**Appendix A.** Background research and factors associated with DUI

The legal limit of alcohol for car drivers in most European countries is 0.5 g/L or less, except for commercial and novice drivers where the lower limit than the one for car drivers is applied (ETSC 2018). Since 2009 the legal limit in Serbia has been set at 0.3 g/L, except for commercial drivers, motorcycle and novice drivers for whom zero tolerance to alcohol is applied. After six years of the strict application of the law, relatively severe punishments and the realization of several campaigns related to DUI prevalence, a high percentage of DUI drivers still participate in traffic accidents. In the last few years, around 600 people died annually in traffic accidents in Serbia, which represents 9 fatalities per 100 000 inhabitants. In 2016, there were 35 967 traffic accidents in Serbia, out of which 13 845 were with injuries and 551 with deaths (RTSA 2018). 607 people died in these accidents, 3 362 were seriously injured, while 17 277 were slightly injured. In 2016, alcohol was the cause of traffic accidents in 9% of all the accidents. However, alcohol as the cause of traffic accidents has a greater share as the severity of accidents increases. Thus, approximately 17% of traffic accidents with fatalities in 2016 were related to alcohol (RTSA 2018).

Despite the strict application of the law, recent years have witnessed a relatively high percentage of DUI drivers causing traffic accidents. Random testing of a large number of drivers in the traffic flow causes various difficulties and requires enormous human and financial resources, so its application is debatable. Since the identification of DUI drivers represents one of the problems of DUI prevalence, the relationship between other factors and DUI was analysed in this study. The aim was to identify other factors which indicated DUI drivers and to direct testing and campaigns towards them. The relationship between risk factors and DUI will enable a cheaper and more efficient prevention of DUI prevalence, which will lead to the reduction of DUI prevalence.

However, the connection of other factors and DUI is unclear. Various studies have registered a large number of risk factors that connect driving under the influence of alcohol and the involvement in an accident.

Studies have shown that drivers of different vehicle categories have different sensitivity to alcohol effects (Fear et al. 2008; Lin and Kraus 2009; Park et al. 2017). This is the reason why the initial hypothesis of this research is that various risk factors are correlated to the drivers of specific vehicle categories.

In addition to alcohol-related factors, risk factors of participating in non-alcohol crashes should also be considered, in order to properly isolate and examine DUI factors. The main objective of this study is isolating risk factors of the participation of DUI drivers in traffic crashes.

Involvement in a traffic crash is related to various factors. Studies have shown the connection between traffic crashes and the journey purpose, i.e. mileage passed (O'Neill and Kyrychenko 2006); traffic conditions on urban and rural roads (Burgess 2005; O'Neill and Kyrychenko 2006); the seatbelt rate, participation of male drivers, drivers older than 64 years, driving under the influence of alcohol (Sivak 2009). The experience of the driver is a very significant risk factor linking the drivers and participation in traffic crashes (Maycock et al. 1991; Copper et al. 1995; Maycock 2001).

On the other hand, there are studies based on the risk factors of driving under the influence of alcohol. Alcohol consumption and accident risk are more often related to young drivers (Christophersen and Gjerde 2014; Peack et al. 2008) and male drivers (Mann et al. 2010; MacLeod et al. 2015; Meesmann et al. 2015).

Most research have stated that drivers under the influence of alcohol often do not use seatbelts (NHTSA 2009; Phillips and Brewer 2011; Tison et al. 2010; Briggs et al. 2008; Foss et al. 1994; Golias and Karlaftis 2002; Kweon and Kockelman 2006; Maron et al. 1986; Oleckno and Blacconiere 1990; Sahai et al. 1998). Also, alcohol is related to traffic accidents with fatalities (Evans 2004) and single-vehicle accidents (Christophersen and Gjerde 2014; Gjerde et al. 1993; Gjerde et al. 2011).

In order to examine the factors related to accidents, the locations of the accidents should be observed. Studying this problem, Burgess (2005) concluded that 42% more accidents occurred on urban than on rural roads. In addition, research has shown that the journey purpose can be related to the occurrence of the accident. Sultana et al. (2016) concluded that the mandatory journey trip (going to and from work) was more frequently linked with an accident than non-mandatory trips. However, the stated study results are limited by the mileage and congestion when examining mandatory journeys.

Alcohol is a significant risk factor for motorcycle drivers (Preusser et al. 1995; Savolainen and Mannering 2007; Lin and Kraus 2009; Albalate and Fernández-Villadangos 2010) and bicycle drivers (Li et al. 2001; Andersson and Bunketrop 2002; Airaksinen et al. 2010; Crocker et al. 2010; Orsi et al. 2014).

It is intuitively clear that it is less likely for drivers to use restraint systems (seat-belt or helmet) when they DUI. However, it is questionable to what extent the non-use of a seatbelt is linked with DUI. This is the reason why this study examines the relationship between risk factors of DUI drivers and their participation in traffic crashes. The study deals with driver factors related to DUI and their share in traffic crashes, with the aim to predict DUI.

The list of the factors’ contribution to driving under the influence of alcohol will represent very useful data for detecting DUI. It will also help to better understand driving under the influence of alcohol for drivers of different vehicle categories and will lead to the reduction of DUI prevalence.

**Appendix B.** Sample

Since 2009 there has been a legal obligation regarding the alcohol testing of every driver included in a traffic crash in Serbia. Drivers are tested even if they participate in non-injury traffic crashes. For non-injury crashes the driver testing is only carried out by breath testing, but when there are injuries or fatalities, the blood test is obligatory. In this study, a driver under the influence of alcohol is considered to be every driver with the level of alcohol >0.00 mg/ml, (DUI). Since 2015, the recording of traffic crashes has been performed according to the Common Accident Data Set (CADaS) protocol in Serbia. More on this topic and CADaS protocol can be found in the report by Yannis et al. (2008).

The research sample includes all car drivers, bus drivers, motorcyclists, truck drivers and bicycle drivers involved in road traffic crashes in the territory of Serbia in 2016. Drivers whose corresponding researched variables were unclear, unknown or irrelevant were excluded from the sample. For example, the sample did not include a driver who had been involved in a crash in the area which represents a combination of rural and urban areas (mixed area) or if the area of the crash was unknown. A similar principle was applied for other variables, and thus the sample for this research represents only the drivers with all clear variables. 60 666 drivers were involved in traffic crashes in Serbia in 2016. 25 574 of those drivers were analyzed (all variables clear), so the study’s sample encompasses: car drivers (20 711); truck drivers (3 335); bus drivers (825); motorcyclists (514); and bicyclists (189). The remaining sample is a convenience sample with complete data for all driver groups. The selection of the convenience sample has no limitations, since the sample was representative. The omission of ‘incomplete’ drivers has not altered the structure of the driver sample or the structure of the BAC results, and this makes the convenience sample representative for all drivers prior to excluding the incomplete drivers.

Out of the total number of 25 574 drivers, 23 138 (90.5%) did not have BAC, while the remaining 9.5% had BAC. 562 drivers or 2.2% had the BAC of 0.01-0.3 mg/ml; 182 drivers or 0.7% had the BAC of 0.31-0.5 mg/ml; 258 drivers or 1% had the BAC of 0.51-0.8 mg/ml; 361 drivers or 1.4% had the BAC of 0.81-1.2 mg/ml; 385 drivers or 1.5% had the BAC of 1.21-1.6 mg/ml; 329 drivers or 1.3% had the BAC of 1.61-2.00 mg/ml and 359 drivers or 1.4% had more than 2.01 mg/ml BAC.

The control sample was isolated from the basic set of traffic accidents and it was used for testing the model. The prerequisite for selecting the control sample was the lack of one variable for a driver group at the most (*i; i=1..5*). The control sample most frequently lacked the driver's age variable. According to the mentioned criterion, if one variable was missing, it was impossible to isolate control samples for all five driver groups but only for car, motorcycle and bicycle drivers.

**Appendix C.** Details of the logistic regression and TOPSIS method

The logistic regression analysis was carried out to evaluate the correlation between the DSC under the influence of alcohol (dependent variable) and the following variables: gender; age; use of restraint systems; the driver’s experience; area; journey purpose; and responsibility for the crash. All analyzed drivers were involved in road traffic crashes.

The adjusted odds ratio (OR) and 95% confidence intervals were calculated for all logistic regression models. OR is a statistical measure of the association between an exposure and an outcome. OR represents the odds for a result with certain exposure compared to the odds for the result which occurs with the absence of the exposure (Hosmer and Lemeshow, 2004). The analysis was completed using SPSS Statistics version 20 (Landau and Everitt, 2004).

Two separate models using TOPSIS were applied for DUI drivers and other drivers. Both models were based on OR values of previous logistic regression analyses. In logistic regressions, the dependent variable for other drivers was DSCs who were not under the influence of alcohol. The priority factor of DUI prevalence was determined on the basis of TOPSIS for DUI crashes and TOPSIS for non-DUI crash models.

The potential of factors for the prevalence of DUI was considered by comparing the results of the TOPSIS model for DUI crashes and the TOPSIS model for non-DUI crashes. A higher score on the DUI crash scale in comparison to the non-DUI crash scale indicates a larger potential of that factor.

The TOPSIS method represents a method of multi-criteria decision making developed by Hwang and Yoon (1981). The concept of the TOPSIS method is based on the distance (relative distance) from the ideal (the most significant factor) and anti-ideal (the least significant factor) solutions. Relative distance values in the TOPSIS method may be found within an interval from 0 to 1. The alternative (investigated risk factors) with the relative distance equivalent to 1 is actually an ideal solution, and the alternative with the distance equivalent to 0 represents an anti-ideal solution (Rosić et al. 2017).

Determination of the risk factors of DUI in a certain territory suggests the discussion of alternatives and possible criteria. In order to obtain performances of this set of factors, a decision matrix X is defined on the given set of criteria. The matrix X has *Аn* alternatives and *m* criteria. The alternatives in the decision matrix represent risk factors of DUI and the criteria represent DSC. Given that the OR=1 value represents the likelihood of 50% when it comes to bicyclists, the value OR=1 was used as the alternative of the driver’s experience.

The factors of DUI have different attribute dimensions, and this is the reason for normalizing the factors. Normalized *Yij* factors are calculated as follows:

(1)

Car drivers participate in traffic crashes most frequently because they represent the most numerous driver group. The consequences of their crashes differ. On the other hand, two-wheelers participate in traffic crashes less frequently but the consequences of their crashes are more serious. Crashes involving commercial vehicle drivers are rare but can have severe consequences. Thus, in addition to the number of crashes involving drivers, the severity of these crashes should be observed. That is why the weighted overall weight was used in the TOPSIS method as the weight factor of certain categories of drivers. According to this, the weighing factor looks like this:

,  (2)

Where *m* represents the number of groups of drivers (*i= 1,2,…m*); *ki* represents the weighted average weight of consequences of a crash of a *j* group of drivers:

 (3)

Where *Acdj* is – the number of non-injury crashes of the *j* group of drivers; *Acij*– the number of injury crashes of the *j* group of drivers; *Acf*j–the number of fatality crashes of the *j* group of drivers. The weighted values are determined on a three-tail scale according to the crash severity *P1=*1; *P2=*2; *P3=*3; n represents a number of traffic crashes by the *j* group of drivers.

According to the previously stated, after weighing the normalized decision matrix by the weighting factors:

(4)

Following the transformations, the most significant factor (PIS) is calculated:

(5)

PIS: (6)

As well as the least significant factor (NIS):

(7)

NIS: (8)

Calculating the score of each risk factor and ranking the risk factors are the last steps in the TOPSIS method:

(9)

According to the score value *RCi* (the risk factor’s value)*,* the alternatives are ranked in a decreasing order (from the largest to the smallest).

The same method of TOPSIS was used for DUI crashes and non-DUI crashes. Miscellaneous OR values were the input variables for DUI and non-DUI models.

**Appendix D.** Discussion of the study purpose

Drivers often use several different types of vehicles (cars, motorcycles, and bicycles). Commercial drivers also drive two-wheelers or cars. If a motorcycle driver is inclined to DUI, it does not mean that this driver is prone to DUI when driving a car. Drivers behave differently when driving different vehicle categories, so the predictors of DUI driving are not the same for motorcycle drivers and for car or bicycle drivers, for instance. This study takes these differences into consideration and deals with the predictors of DUI driving for each driver group.

The driver groups observed in this paper were classified according to the common characteristics typical of their driving. It is important to differentiate between motorcycle drivers and bicycle drivers, in order to identify the specific features of both groups. Although both groups of drivers have a high level of DUI, motorcycle drivers are the youngest and bicycle drivers are the oldest driver category. Their common characteristic is that in both groups DUI drivers are two years older than average drivers.

Modern technology offers one of the basic challenges of improving traffic safety – automated identification of traffic violations. The application of the automated identification of traffic violations contributes to the traffic safety. It is simple to develop the automatic detection system for the violations which can be detected using radars or cameras. However, there are violations which cannot be easily detected by means of a device. Thus, there is an issue of recognizing the drivers who make such violations. This paper offers a possible development direction - the development of a DUI detection model on the basis of several DUI-related risk factors. The application of the DUI detection model to the control sample has shown that the model can accurately identify about 70% of DUI drivers. Depending on the requested accuracy criterion, the model can be calibrated according to various demands. The model includes the factors available in all countries, so it can be applied worldwide. The models developed in this study do not involve all predictors of DUI, so the development of the remaining predictors should be conducted in order to detect DUI in the most efficient manner.

The presented DUI prediction models can significantly improve DUI control. Particularly significant part of the model development is the possibility of implementing the model in automated systems for controlling traffic violations. Today the development of traffic violations has a few directions, the automatic control system being the most challenging one. With the probability above 50%, the model can accurately predict approximately 70% of DUI drivers. Collecting predictors such as the driver's age or driver’s experience is debatable. However, the model has shown that the driver's age and driver’s experience have the lowest partial contribution to DUI prediction. Thus, the imprecision related to the driver's age cannot compromise the prediction result. This represents the limitation of the study, but it does not mitigate the result of DUI driver prediction. The driver's age, driver’s experience and drink-driving should definitely be studied in future research. The mandatory journey purpose has been distinguished to be a predictor for professional drivers, so these journeys are not difficult to identify. For car and two-wheeler drivers, the mandatory journey purpose can be implemented by transferring it into the probability of the non-mandatory journey purpose at the specific location. The non-mandatory purpose is more characteristic of certain locations (streets). When it comes to other predictors, we believe that there are no methodological problems regarding their collection.

In addition to the development of DUI prediction, the significance of this paper lies in its contribution to the development of other models of automated control of traffic participants. The problem of DUI detection is one of the most complex problems in traffic, which was the challenge this study tried to respond to.

For the additional perception of DUI-related risk factors, it is necessary to include a greater number of variables. The speed represents a risk factor, so it would be interesting to include it in future research. Reliable data on the speed at the time of crashes were not available for the work on this study, which represents the limitation of this research. The available data could not define the effect of each stated driver’s mistake, so this also represents the limitation of the research.

Future research should apply this model to a broader number of risk factors, include new factors in addition to the existing ones such as speed, average mileage, weather and road conditions, and estimate the quantitative effect of drivers’ mistakes on DUI.

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**Appendix F.** Table 2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Modelling of odds of risk factors for drivers with DUI. | | | | | | |
|  | OR1 | OR2 | OR3 | OR4 | OR5 | |
| Age | 1.001 | 1.007 | .994 | .950 | 1.017 | |
| Driver experience | 0.988\*\* | **-** | 1.033 | 1.049 | 1.011 | |
| Gender (ref. = female) | 3.623\*\*\* | 5.371\* | 1.058 | 0.012\* | 2.341 | |
| Use of restraint systems (ref. = no use) | 0.373\*\*\* | .151 | 0.414\* | .246 | .587 | |
| Area (ref. = rural) | 1.037 | .699 | 1.091 | .536 | .680\* | |
| Journey purpose (ref. = mandatory) | 1.840\*\*\* | .824 | 1.399 | 85.282\*\* | 4.502 \*\*\* | |
| Responsibility (mistake) (ref. = others) | 6.486\*\*\* | 2.514\* | 4.457\*\*\* | 3.507 | 3.387 \*\*\* | |
| Constant | .022\*\*\* | 0.035\*\* | .083 | 13.324 | 0.008 \*\*\* | |
| Likelihood ratio test | p<.001 | p<.005 | p<.001 | p<.01 | | p<.001 |
| Hosmer and Lemeshow test | 16.652 (df=8) | 4.947 (df=8) | 4.741 (df=8) | 3.959 (df=8) | | 10817 (df=8) |
| \* Wald statistical significance p<.05; \*\* Wald statistical significance p<.01; \*\*\* Wald statistical significance p<.001; OR1 – Car drivers; OR2 – Bicycle drivers; OR3 – Motorcycle drivers; OR4 – Bus drivers; OR5 – Truck drivers. | | | | | | |

**Appendix G.** Table 3

|  |  |  |  |
| --- | --- | --- | --- |
| DUI and non-DUI risk factors based on TOPSIS. | | | |
| Risk factors | DUI risk factors | | Non-DUI risk factors |
| Score | Rank | Score |
| The driver’s mistakes | 0.856 | 1 | 0.001 |
| Male gender | 0.528 | 2 | 0.063 |
| Non-mandatory journey purpose | 0.182 | 3 | 0.041 |
| The driver’s experience | 0.029 | 4 | 0.221 |
| Young | 0.028 | 5 | 0.228 |
| Area of driving | 0.023 | 6 | 0.320 |
| Non-use of restraint systems | 0.000 | 7 | 1.000 |