportation companies.

The facts related to driver fatigue were explored by trained researchers together with dispatchers. Trained researchers are graduate traffic engineers who were trained by the authors on how to use the questionnaire, i.e. how to quickly and easily collect reliable data from drivers before the start of the shift, as well as data from dispatchers. The research consists of two parts:

1) For each driver, the following data was collected: age, type of vehicle, monthly mileage, driving time (last day, last week and last two weeks, by visibility) and last daily rest. The data was linked to the driver's ID.
2) Then an interview was conducted with the drivers in order to collect data on the amount and quality of sleep and the measures they take to eliminate fatigue. Before the start of the shift, each driver answered three questions: how many hours they slept the previous night, what was the quality of their sleep and what measures they use to eliminate drowsiness while driving.

It was a sample of 1340 commercial vehicle drivers of 15 selected transportation companies from different parts of the Republic of Serbia, all age groups, who voluntarily participated in the research. The majority of drivers are aged 36 to 45 (38%), followed by drivers aged 25 to 35 (28%). The least number of drivers belong to the age category up to 25 years (5%), due to the legal limit, which at the time of the research was 24 years for a bus driver and 21 years for a truck driver.

Among the drivers of commercial vehicles in the Republic of Serbia, 3% are women, so this sample also consists of about 3% women. The sample consists of 43% truck drivers (over 3.5 t), 34% commercial vehicle drivers and 23% bus drivers. Any ambiguity about issues was solved on the spot, so all answers were used and there were no missing data.

3. RESULTS

The results are systematised in three parts. The first part presents the results obtained on the basis of expert evaluation. The second part presents the results of defined classes of fatigue indicators. Finally, in the third part, a case study applied in transport companies with drivers of commercial vehicles is presented.

3.1 Experts research

The expert estimation showed that the most influential indicator, sleep quality, had a 2.92 times stronger impact than the least influential factor, i.e. the type of the vehicle the driver operated (*Table 2*).

Table 2 presents the ranking of the indicators (factors) related to commercial vehicle driver fatigue, from the most influential (Sleep quality) to the least influential (Type of vehicle).

In addition, the experts also defined weighting coefficients for each subcategory of the influential factors used in the model (*Table 3*). *Table 3* presents weighting coefficients of the subcategories of the influential factors obtained on the basis of *Equation 2.3* for each influential factor (i).

Table 2 – Ranking of the indicators related to commercial vehicle driver fatigue, from the most influential (Sleep quality) to the least influential (Type of vehicle)

INFLUENTIAL FACTORS	CR_i	%
Sleep quality	14909	14.9
Sleep quantity	14455	14.5
Daily driving time	10545	10.5
Working period – time of the day	10455	10.5
Daytime rest	9364	9.4
Weekly driving time	7909	7.9
Age	7727	7.7
Fatigue prevention measures	7364	7.4
Fortnightly driving time	6545	6.5
Monthly mileage	5636	5.6
Type of vehicle	5091	5.1
SUM	100,000	100%

Table 3 – Weighting coefficients of the subcategories of the influential factors

INFLUENTIAL FACTORS	Subcategory	W_s
Age	Up to 25	2.3
	25–35	1.6
	36–45	1.6
	45+	2.3
Type of vehicle	Passenger cars and commercial vehicles up to 3.5	1.1
	Trucks 3.5 t +	2.1
	Bus	1.8
Monthly mileage	Up to 1,600 km	1.7
	Over 1,600 km	4.0
The amount of sleep	At least 6 hours	8.5
	More than 6 hours	6.0
Sleep quality	Good	2.5
	Bad	12.4
Driving time (by visibility)	About the same day and night	2.6
	Day – 90% of the time	1.7
	Night – 90% of the time	6.2
Daily driving time*	≤ 9 hours	3.0
	> 9 hours	7.5
Weekly driving time*	≤ 56 hours	2.2
	> 56 hours	5.7
Fortnightly driving time*	≤ 90 hours	1.9
	> 90 hours	4.6
Daily rest of the driver*	≥ 11 hours	2.7
	< 11 hours	6.6
The measures used to eliminate sleepiness	Listening to the radio	1.5
	Consuming caffeinated beverages	1.8
	Sleeping	3.0
	Other measures	1.0

* In accordance with the legal limit at the time of the research (daily driving time up to 9 hours, weekly up to 56 hours, fortnightly up to 90 hours and a minimum daily rest up to 11 hours)

3.2 Defining classes

The values of the F range from 25.3 (minimum sum) to 62.9 (maximum sum). According *Equations 2.4* and *2.5,* we defined 5 equal classes:

$$C = \frac{62.9 - 25.3}{5} = 7.52$$

$$CLASS_1 = 25.3 + 1 \cdot 7.52 = 32.82$$

$$CLASS_4 = 25.3 + 4 \cdot 7.52 = 55.38$$

Table 4 – Classes of fatigue indicators

Class	F value
UNFATIGUED	F≤32.82
SLIGHTLY FATIGUED	32.82<F≤40.34
MODERATELY FATIGUED	40.34<F≤47.86
VERY FATIGUED	47.86<F≤55.38
COMPLETELY FATIGUED	F>55.38

Classes are given in *Table 4*. Drivers who have a value of F above 55.38 are in a completely fatigued state, while drivers with values below 32.82 are unfatigued.

3.3 Serbian drivers – Case study

Input:

Trained researchers together with dispatchers collected the data, entered it into the database and applied the fatigue identification model. Input indicators are shown in *Table 5*. *Table 5* shows the values of the input indicators. The largest percentage of the sample consists of drivers aged 36 to 45 (37.9%). There are the fewest drivers under the age of 25, because they are the least represented among drivers of commercial vehicles.

The research was carried out in companies dealing with passenger transportation (22.6%), goods transportation by trucks over 3.5 tonnes (43.6) and delivery vehicles up to 3.5 tonnes (33.8). Around a third of drivers sleep at least six hours, but slightly more than half have poor sleep quality (54.7%). About 4% of drivers drive only in night visibility conditions, and two thirds drive equally in day and night conditions. When analysing driving time, the biggest problem for drivers is the two-week driving time, which about 40% of drivers did not comply with in the previous two weeks. Almost a quarter of drivers did not have a daily rest of at least eleven hours the previous day. Among the measures, the least used was consuming caffeinated beverages (12.3%).

Table 5 – Input indicators

INFLUENTIAL FACTORS	Subcategory	N	%N
Age	Up to 25	64	4.8
	25–35	372	27.7
	36–45	508	37.9
	45+	396	29.6
Type of vehicle	Passenger cars and commercial vehicles up to 3.5	453	33.8
	Trucks 3.5 t +	584	43.6
	Bus	303	22.6
Monthly mileage	Up to 1,600 km	152	11.3
	Over 1,600 km	1188	88.7
The amount of sleep	At least 6 hours	414	30.9
	More than 6 hours	926	69.1
Sleep quality	Good	607	45.3
	Bad	733	54.7
Driving time (by visibility)	About the same day and night	827	61.7
	Day – 90% of the time	465	34.7
	Night – 90% of the time	48	3.6
Daily driving time	≤ 9 hours	1085	81.0
	> 9 hours	255	19.0
Weekly driving time	≤ 56 hours	1100	82.1
	> 56 hours	240	17.9
Fortnightly driving time	≤ 90 hours	822	61.3
	> 90 hours	518	38.7
Daily rest of the driver	≥ 11 hours	1028	76.7
	< 11 hours	312	23.3
The measures used to eliminate sleepiness	Listening to the radio	462	34.5
	Consuming caffeinated beverages	165	12.3
	Sleeping	350	26.1
	Other measures	363	27.1

Example:

The data entered into the database is encrypted to facilitate the work of dispatchers and drivers. For example, the driver with ID 145 is under 25 years old, drives a truck and travels over 1,600 km per month, sleeps less than 6 hours but considers his sleep to be of good quality.

They drive equally in day and night visibility conditions. The previous day and the previous week they drove in accordance with the regulations, but they exceeded the two-week driving time. The previous day they had a day off in accordance with the regulations. When they feel tired while driving, they listen to the radio.

The next step is the assignment of appropriate weighting coefficients, in accordance with the data given in *Table 3*. Furthermore, by applying the fatigue identification model, the weighting coefficients for all eleven indicators, from W_{s1} to W_{s11}, were summarised for each driver, i.e. after applying the formula 2.2, the following is obtained:

…

F_{145}=2.3+2.1+4.0+8.5+2.5+2.6+3.0+2.2+4.6+2.7+1.5=36.0

…

F_{148}=1.6+2.1+4.0+6.0+2.5+2.6+3.0+2.2+1.9+2.7+1.5=30.1

…

F_{155}=2.3+2.1+4.0+8.5+2.5+2.6+7.5+5.7+4.6+6.6+3.0=49.4

F_{156}=1.6+1.1+4.0+8.5+12.4+6.2+7.5+5.7+4.6+6.6+1.8=49.4

…

F_{162}=2.3+2.1+1.7+6.0+12.4+6.2+3.0+2.2+1.9+2.7+1.5=42.0

…

Table 6 – Output indicators

Driver ID	F value	Indicator class
	...	
145	36.0	SLIGHTLY FATIGUED
	...	
148	30.1	UNFATIGUED
	...	
155	49.4	VERY FATIGUED
156	60.0	COMPLETELY FATIGUED
	...	
162	42.0	MODERATELY FATIGUED
	...	

The last step represents the definition of the class, i.e. the level of fatigue. According to the data (classes) from *Table 4*, the driver with ID 148 is not tired and can start driving. On the other hand, the driver with ID 155 is in very fatigued state and will represent a high risk for traffic safety if they start driving in that condition. Analogously, the driver with ID 156 is completely fatigued and must not drive (*Table 6*).

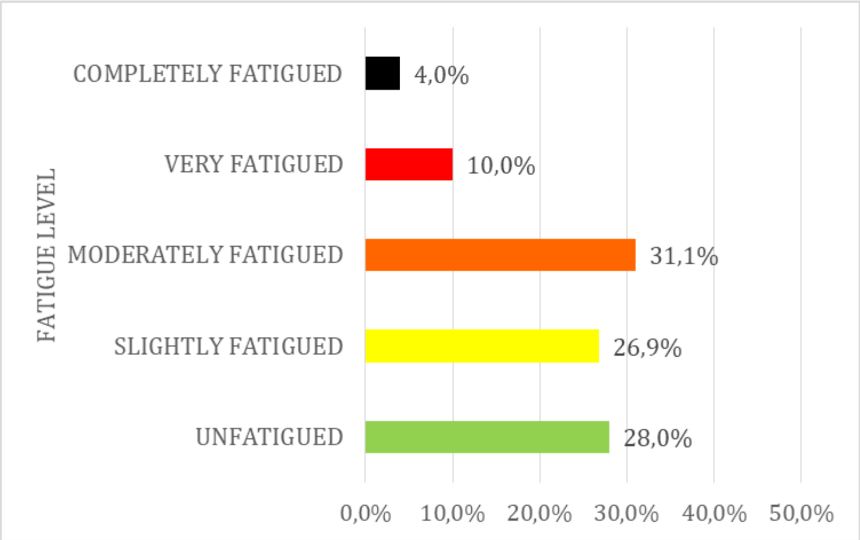

Figure 2 – Summary results for research population

In all drivers included in the research, the level of fatigue was determined, and then the summarised results are shown in *Figure 2*. As many as 4.0% of drivers were in a state of complete fatigue before the start of their shift. Only 28.0% of drivers were fully rested before the start of their shift. The results show that fatigue is common among drivers. Accordingly, it is necessary to monitor these indicators and take measures at the level of the transport company to solve this problem.

4. DISCUSSION

By applying the fatigue identification model we developed, it was determined that 4% of commercial vehicle drivers were at state of complete fatigue at the time of testing, which is in accordance with the data on traffic accidents of the Ministry of Internal Affairs, according to which in the period from 2018 to 2022, 3% of traffic accidents with commercial vehicles in the Republic of Serbia occurred due to driver fatigue.

The advantage of this model compared to previously developed fatigue detection systems is that it does not distract the driver in any way while driving and is based on objective data. It does not require recording the driver with a camera or hooking up to an electrode to record heart or brain activity. Another advantage of the model is that it is based on objective data obtained from the tachometer analysis. This method involves reading the document which, among other things, provides data on the driver's driving and resting hours. The combination of these data with the legal regulations regarding driving and resting hours provides the input data for the model. Data such as the amount and quality of sleep and the measures they take to eliminate fatigue can be collected through a subjective method by asking the driver. However, the subjective method can be overcome by developing a certified smartwatch that will track this data at the drivers.

Age was selected to be an influential indicator, which has been confirmed in various studies. For example, Diependaele [51] stated that drivers younger than 30 had higher chances of participating in fatigue-related traffic accidents. The model included the age of the driver as one of human characteristics, since fatigue does not develop at the same speed in a driver aged 25, 40 or 60. Age has an impact on the appearance of fatigue, but also on the way fatigue is accepted. It occurs less frequently among young people, but they ignore it. On the other hand, it occurs more often in the elderly, but they take measures as soon as they feel it.

The vehicle type was observed as an influential factor. Charlton et al. [54] had shown that the level of driver fatigue differed depending on the vehicle type (whether it transported goods or passengers). The travelled mileage was also observed. Vujanić et al. [62] stated that measures used by young drivers for preventing drowsiness differed depending on the travelled mileage. Truck drivers who cover long distances are the most vulnerable because they have a large percentage of night driving on monotonous sections and are usually alone in the vehicle.

Sleep quantity and sleep quality represent very significant influencing factors. Young drivers could experience various levels of sleepiness if their sleep quantity was restricted to five hours in the previous night and if they had been driving constantly for two hours in the afternoon on a monotonous route [46–47, 49]. Also, less than five hours of sleep had an impact on the development of drowsiness [51] and if the driver sleeps less than six hours in 24 hours, the probability that they will have poor quality sleep is eight times higher. Sleep quality was one of the most influential factors of the occurrence of fatigue-related traffic accidents [52], there was a 1.6 times higher probability for the occurrence of traffic accidents if the professional drivers believed that they had poor quality sleep [45]. Sleep plays an important role in the safe driving of a vehicle. Poor sleep quality and an insufficient amount of sleep have a great influence on the occurrence of traffic accidents due to fatigue.

The time of operating the vehicle was selected as an important influential factor because the body clock was programmed so that sleepiness happened twice a day: once during the usual sleep period, (01:00 a.m.–06:00 a.m.) with the critical period at 6 a.m., and then at 12:00 p.m.–04:00 p.m. [48]. Moreover, Sparrow et al. [44] concluded that having at least two nights in the break period helped sleep recuperation and driver fatigue reduction. With that in mind, driving at night presents the greatest risk.

Drivers who drive longer shifts and had shorter rest time before the beginning of the shift had a higher probability of participating in traffic accidents [53]. Operating time longer than 4 hours influenced the occurrence of sleepiness while driving [51], and operating time longer than 10 hours was certainly one of the causes of the accidents [45]. After eleven hours of work, the risk of being involved in an accident doubled [56]. Having this in mind, the following indicators were selected as relevant – "daily driving time", "weekly driving time", "fortnightly driving time" – and they can be simply determined by reading a tachometer.

The chance for the occurrence of a traffic accident was the lowest when the resting time was longer than eight hours [53]. Sparrow et al. [44] indicated that the driver's resting time should be at night, since solely in this manner they could adequately rest and prepare for the following shifts. All presented studies agree that resting time is one of the influential factors for the occurrence of driver fatigue-related traffic accidents.

The measures which drivers undertake to prevent sleepiness represent a significant indicator, which is included in the fatigue identification model, because the level of fatigue increases if the prevention measure is not adequate.

In the US, drivers undertook a series of strategies for preventing sleepiness: 68% of the drivers opened windows or increased the air-conditioning, 57% of them stopped the vehicle and went out for a walk, 30% of them listened to the radio, 25% of them talked to passengers, 14% of them drank coffee and 15% of drivers did something else [60]. In Turkey drivers took gripin in order to prevent sleepiness [59], while in Sweden they applied the following measures: stopping the vehicle, taking a nap, drinking caffeine, exposing themselves to strong light [58].

In the Republic of Serbia, it was determined that the measure depends on the age of the driver and type of vehicle. Coffee or tea was most often consumed by 36–45 years old drivers, whereas participants who were over 56 never consumed energy drinks [45]. Significant differences were found between truck, bus and passenger car drivers related to taking measures if they feel fatigued while driving, and it was the poorest for bus drivers because, in contrast to the drivers of trucks and passenger vehicles, they cannot stop and take a break or take a nap because they drive passengers according to the prescribed timetable [9].

5. CONCLUSION

This paper presents a new tool for driver fatigue monitoring which requires only a few minutes to determine the level of driver fatigue before engaging them in traffic. The model can be applied in all transportation companies, it does not require recording the driver with a camera or hooking up to an electrode to record heart or brain activity as previous models. The developed fatigue identification model is based on the results of numerous research conducted worldwide in the previous years, as well as on the experts' estimations (professionals in the field of traffic safety). The fatigue identification model consists of eleven influential factors which are defined on the basis of numerous statistical surveys conducted around the world in the last couple of decades. The influential factors are: sleep quality, sleep quantity, daily driving time, vehicle operation time, driver's daily rest, weekly driving time, fortnightly driving time and measures used for preventing sleepiness, driver age, monthly covered mileage, type of the vehicle they operated.

In addition to its scientific importance, this work is of great practical importance as it represents a new approach to reducing work related road deaths that can easily, quickly and simply be applied in transportation companies.

Approach presented in this paper can affect the achievement of vision zero in accordance with ISO39001 (2050 – Zero work related road deaths) and the global UN goal to reduce the incidence and risk of death and serious injury related to road traffic accidents.

The developed model can be applied in two ways:

- **Dispatcher approach** – A dispatcher in a transportation company can easily test drivers on fatigue. The respondent is asked three questions (the amount of sleep, sleep quality, measures used to eliminate sleepiness), and the dispatcher provides eight answers (age, type of vehicle, monthly mileage, daily driving time, weekly driving time, fortnightly driving time, daily rest of the driver, driving time (by visibility)). After the input of the responses, the dispatcher will receive information about the driver's level of fatigue.
- **Software** – Development of the software based on the data provided in this paper. Investing in certified smart watches for professional drivers can ensure daily monitoring of sleep quantity and quality. Considering the current development of technology, the use of smart watches is very comfortable. By creating the appropriate software that will connect the records from the smart watch and the digital tachometer, the final result can be obtained by entering data on measures to eliminate drowsiness, at any time, in any place. With software development this model excludes the possibility of "socially desirable responses" and is based on objective data. This model, with the development of an adequate software, can be a very reliable tool for monitoring the level of fatigue in professional drivers – faster, simpler and cheaper than alcohol or drug testing.

During the research, certain limitations were noticed. The first limitation was the assumption that all experts were equally weighted. Experts differ according to experience and the country in which they work. However, this shortcoming was somewhat overcome because all the experts are university professors. Another limitation is the impossibility of monitoring the information such as whether the drivers do something else during their resting hours (e.g. cultivate the land, grow plants, work in their or a friend's workshop, etc.), whether they are preoccupied with personal problems and deal with them during their daytime resting hours, which is not reflected in the sleep quantity and quality, etc.

This research provides a good basis for future research on the professional driver's road safety. Future research should be focused on tracking fatigue levels in transport companies based on software. In order to apply the model in other areas (countries, regions and continents), future research should be focused on additional calibration of coefficient values in the presented model due to the specificity of the area, such as driving and rest times, etc.

In the future, it is necessary to develop a model for non-professional drivers, because due to a dynamic lifestyle and a constant lack of time, many drivers decide to drive when they are tired, which leads to traffic accidents with serious consequences.

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Jelica Davidović, Dalibor Pešić, Boris Antić

Kako smanjiti broj poginulih radnika u saobraćaju? Praćenje umora kod vozača – studija slučaja

Rezime

Smrtno stradanje radnika u saobraćaju je vodeći uzrok smrtnog stradanja na poslu. Ove saobraćajne nezgode čine najmanje četvrtinu svih smrtnih stradanja na poslu. Glavni faktori rizika koji su povezani sa vožnjom na poslu su umor i prekoračenje brzine. Umor kod vozača je rastući problem nove ere. Zbog izloženosti u saobraćaju, komercijalna vozila su identifikovana kao posebno rizična kategorija. Prema podacima o saobraćajnim nezgodama, u zavisnosti od države, procenat saobraćajnih nezgoda nastalih usled umora kod vozača kreće se i do 40%. U ovom radu prikazana je jedinstvena procedura za identifikaciju umora kod vozača koja se zasniva na 11 faktora, ekspertskoj oceni, metodama alokacija budžeta i kompozitni rang. Studija slučaja je realizovana u Republici Srbiji, koja predstavlja državu sa velikim problemom nedovoljnog broja profesionalnih vozača. Glavni cilj ovog rada je da se predstavi pristup smanjenju smrtnog stradanja radnika u saobraćaju u cilju dostizanja vizije nula, koji se zasniva na modelu za identifikaciju umora kod vozača komercijalnih vozila pre nego što započnu smenu. Prednost ovog modela je što ni na koji način ne odvlači pažnju vozača tokom vožnje i zasniva se na objektivnim podacima. Ne zahteva snimanje vozača kamerom ili spajanje na elektrode za snimanje srčane ili moždane aktivnosti.

Ključne reči

smrtno stradanje radnika u saobraćaju; umor; bezbednost saobraćaja; vozači komercijalnih vozila; indikatori performansi bezbednosti saobraćaja; novi model za identifikaciju umora.