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Transformation of Transportation

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Preface

This monograph presents the original scientific manuscripts submitted for publication at the International Conference—The Science and Development of Transport (ZIRP 2020), organized by the University of Zagreb, Faculty of Transport and Traffic Sciences, Zagreb, Croatia. Co-organizers of the ZIRP 2020 conference are Wrocław University of Science and Technology, University of Bremen, International Road Federation, University of Zagreb Faculty of Mechanical Engineering and Naval Architecture, University Politehnica of Bucharest, UNESCO Chair of Engineering for Society, University of Zagreb Faculty of Economics & Business, European Platform of Transport Science, Croatian Academy of Engineering and AMAC-FSC. The conference was held online, from September 29 to 30, 2020, aiming to bring together the scientists and the practitioners by putting forward innovative solutions available to everyone. This monograph presents the newest scientific research, case studies and best practices in transport and logistics. The monograph will be of interest for experienced researchers, professionals as well as Ph.D. students in the field of transport and logistics. We would like to express our gratitude to the authors that contributed to this monograph.

In the paper "Effect of Different Stop Sign Configurations on Driving Speed When Approaching a Rural Intersection at Night-Time," the research aims to evaluate how enhanced visibility stop signs (fluorescent signs) affect the driving speed when approaching a rural intersection at nighttime. The research was conducted using a driving simulator.

The next paper "Traffic Flow Simulators with Connected and Autonomous Vehicles: A Short Review" pairs the three most common validated traffic simulators VISSIM, AIMSUN and SUMO with network simulators NS-3 and OMNET++ to model AVs and CAVs in a simulation environment and compares their features.

The following paper "Application of Dimensionless Method to Estimate Traffic Delays at Stop-Controlled T-Intersections" discusses current research on developing a new model of estimating traffic delays experienced by the minor approach vehicles at stop-controlled T-intersections.

"In-Depth Evaluation of Reinforcement Learning Based Adaptive Traffic Signal Control Using TSCLAB" applies an augmented version of the previously developed MATLAB-based tool Traffic Signal Control Laboratory (TSCLab) to evaluate a newly proposed ATSC based on self-organizing maps and reinforcement learning. Its performance is evaluated using appropriately chosen measures of effectiveness obtained in real time using a VISSIM-based microscopic simulation environment and a realistic traffic scenario.

The paper "Discrete Simulation Model for Urban Passenger Terminals" develops a simulation model for a hypothetical passenger terminal using the main Romanian train station's topology. The obtained data can be used to optimize the number of access gates, the stairs, the waiting area, etc.

The aim of the paper "Characteristics of Departing Passenger Reports to the Passport Control Queuing System" is to present the research results concerning the analysis of the stream of passenger reports to the queuing system of passport control in the departure hall.

The next paper "Situation in Railway Sidings Operation in Slovakia Based on the Selected Criteria" focuses on examining the railway siding performance share in the overall rail transport performance. It provides a dependence analysis of railway siding performance on selected criteria: total transport volume in international transport, transport price and the number of railway siding services.

The following paper "Applying Multi Criteria Analysis in Evaluation of Distribution Channels" outlines the possibilities of applying the AHP method of multi-criteria analysis in evaluating optional distribution channels in the distribution of confectionery products.

The object of the paper entitled "Development Barriers of Eurasian Container Transportation" is container transportation of goods through the countries of the Eurasian Eco-nomic Union (EAEU), the People's Republic of China (PRC), and the European Union (EU). The relevance of this topic is due to the existence of certain barriers and the need to overcome them for the development of cargo turnover in this direction.

The purpose of the next paper "Airline Fleet Rotables Staggered Replacement Scheduling Using Dynamic Approach" is to describe the application of a dynamic approach for scheduling airline rotables preventive maintenance to minimize earliness costs and maximize on wing time of the components.

The paper "Monitoring Traffic Air Pollution Using Unmanned Aerial Systems" introduces unmanned aerial vehicles (UAVs) equipped with various air quality sensors offering new approaches and capabilities for monitoring air pollution, as well as studying atmospheric trends, such as climate change while ensuring safety in urban and industrial areas.

The authors of "Instruments for Career Development in the Air Transport Industry" propose the following tools for supporting the employment, carrier development and professional orientation in air transport: two methodology developments within a European project and online platforms providing information on employment opportunities and qualifications in aviation.

The next paper "Drivers of Change for Smart Occupations and Qualifications in Aviation" focuses on the challenges and changes in future occupations and identifies new qualifications needed to meet the new air transport trends.

The final paper "A Framework to Understand Current and Future Competences and Occupations in the Aviation Sector" presents an analysis of occupations and competencies required for current and emerging roles in the aviation sector. A mixed-method approach was employed, which combined desk studies and the involvement of external aviation stakeholders.

Zagreb, Croatia

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Contents

Effect of Different Stop Sign Configurations on Driving Speed When Approaching a Rural Intersection at Night-Time

Dario Babić, Darko Babić, Mario Fiolić, and Marko Ružić

Abstract As part of the road network utilized by all road users, intersections are places of high complexity and conflict risks. Statistics show that 40–60% of all road accidents occur at intersections, while around 20% of them result in fatalities. The consequences of collisions at intersections are particularly severe on rural roads during night-time due to higher speeds than in urban areas and poor visibility. Therefore, the aim of this study is to investigate how enhanced-visibility stop signs (fluorescent signs) affect driving speed when approaching a rural intersection at night-time. The study was conducted using a driving simulator comprising a 6.61 km rural road with six intersections. The results show that additional stop signs influence driving behavior and encourage drivers to reduce speed when approaching a rural intersection at night. This particularly relates to signs with enhanced visibility (fluorescent signs). The results of the study could be useful for road engineers and authorities, especially in developing countries, to increase road safety at dangerous unsignalized rural intersections by implementing low-cost traffic control measures.

Keywords Traffic signs · Unsignalized intersection · Fluorescent traffic signs · Road safety · Driving speed

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1 Introduction

Road accidents are one of the leading causes of death worldwide (World Health Organization 2018). Although road safety is improving in most countries, progress remains slow due to the dynamic and complex nature of road traffic and the interconnectedness of factors related to the roadway and its environment, the vehicle, and the human. Statistics show that most accidents (54%) in the EU occur on rural roads although traffic volumes are much lower compared to urban areas (European Commission 2019). Furthermore, intersection collisions account for 40–60% of all road accidents (European Commission 2018a). This is because, intersections are in most cases, part of the road network used by all road users (cars, trucks, motorcycles, bicycles, pedestrians), and as such, are places of high complexity and conflict risks. In the EU, around 20% of traffic accidents that occur at intersections are fatal (European Commission 2018b). In contrast, in the US, on average a of quarter of road fatalities and roughly half of all injuries occur at intersections (Federal Highway Administration 2019).

From a safety perspective, there are several causes of intersection collisions, namely high approach speed, improper speed control, insufficient sight distance to oncoming vehicles, lack of intersection visibility (road users do not perceive the intersection), lack of gaps in traffic, complex intersection layout and poor road surface condition (Biancardo et al. 2019; Yang et al. 2019; Himes et al. 2018).

This shows that visibility is a major factor in maintaining safety at intersections. While driving, drivers receive more than 90% of information visually (Gregersen and Bjurulf 1996), so the timeliness of the information they receive is critical for appropriate response. At night, the human field of vision is narrowed and shortened, and the perception of colour, shape, texture, contrast and movement is reduced (Plainis et al. 2006), which impairs the driver's ability to avoid collisions and thus increases the overall risk of accidents (Rice et al. 2009; Sullivan and Flannagan 2002; Li et al. 2018).

In order to achieve satisfactory level of traffic flow and safety, most countries use different types of traffic control at intersections, namely uncontrolled intersections, intersections controlled by traffic signals, the use of a right-of-way sign on the minor road, the use of a stop sign on the minor road, and the use of stop signs on both minor and major roads (Polus 1985). The decision as to which of these or other alternatives should be used depends on traffic safety, road type and function, number of merging routes, traffic volume and type, design and operating speed, priority setting, terrain, available space, environmental concerns, cost, etc. The relative importance of each factor varies from case to case and should be taken into account (World Road Association 2003).

When looking at efficient low-cost solutions, traffic signs and road markings have proven to be the most cost-effective measures (Hummer et al. 2010; Thurston 2009; Hallmark et al. 2012; McGee and Hanscom 2006). Although most rural intersections are regulated by right-of-way or stop signs, drivers often perceive them too late and thus do not adjust their driving speed in a timely and proper manner to the upcoming situation. This is mainly due to the inadequate quality of the signs, their lack of maintenance and drivers' familiarity with the route. The quality of the sign is mainly determined by its retroreflection and chromaticity properties. The studies have shown that signs which do not meet the minimum prescribed values and are improperly maintained may contribute to traffic accidents, especially at night-time (Xu et al. 2018; Šarić et al. 2018; Ferko et al. 2019). Also, several studies show that route familiarity affects driver perception of different road and safety elements, including traffic signs, and that drivers, especially older and more experienced ones, perceive fewer signs as they become more familiar with the route (Babić 2017; Yanko and Spalek 2013).

From all the above, it can be concluded that rural road intersections at night time are a high collision risk location. Therefore, this study aims to evaluate how enhanced-visibility stop signs (fluorescent signs), as a low-cost traffic-control measure, affect driving speed when approaching a rural intersection at night-time. The study was conducted using a driving simulator in which a 6.61 km long rural road with six identical, but differently controlled intersections has been created. The results of the study could be useful for road engineers and authorities to increase road safety at dangerous unsignalized rural intersections through low-cost traffic control measures.

2 Methodology

2.1 Research Equipment

For the study, we used the Carnetsoft B. V. driving simulator (Fig. 1) consisting of a driver section (driver's seat with pedals, steering wheel, and shifter) and three interconnected displays, 30' in size, 5760 × 1080 resolution, and 30 Hz refresh rate. The hardware consisted of a computer with NVidia GeForce GTX 1080 Ti graphics processing unit (GPU) and 3 GB of video memory, Intel Core i7 7700 K central processor unit (CPU) with four cores, eight threads and frequency of 4.20 GHz, 32 GB of RAM, 250 GB SSD for storage and Windows 10 Pro 64-bit operating system. The simulator provides an interactive representation of reality with a 210° environment with over six channels (left, centre, and right views plus three rearview mirrors).

The described simulator has been used in several studies related to driver behaviour, which validates its use in this study (van Winsum 2018, 2019a, b).

2.2 Scenario Design

The scenario simulated night-time driving on a two-way rural road with 3.25 m wide roadway lanes and with active traffic in the opposite direction. The road section

Fig. 1 Carnetsoft B. V. driving simulator used in the study

was 6.61 km long and included six four-way intersections with traffic from other directions. Drivers had the right of way at three intersections (RW 1, RW 2, and RW 3), but not at the other three (Stop 1, Stop 2 and Stop 3). At one of these three intersections, traffic was controlled by a stop sign placed at the intersection according to Croatian standards (Stop 1). At the second, in addition to the stop sign at the intersection, an additional sign was placed 200 m before the intersection (Stop 2) with a supplementary plate defining the distance to the intersection. The third controlled intersection had in total three stop signs: the first one was placed on the right side of the roadway, 200 m before the intersection with an additional plate defining the distance to the intersection, while the second two were fluorescent stop signs located at the intersection on both the right and the left side of the roadway (Stop 3). The design of the intersections is presented in Fig. 2.

The roadway was marked with 15 cm wide white edge and centre lines according to Croatian design standards. The speed limit was set between 50 and 90 km/h. The scenario also included houses and other environmental elements such as trees. Both the sound of traffic in the environment and the sound of the participant's car were included. The summary of the scenario configuration is presented in Table 1.

Fig. 2 Different configurations of stop signs in the scenario

a) RW 1, RW 2 and RW 2

b) Stop 1

c) Stop 2

d) Stop 3

Table 1 Summary of scenario design

Parameter	Description
Length	6.61 km
Conditions	Night-time
Road type and width	Two-way rural road
Road lane width	3.25 m
Traffic signs	Active; placed according to the Croatian standard
Road markings	15 cm white centre and edge lines
Number of intersections	6 – 3 with the right of way (RW 1, RW 2, and RW 3) – 3 with traffic controlled by a stop sign: (a) Stop 1—stop sign placed at the intersection (b) Stop 2—stop sign at the intersection + stop sign 200 m before the intersection with a supplementary plate defining the distance to the intersection (c) Stop 3—three stop signs: one placed on the right side of the roadway 200 m before the intersection with an additional plate defining the distance to the intersection, and two fluorescent stop signs located at the intersection on both the right and the left side of the roadway
Speed limit	50–90 km/h
Sound	Active
Traffic	Active

2.3 Participants

A total of 32 volunteers with valid driving license were recruited, of which 23 were male (71.88%), and nine were female (28.13%). The mean age of the participants was 25 years ($\bar{x}$ = 25.11; range = 21.6–29.8; SD = 1.81) while their mean driving experience was six years ($\bar{x}$ = 6.53; range = 2–11; SD = 2.18). Participant selection criteria were based on the fact that young, predominantly male drivers are more likely to be involved in road accidents, although they tend to drive less frequently than older drivers (Bener and Crundall 2008; Gray et al. 2008; Scott-Parker and Oviedo-Trespalacios 2017).

Participants rated their driving ability with a mean score of 8.22 (on a scale of 1-10), and most of them (40.62%) reported that they were active drivers. Out of 32 participants, nine (28.12%) were involved in a traffic accident as a driver (they were involved in ten accidents in total), and 40% of them caused the accident. Six participants have mild refractive error and wear glasses or lenses while driving.None of the participants reported any signs of driving simulator sickness.

None of the participants reported any sign of driving simulator sickness.

2.4 Procedure

The testing room was set up in the Department of Traffic Signaling, Faculty of Transport and Traffic Sciences, University of Zagreb, Croatia. Before conducting the test, each participant was familiarized with the research equipment and the research procedure. The researchers instructed the participants that their driving skills and abilities would not be assessed and that they were free to drop out at any time, especially if they experienced side effects such as simulator sickness. Participants also signed an informed consent form to participate and completed a short questionnaire related to personal information such as age, gender, date of obtaining a driver's license, assessment of their driving ability, number of traffic accidents they were involved in and caused, frequency of driving, and other comments and possible problems related to their visual system. The overall aim of the study was not revealed to the participants in order to avoid bias in the results.

Prior to test driving, participants had a warm-up period of approximately 5-10 minutes to familiarize themselves with the driving simulator.

2.5 Data Analysis

To validate the effect of different stop sign configurations on driving speed when approaching rural intersections at night-time, driving speed was recorded at four locations before each intersection, namely 300, 200, 100, and 150 m. The measurement points were established based on the results of previous studies that used a similar methodology to evaluate the effectiveness of different perception measures to increase road safety (Ariën et al. 2017; Hussain et al. 2019; Montella et al. 2015).

The above data were extracted from the Carnetsoft B. V. "Data Analysis" software and analysed using univariate ANOVA.

3 Results

First, the interaction between driving speed and intersection type, measurement points, and participants' gender and driving experience was tested. Participants' age was excluded as a variable for two reasons: (1) the range was small (21.6–29.8 years with $SD = 1.81$ years); (2) participant age was highly correlated with driving experience ($\text{Spearman} = 0.867$).

The results of the ANOVA analysis show that driving speed differs significantly between intersections and measurement points ($p < 0.05$) while gender and driving experience do not ($p = 0.342$ and $p = 0.439$, respectively).

Table 2 Results of multiple comparisons between driving speed and intersections

(I) Intersection	(J) Intersection	Mean difference (I − J)	p	95% Confidence interval	
				Lower bound	Upper bound
RW 1	RW 2	−1.5599	0.072	−3.2603	0.1405
	RW 3	−1.4183	0.102	−3.1187	0.2821
	Stop 1	2.8289	0.001	1.1285	4.5293
	Stop 2	6.2186	0.000	4.5182	7.9190
	Stop 3	15.4176	0.000	13.7172	17.1180
RW 2	RW 3	0.1416	0.870	−1.5588	1.8420
	Stop 1	4.3888	0.000	2.6884	6.0892
	Stop 2	7.7785	0.000	6.0781	9.4789
	Stop 3	16.9775	0.000	15.2771	18.6779
RW 3	Stop 1	4.2472	0.000	2.5468	5.9476
	Stop 2	7.6369	0.000	5.9365	9.3373
	Stop 3	16.8360	0.000	15.1356	18.5364
Stop 1	Stop 2	3.3897	0.000	1.6893	5.0901
	Stop 3	12.5888	0.000	10.8884	14.2892
Stop 2	Stop 3	9.1990	0.000	7.4986	10.8994

Second, we analysed the difference in speed for each intersection. We conducted a post-hoc test using the LSD test (the significance level was set at 0.05). The results are presented in Table 2.

The results in Table 1 show that there was no statistical difference in driving speed ($p > 0.05$) between all three intersections where participants had the right of way (RW 1, RW 2, and RW 3). However, driving speeds at these intersections were statistically higher ($p < 0.05$) than at the intersections where traffic was controlled with stop signs (Stop 1, Stop 2, and Stop 3), which was expected.

A statistical difference ($p < 0.05$) in driving speed was also found between each controlled intersection (Stop 1, Stop 2, and Stop 3). The driving speed was lowest at the intersection "Stop 3" which was controlled with three stop signs: a regular stop sign placed on the right side of the roadway 200 m before the intersection with an additional sign defining the distance to the intersection, and two fluorescent stop signs located at the intersection on both the right and left sides of the roadway. The intersection that was controlled with two stop signs (Stop 2): one at the intersection and one with additional sign defining the distance to the intersection placed 200 m before the intersection, had an average speed 9.2 km/h higher compared to the intersection "Stop 3". The intersection with only one stop sign (Stop 1) had, on average, 3.4 km/h higher driving speed compared to the intersection "Stop 2" and 12.6 km/h to intersection "Stop 3". The mean driving speed for each intersection is shown in Fig. 3.

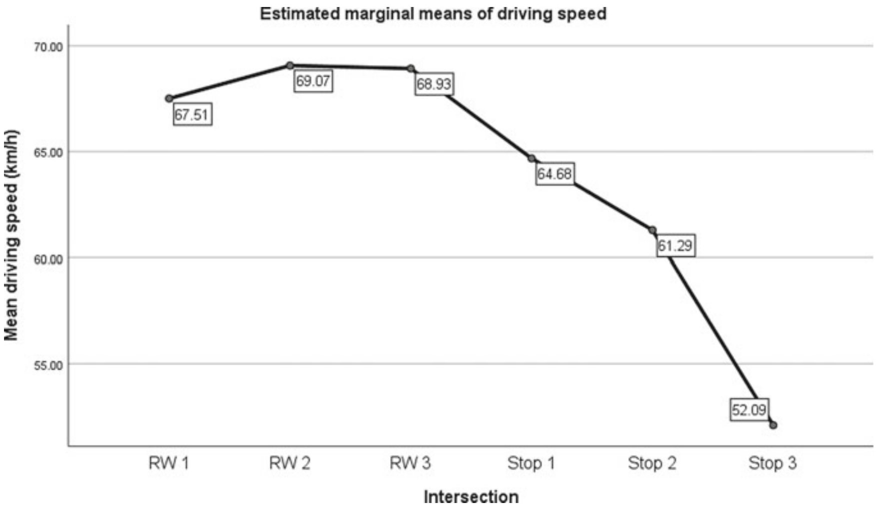

Fig. 3 The mean driving speed for each intersection

In addition, we analysed how driving speed changed at each measurement point (300, 200, 100, and 150 m before the intersection) depending on the type of intersection. From Table 3, one can conclude that the average driving speed at the same measurement points differs to some extent between intersections with right-of-way (RW1, RW 2, and RW 3) and the intersection with a stop sign (Stop 1). In contrast, a continuous decrease in speed at the same measurement points was observed at the controlled intersections (Stop 2 and Stop 3).

4 Discussion and Conclusion

Due to the interactions between the different road users and thus the overall complexity of the situation, intersections have a high accident risk. Statistics show that around 40–60% of all road accidents (depending on the country) occur at intersections, of which around 20% are fatal. Due to higher driving speeds, the consequences of collisions at rural intersections are particularly severe. In addition, the risk and severity of accidents increase at night (Rice et al. 2009; Sullivan and Flannagan 2002; Li et al. 2018).

For these reasons, this study aimed to evaluate how enhanced-visibility stop signs (fluorescent signs) affect driving speed when approaching a rural intersection at nighttime. To achieve the aim of the study, a scenario simulating a 6.61 km long rural road with six intersections has been created. Drivers had the right of way on three intersections while on the other three the traffic was controlled with a stop sign. The first intersection had a stop sign. The second one had a stop sign at the intersection and an additional sign 200 m before the intersection with a supplementary plate

Table 3 Average driving speed at each measuring point for every intersection

Intersection	Measuring point (m)	Mean	95% Confidence interval	
			Lower bound	Upper bound
RW 1	300	75.158	72.753	77.563
	200	70.056	67.651	72.460
	150	65.039	62.634	67.443
	50	59.777	57.372	62.182
RW 2	300	72.418	70.013	74.823
	200	72.323	69.919	74.728
	150	70.471	68.067	72.876
	50	61.056	58.651	63.461
RW 3	300	68.954	66.549	71.359
	200	71.946	69.542	74.351
	150	72.709	70.304	75.114
	50	62.093	59.688	64.498
Stop 1	300	66.194	63.789	68.599
	200	70.285	67.880	72.690
	150	69.489	67.084	71.893
	50	52.746	50.342	55.151
Stop 2	300	71.674	69.269	74.078
	200	64.874	62.470	67.279
	150	58.715	56.310	61.120
	50	49.892	47.487	52.296
Stop 3	300	60.097	57.692	62.502
	200	51.835	48.930	53.739
	150	51.313	49.408	54.218
	50	45.114	42.709	47.519

defining the distance to the intersection. The third controlled intersection had in total three stop signs: regular stop sign placed on the right side of the roadway, 200 m before the intersection with additional plate defining the distance to the intersection, and other two were fluorescent stop signs located at the intersection on both the right and the left side of the roadway.

The results show that participants did not significantly change their driving speed when approaching an intersection where they had the right of way. Driving speed for this intersection ranged from 67.5 km/h (RW 1) to 69.1 km/h (RW 2). On the other hand, as expected, driving speed at controlled intersections was lower than at intersections with right-of-way, ranging from 52.1 km/h (Stop 3) to 54.7 km/h (Stop 1).

Further analysis confirmed a statistical difference in driving speed between each controlled intersection. Comparison of the three controlled intersections revealed that driving speed was lowest at the intersection "Stop 3" controlled with three stop signs: a regular stop sign located 200 m before the intersection on the right side of the roadway, with an additional plate defining the distance to the intersection, and two fluorescent stop signs located at the intersection on both the right and left sides of the roadway. The intersection controlled by two stop signs (Stop 2) had an average speed 9.2 km/h higher compared to the "Stop 3" intersection. The intersection with only one stop sign (Stop 1) had an average of 3.4 km/h higher driving speed compared to the "Stop 2" intersection and 12.6 km/h higher driving speed compared to the "Stop 3" intersection.

Analysis of changes in driving speed at each measurement point (300, 200, 100 and 150 m before the intersection) by type of intersection suggests that there is some difference in average driving speed at the same measurement points for both intersections with right-of-way and intersection with a stop sign. This could be explained by the fact that participants did not know that a controlled intersection was ahead of them until they recognised the stop sign , which according to (Priambodo and Siregar 2018) is about 70 m on average. At the other two controlled intersections, driving speed decreased continuously at each measurement point because an additional stop sign was placed 200 m before the intersection.

The results confirm that additional stop signs affect driver behaviour and encourage drivers to reduce speed when approaching a rural intersection at night. This especially refers to enhanced-visibility signs (fluorescent signs). Namely, fluorescent is not a natural colour and stands out from the environment. For this reason, signs of that colour attract the driver's eye more and have greater detection and legibility distance compared to non-fluorescent signs (Zwahlen and Schnell 1977; Schnell et al. 2001; Burns and Johnson 1997). Also, previous studies suggest that a more active eye, to some extent, means greater attentional functions and better overall driving performance (Mackenzie and Harris 2017; Anstey et al. 2012).

This study confirms the general findings from previous studies (Hummer et al. 2010; Hallmark et al. 2012; Montella et al. 2015) that traffic signs represent one of the most cost-effective solutions for increasing traffic safety. Overall, this study could be useful to road engineers and authorities, especially in developing countries, in order to increase road safety on dangerous unsignalized rural intersections by implementing low-cost traffic control measures.

Although this study provided valuable results, it has certain limitations. They are primarily related to the number and age distribution of participants. All participants in the study were young, so we recommend a more extensive research including a broader range of participants. Also, there are limitations related to the driving simulator, where the external validation is an often-mentioned issue even though the method has many advantages. In other words, a fixed-base simulator used in the research does not provide a completely realistic, real-life driving feeling. However, this disadvantage has been somewhat reduced by including the sound and by conducting the research in a completely dark environment (in order to get a more realistic feeling of night-time conditions).

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Traffic Flow Simulators with Connected and Autonomous Vehicles: A Short Review

Filip Vrbanić, Dino Čakija, Krešimir Kušić, and Edouard Ivanjko

Abstract Autonomous Vehicles (AVs) and Connected Autonomous Vehicles (CAVs) are being widely tested and rapidly developed over the past few years. With the development and increasing number of AVs and CAVs in mixed traffic flow, it is necessary to analyze their impact on traffic safety, flow, speed, fuel consumption, and emissions. Also, appropriate traffic control algorithms need to be developed before they can be fully implemented and integrated into the traffic environment. To do so, such mixed traffic flows must be simulated in various traffic scenarios. Traffic flow simulators paired with communication network simulators are commonly used to perform multiple simulations of such traffic flows. In this paper, three often used traffic simulators VISSIM, AIMSUN, and SUMO paired with network simulators NS-3 and OMNET++ with their features to model AVs and CAVs in a simulation environment are analyzed. According to currently available and tested simulators in the research community, the most used ones were compared. Results of the synthesized technical aspects of each suggest that AIMSUN Next is more suitable for a less complex traffic model. At the same time, VISSIM is more suitable for a more complex traffic model.

Keywords Autonomous vehicle · Connected autonomous vehicle · Mixed traffic flow · Traffic simulator · Communication network simulator

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