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THE INTERACTION BETWEEN A DRIVER AND INTELLIGENT TRANSPORT SYSTEMS

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Abstract. A road traffic system is a complex system which includes four main parts – human, vehicle, road, and the natural environment. Road safety in Slovakia is based on the strategy of the government, as well as on European policies. It is important to implement complex strategic measures in the fields of traffic accidents, emergency services, and definitions of classifying injuries and deaths to decrease the number of injuries. The National plan's measures must be included in strategic documents, which discuss road safety. It is necessary to combine several strategic goals in the transport process, to provide transport services according to users' needs. The increase in the safety on the roads is a process that tries to mitigate negative impacts of traffic accidents. In recent years, Intelligent Transport Systems (ITS) have reduced several road traffic fatalities, particularly amongst passenger deaths. Various types of intelligent transport systems (ITS) are currently implemented in passenger cars and provide a higher level of road safety. However, there is a need to assess the effects of these systems on traffic safety. Drivers must perceive technologies as useful, effective, easy to use, affordable, and socially acceptable. There is also a need for drivers' willingness to use ITS. This paper discusses the benefits of using intelligent transport systems (ITS) in urban conditions. They can enable the safety of road traffic. We verified it with a questionnaire. We have gathered 519 answers. The results were processed and evaluated in this article.

Keywords: Traffic accidents, Intelligent Transport Systems, safety of road traffic.

1. Introduction

Intelligent Transport System (abbreviation ITS) has been developing since the 1970s. It helps to maintain an efficient, accurate and real-time management system for humans, vehicles, and roads in the natural environment [1, 2].

Intelligent Transport System uses information and communication technologies as sensors, controllers, high technology devices and mathematical methods in combination with existing infrastructure [3].

The literature [4] describes how intelligent transport systems became a generic concept that covers a wide range of systems. Within this context, the concept is applied to automotive systems and comprises systems generally as advanced driver assistance systems (ADAS/DAS), in-vehicle information systems, and road telematics.

Behavioural adaptation and risk compensation are regarded as core problems, which must be addressed in terms of safety [5, 6]. One aim of the proposed driver behaviour model is to explain and predict risk compensation that might be associated with a given ITS [7].

The main objectives of Slovak transportation policy are to decrease traffic accidents and improve road safety. To achieve the goal for 2011-2020, the Slovak Republic's National Plan for Road Safety should generate support for transportation policy. The use of intelligent transport systems in road transportation

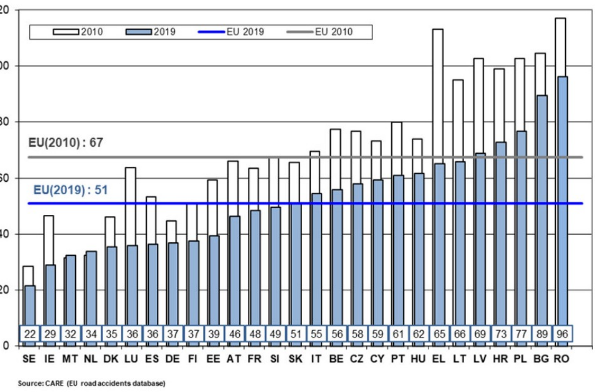

Figure 1. Comparison of road fatalities per million inhabitants in EU countries [5].

is also in this proposal. A comparison of road fatalities between the Slovak Republic and the other EU Member States is shown in Figure 1 [8].

At present, the direction of European policy of gradually increasing the level of safety is defined by the strategy of the Single European Transport Area. Its central idea is global transport, which requires international cooperation for effective actions. This statement creates a significant imperative for security to [9]:

- develop and harmonize technologies in the field of transport safety – driver assistance systems, cooperation systems and vehicle-infrastructure connections, etc.,

- develop a comprehensive strategy for action in the field of road accidents and emergency services,
- focus on training and education of road users,
- target vulnerable road users, including safer vehicle infrastructure and technology.

One of the basic principles of the current safety strategy at the EU level is to achieve higher safety standards in the transport system – creating a safe transport area. An integrated approach used to create a secure transport area aims to integrate the security component into other EU economic and social policies. The current EU strategy and the resulting activities look for synergies with the requirements of a functioning transport system. Primary topics aimed at the reduction of environmental burdens, promotion of multimodality and reduction of individual car transport shares have come to the forefront of EU transport policy.

To deliver transportation services that meet consumers' needs, it is required to integrate a number of strategic goals into the transport process. The process of making roads safer aims to lessen the detrimental effects of traffic accidents.

In recent years Intelligent Transport Systems (ITS) have assisted in the decrease in road traffic fatalities, particularly amongst passengers. The advantages of using intelligent transport systems (ITS) in urban conditions which enable secure road traffic, reduce the number of road traffic accidents and the death rate on roads are described in this article. Drivers must perceive technologies as useful, effective, easy to use, affordable, and socially acceptable.

2. Materials and Methods

Recent research indicates that driver error contributes to up to 90 % of all roadway crashes. Despite this, the problem of human errors is very complicated. We still do not have complete information on what mistakes drivers make and what are the causal factors that contribute to these errors [10].

Intelligent Transport Systems (ITS) substantially reduce the number of crashes caused by human errors on traffic roads. Such systems, however, will influence driving behaviour only if a driver accepts them. Our study is aimed at the assessment of driver acceptance of different ITS interventions designed to enhance driver behaviour.

Thanks to recent developments in ITS technologies, autonomous vehicles are becoming a reality. Leading technology companies and automotive manufacturers have invested enormous resources in autonomous car technology. However, several technical and nontechnical issues must be specified to achieve this goal: software complexity, real-time data analytics, and testing and verification are among the technical challenges; consumer stimulation, insurance management, and ethical/moral concerns are among the non-technical concerns. To address these issues, intelligent solutions must be developed that meet the needs of consumers, businesses, and government regulations and policies [11].

Intelligent transport systems can enhance safety and reduce traffic accidents. This can be ensured when drivers accept and use them. Acceptance of drivers can be different. It is defined as a predisposition towards using some system. The system should be reliable and easy to use [12]. At least that's how drivers must perceive it. If people do not trust systems or they do not correspond to their needs and expectations, they will not be widely used [13]. Therefore, the design must focus on the user and not only on the technology itself.

The goal or motive of a person to use the device is a key element in determining ITS utilisation. Intentions are the closest predictor of behaviour, according to [14]. A new technology's actual use and a person's behavioural intention to utilise it are strongly correlated, according to research [15]. In numerous significant explanatory models of human behaviour, intention is viewed as a crucial antecedent of behaviour.

In the transport process, it is necessary to combine several strategic goals to provide transport services according to the users' needs. Increasing safety on the roads is a process that tries to mitigate the negative impacts of traffic accidents [16]. The application of Intelligent Transport Systems is important for keeping sustainable development and increasing traffic safety, which is based on collecting, processing, evaluating, and distributing traffic information. The information and communication technologies create the base of transport telematics systems, which include information about the transport process and transport users. The decrease in traffic accident rates can be achieved by informing drivers and other users of transport sufficiently. The drivers' voluntary acceptance of information is important for traffic management, using Advanced Traveller Information Systems and because of this fact, the credibility of the provided information is important. Variable Message Signs comprise a suitable solution to traffic flow management. It is possible to provide information on queues, traffic delays and works on pavement, traffic accidents and weather conditions. It is also possible to provide information to drivers directly inside the car. With these systems, it is possible to reduce traffic accident rates and to increase drivers' comfort during travel.

We decided to survey the acceptance of intelligent technologies using questionnaires from drivers, particularly how and whether they use them. We wish to ascertain if they are understandable and easy to use.

3. Results

In general, Slovak drivers are not informed sufficiently about the possibilities of obtaining traffic information

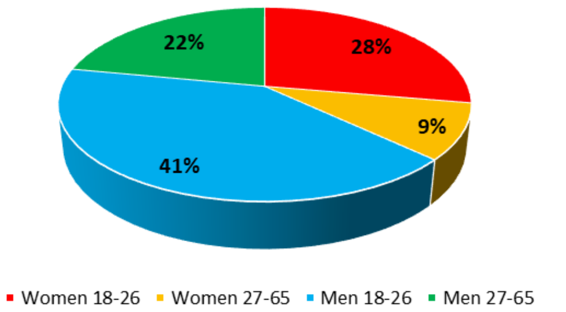

FIGURE 2. The distribution of each age and gender category.

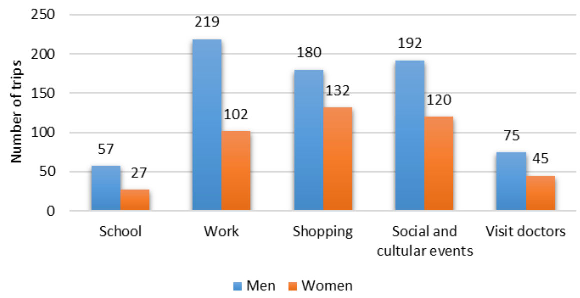

FIGURE 3. The division of motor vehicle trips by trip purpose.

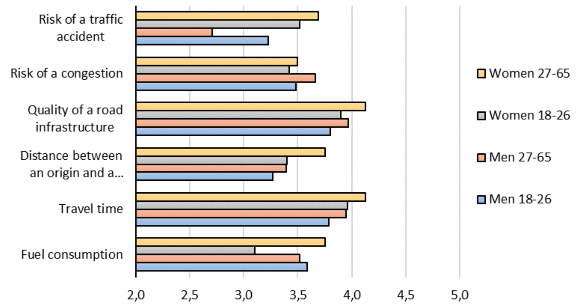

FIGURE 4. Criteria evaluation for route choice.

and using ITS. This must become known to the public. Since this research aims to find out how drivers perceive the establishment and the development of Intelligent Transport Systems, we carried out a questionnaire survey. We collected data from April to May 2021 in electronic form.

The minimum sample was determined with the help of a “Sample size calculator” [17] which is used to determine how many people you need to interview to get results that reflect the target population as precisely as needed. This calculator is available on the internet. We used the following parameters:

- Confidence Level – usually 95 %, therefore we have used this typical value.
- Confidence Interval – in statistics, it is a type of interval estimation of an unknown parameter. We have chosen 5.
- Population – The total number of statistical units of the basic set. In this case, it is the number of drivers registered in Žilina (112,257).

The result of these parameters is that 383 samples are needed at minimum. However, we were able to reach 419 respondents.

From all respondents participating in the survey, there were 192 women and 327 men, so the results better reflect the target population. Figure 2 shows the distribution of each age and gender category.

We asked a total of 10 questions. The respondents answered mainly electronically, but we also contacted them in person. The results were evaluated and described in the following pages.

The next step was to select respondents according to trip purpose. Figure 3 shows that most drivers use their motor vehicles to commute to work. Some also use them to travel to school and for healthcare.

Each driver, when choosing the route, prefers the one which best suits their needs and criteria. Fuel consumption, travel time, the distance between the start and the destination, the likelihood of traffic accidents, and other factors are the primary considerations when choosing the best route. The weighted arithmetic averages of the relative weights of the various criteria, which are also represented graphically in Figure 4, are shown in Table 1. The standard of road infrastructure is the most crucial factor for men in both age groups. Travel time to the destination is the most crucial factor for women.

The values in Table 1 were calculated as a weighted arithmetic average according to Equation (1):

$$c = \frac{\sum_{i=1}^{5} p_i r_i}{m}, \qquad (1)$$

where:

c – criterion from Table 1,

p_i – number of points given by respondents,

r_i – number of respondents that used i-points,

i – point scale from the range $1; 2; \ldots; 5$,

m – total number of respondents.

The rating in Table 1 is as follows: The higher the number, the more significant the given factor. In the case of the traffic accident risk factor, it is obvious that men of active age perceive this factor as less important. On the contrary, they realize the importance of their time and consider the risk of traffic congestion. Figure 4 better presents the results from Table 1.

The next question is related to the respondents' acceptance of an alternative route suggested by information systems when a traffic accident or other obstacle occurs (Figure 5). As shown in Figure 6, the most common response was that respondents would

Criteria	Men 18-26	Men 27-65	Women 18-26	Women 27-65
Fuel concumption	3.59	3.52	3.10	3.75
Travel time	3.79	3.95	3.96	4.13
Travelled distance	3.27	3.39	3.40	3.75
Quality of road infrastructure	3.80	3.97	3.90	4.13
Risk of congestion	3.48	3.66	3.42	3.50
Risk of a traffic accident	3.23	2.71	3.52	3.69

Table 1. Weighted arithmetic averages of criteria evaluation for choosing route.

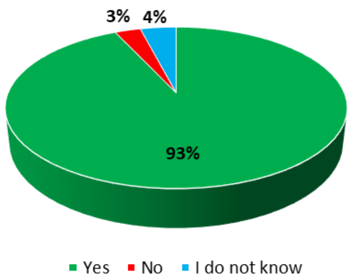

Figure 5. Use of an alternative way offered by information system.

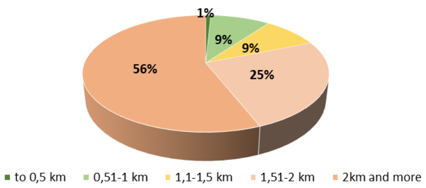

Figure 6. Acceptance of alternative according to detour length.

be willing to adopt an alternative route, even if the distance to their destination would be longer than 2 km (detour route 2 km longer than the original) and the travel time increases more than 16 minutes (Figure 7).

Current traffic information, which the driver can acquire before or during the trip via information technology, is helpful while planning a trip. Radio and the internet are the two most mentioned sources of traffic information, with 48 % and 24 % of respondents, respectively, using each (Figure 8). Figure 9 displays the proportion of women who use various systems. Abbreviation VMS means Variable Message Signs. There are only shortcuts in the graph – GPS includes all applications that allow navigation of the vehicle or pedestrians (Google Maps, Sygic, etc.). We especially asked about Waze as the most used navigation.

The following query concerned whether or whether drivers would anticipate Intelligent Transport Systems to alert them to potential dangers, as well as which dangers they deemed to be the most significant ones (Figure 10). Analysis was done on the value of notifying people about various dangerous driving scenarios from both the women's and the men's perspectives. According to the report, women rate blind roads as having the least importance and black ice as having

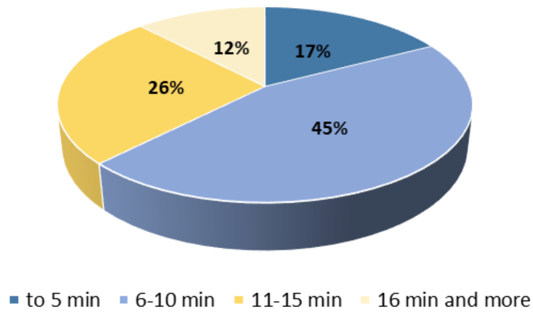

Figure 7. Acceptance of alternative route according to travel times.

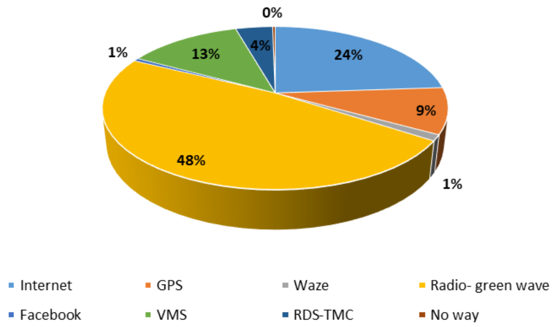

Figure 8. Sources of information about traffic according to respondents.

the greatest importance. Men rank black ice and traffic accidents as being the most vital things to be wary of, while a blind road and a one-way street are considered the least significant (Table 2). Figure 11 displays the survey results graphically.

Our research confirmed that respondents are open to new possibilities offered by ITS. Those ITS applications that, in addition to comfort, increase safety during the journey appear to be particularly important.

4. Conclusions

It is described in the literature [18, 19] that human or driver error contributes to as much as 75 % of all roadway crashes. Despite this [data], there hasn't been much research focused on the kinds of driving errors that people make. As a result, very little is now understood about the various mistakes that drivers

Traffic situations	Males 18-26	Males 27-65	Females 18-26	Females 27-65
Blind junction	3.01	2.97	3.33	3.38
One-way street	2.69	2.89	3.06	3.06
Changed traffic organization	3.56	3.87	2.62	4.19
Sharp bend	2.99	3.08	3.35	3.13
Blind road	2.35	2.71	3.69	2.75
Traffic accident	4.20	4.37	4.04	4.25
Congestion	3.96	4.24	3.71	4.63
Black ice	4.18	4.53	4.29	4.94
Foggy weather	3.17	3.61	3.83	4.69
Windy weather	2.76	3.42	3.40	4.44
Rainy weather	3.15	3.68	3.83	4.50

TABLE 2. The evaluation of warnings' importance of traffic situations.

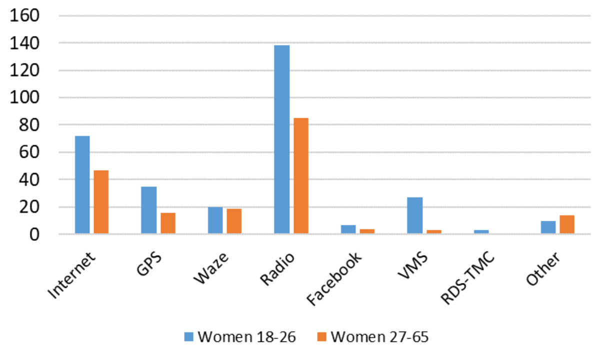

FIGURE 9. Usage of Advanced Traveller Information Systems by women.

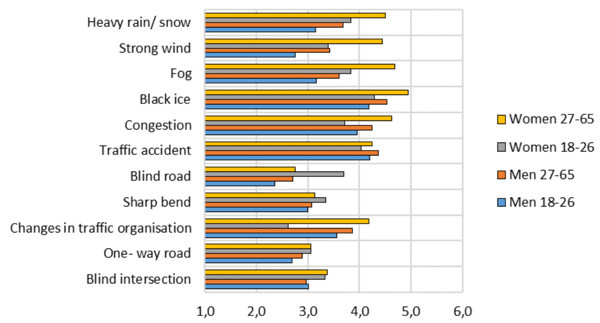

FIGURE 11. Dangerous traffic situations in which respondents consider warnings important. The importance rating is graded according to age and gender.

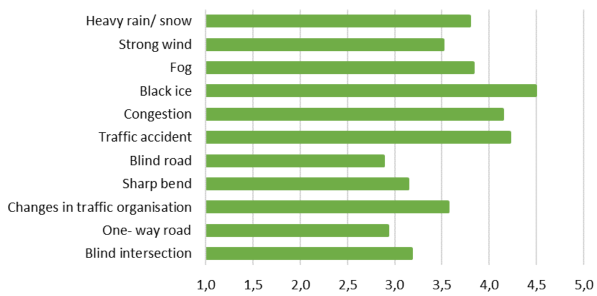

FIGURE 10. The evaluation of the importance of warnings of dangerous traffic situations.

make or the causal elements that contribute to these mistakes being made. This is because there aren't many structured techniques for gathering data on human mistakes in the transportation system, and even when there are, there aren't many reliable taxonomic systems for correctly categorising driver errors and their contributing causes.

Literature [20] on 'cognition and reality' describes how human thought is closely coupled with a person's interaction with the world. It is argued in the literature that knowledge of how the world works leads to the anticipation of certain kinds of information, which in turn directs behaviour to seek out certain kinds of information and provide a ready means of interpretation.

The in-depth reported driver error study was carried out by [21], who aimed to distinguish between violations and driver errors. Errors are instances in which a driver intended to perform well, but their actions fell short (for example, meaning to drive within the speed limit but inadvertently pressing the accelerator pedal too far, which is called a slip, or forgetting the speed limit, which is called a lapse, etc.). In contrast, deliberate violations, such as going over the speed limit on purpose, might be described as situations when the driver intended to commit the offence. The authors in [21] created the driver behaviour questionnaire (DBQ), a 50-item survey with five categories of aberrant driving behaviour (slips, lapses, mistakes, inadvertent violations, and deliberate violations). They selected 520 drivers from a sample in nine age groups, ranging from 20 to 56 years old. Drivers were asked to report how frequently they made different kinds of driving mistakes and offences.

The classification of the contributing elements involved in traffic accidents was also studied in the literature [22, 23]. Data on errors were gathered from accident evaluations, on-site accident investigations, and incident cases that were documented.

There were found to be four main categories of incident causation factors. These included human traits (physical/physiological, mental/emotional, experience/exposure), direct human causes (identification errors, choice errors, performance errors), environmental factors (road-related, ambient condition), and vehicular factors.

When examining the psychological factors that contribute to errors, authors in the literature [24] estimated that roughly 40 % of errors were caused by attentional problems (such as carelessness, distraction, failing to see out of the car, and lack of attention), roughly 25 % by perceptual problems (such as looking but failing to see, misjudging speed and distance), and roughly 15 % by judgmental problems (e.g., lack of judgement and wrong decision).

Nowadays, we can use new technologies to reduce traffic accidents or mitigate their consequences. Of course, the drivers must use them efficiently. These systems include adaptive cruise control, navigation systems that use GPS (global positioning system) or intelligent speed adaption systems. Their main advantage is that they make wider tolerance to human mistakes and errors.

From the view of traffic psychology, it is necessary to examine and investigate drivers' errors and mistakes made by other traffic users such as cyclists or pedestrians. But what is the purpose of this difficult investigation? We need to know the impact of drivers' mistakes on the design of intelligent transport systems and on the intelligent vehicle.

We can observe human errors in laboratory conditions, but focusing on accidents is essential, too. Thanks to high-quality reports from police forces, it is possible to make detailed statistical analyses of traffic accidents. After this research, we can develop a generic model for driver errors.

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References

[1] L. Qi. Research on intelligent transportation system technologies and applications. In *2008 Workshop on Power Electronics and Intelligent Transportation System*, pp. 529–531. 2008. https://doi.org/10.1109/PEITS.2008.124

[2] R. V. Zinko, Z. Stotsko, M. Hlobchak. Modeling of the ecological condition of the large cities road network. *The Archives of Automotive Engineering – Archiwum Motoryzacji* **84**(2):91–101, 2019. https://doi.org/10.14669/AM.VOL84.ART7

[3] Y. Lin, P. Wang, M. Ma. Intelligent Transportation System(ITS): Concept, challenge and opportunity. In *2017 IEEE 3rd International Conference on Big Data Security on Cloud (Bigdatasecurity), IEEE International Conference on High Performance and Smart Computing (HPSC), and IEEE International Conference on Intelligent Data and Security (IDS)*, pp. 167–172. 2017. https://doi.org/10.1109/BigDataSecurity.2017.50

[4] D. Canamero. Modeling motivations and emotions as a basis for intelligent behavior. In *Proceedings of the first International Conference on Autonomous Agents*, pp. 148–155. 1997. https://doi.org/10.1145/267658.267688

[5] J. Vrábel, B. Sarkan, A. Vashisth. Change of driver's reaction time depending on the amount of alcohol consumed by the driver – the case study. *The Archives of Automotive Engineering – Archiwum Motoryzacji* **87**(1):47–56, 2020. https://doi.org/10.14669/AM.VOL87.ART4

[6] Z. Matuszak, A. Nowak, I. Żabińska, F. X. Martínez de Osés. Road safety on the example of the city of Bytom. *The Archives of Automotive Engineering – Archiwum Motoryzacji* **83**(1):43–57, 2019. https://doi.org/10.14669/AM.VOL83.ART3

[7] J. Ondruš, E. Kolla, P. Vertaľ, Željko Šarić. How do autonomous cars work? *Transportation Research Procedia* **44**:226–233, 2020. LOGI 2019 - Horizons of Autonomous Mobility in Europe. https://doi.org/10.1016/j.trpro.2020.02.049

[8] CARE: Community database on road accidents. [2021-10-25], https://ec.europa.eu/transport/road_safety/specialist/observatory/care-database_en.

[9] Národná stratégia Slovenskej republiky pre bezpečnosť cestnej premávky na roky 2021 – 2030. [2021-10-25], https://www.mindop.sk/ministerstvo-1/doprava-3/bezpecnost-cestnej-premavky/narodna-strategia-slovenskej-republiky-pre-bezpecnost-cestnej-premavky-na-roky-2021-2030.

[10] A. L. Medina, S. E. Lee, W. W. Wierwille, R. J. Hanowski. Relationship between infrastructure, driver error, and critical incidents. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* **48**(16):2075–2079, 2004. https://doi.org/10.1177/154193120404801661

[11] R. Hussain, S. Zeadally. Autonomous cars: Research results, issues, and future challenges. *IEEE Communications Surveys & Tutorials* **21**(2):1275–1313, 2019. https://doi.org/10.1109/COMST.2018.2869360

[12] J. Abraham, T. K. Datta, S. Datta. Driver behavior at rail-highway crossings. *Transportation Research Record* **1648**(1):28–34, 1998. https://doi.org/10.3141/1648-04

[13] J. D. Van Der Laan, A. Heino, D. De Waard. A simple procedure for the assessment of acceptance of advanced transport telematics. *Transportation Research Part C: Emerging Technologies* **5**(1):1–10, 1997. https://doi.org/10.1016/S0968-090X(96)00025-3

[14] I. Ajzen. The theory of planned behavior. *Organizational Behavior and Human Decision Processes* **50**(2):179–211, 1991. Theories of Cognitive Self-Regulation. https://doi.org/10.1016/0749-5978(91)90020-T

[15] P. Y. K. Chau, P. J.-H. Hu. Information technology acceptance by individual professionals: A model comparison approach. *Decision Sciences* **32**(4):699–719, 2001. https://doi.org/10.1111/j.1540-5915.2001.tb00978.x

[16] J. Ondruš, P. Hockicko. Braking deceleration measurement using the video analysis of motions by SW tracker. *Transport and Telecommunication Journal* **16**(2):127–137, 2015. https://doi.org/10.1515/ttj-2015-0012

[17] Sample size calculator. [2021-10-25], http://www.surveysystem.com/sscalc.htm.

[18] N. A. Stanton, P. M. Salmon. Human error taxonomies applied to driving: A generic driver error taxonomy and its implications for intelligent transport systems. *Safety Science* **47**(2):227–237, 2009. https://doi.org/10.1016/j.ssci.2008.03.006

[19] W. Wierwille, R. Hanowski, J. Hankey, et al. Identification of driver errors: Overview and recommendations. *Tech Report* **FHWA-RD-02-003**, 2001.

[20] A. Fu. Cognition and reality. *Science & Philosophy – Journal of Epistemology, Science and Philosophy* **7**(2):49–58, 2019. https://doi.org/10.23756/sp.v7i2.475

[21] J. Reason, A. Manstead, S. Stradling, et al. Errors and violations on the roads: A real distinction? *Ergonomics* **33**(10-11):1315–1332, 1990. https://doi.org/10.1080/00140139008925335

[22] J. Treat, N. Tumbas, S. McDonald, et al. Tri-level study of the causes of traffic accidents: Final report. *Executive summary* 1979.

[23] E. Nedeliaková, M. Hudáková, V. Štefancová. Application of risk management methods in transport companies. In *Transport Means-Proceedings of the International Conference*, pp. 237–241. 2017.

[24] I. Brown. Drivers' margins of safety considered as a focus for research on error. *Ergonomics* **33**(10-11):1307–1314, 1990. https://doi.org/10.1080/00140139008925334