DOI 10.52209/1609-1825_2022_2_195 UDC 629.3.07

Prerequisites for Creating an Interactive Simulator for Training Drivers of Motor Vehicles

[1]**BALTABEKOVA Almagul,** *doctoral student, almagul_bn@mail.ru,*
[2]**BOUCHNER Petr,** *PhD, Associate Professor, bouchner@lss.fd.cvut.cz,*
[1]**KASSENOV Assylbek,** *Cand. of Tech. Sci., Professor, asylbek_kasenov@mail.ru,*
[1]***ABISHEV Kairatolla,** *Cand. of Tech. Sci., Professor, a.kairatolla@mail.ru,*
[1]*Toraighyrov University, Kazakhstan, Pavlodar, Lomov Street, 64,*
[2]*Czech Technical University in Prague, Czech Republic, Prague, Konviktska Street, 20,*
**corresponding author.*

Abstract. *The article analyzes the accident rate and causes of road accidents. It has been found that in most cases traffic accidents occur due to drivers' fault. This is due to the low level of professional training and limited psychophysiological condition of the driver of the vehicle. The project of an interactive simulator is proposed. The analysis of existing designs of car simulators is carried out. The concept of a car simulator is substantiated based on the analysis. The use of the described driving simulator will allow identifying and weeding out potential traffic violators at the very stage of training.*

Keywords: *accident rate, traffic accident, motor vehicle driver, car simulator, psychophysiology, concept, road safety, professional selection.*

Introduction

Within the framework of international cooperation, a team of authors is conducting research work on the development of automobile simulators to study the influence of the psychophysiological state of the driver on road safety and comprehensive training of future drivers of motor vehicles in safe behavior on the road [1, 2].

The relevance of the work and the scientific significance of the study is determined by the fact that the growth of the automobile fleet in the Republic of Kazakhstan and that the constant increase in traffic intensity have brought to the fore the problem of road safety as one of the most important national tasks to be solved.

Analysis of accidents and causes of road accidents

Road transport is an integral and most important component of the transport and communication complex of the Republic of Kazakhstan, which is in a state of continuous development (traffic intensity, speed and load capacity are increasing). Along with the indisputable advantages of motorization, there is a trend of increments in human and material losses due to accidents related to vehicles. A vehicle is a potential source of high danger to people, and its level has increased dramatically in recent years as a result of growth in engine power and speed [3].

During the period from 2015 to 2019, 86 318 road accidents occurred on the public roads of the Republic, 11 430 people were killed, 112 325 people were injured.

Since 2015, the level of accidents with road transport has decreased annually in the Republic of Kazakhstan (with the exception of year 2019). The reduction in the number of road accidents, as well as people killed and injured in them, continued against the background of an increase in the country's fleet. The main indicators of accidents in the Republic of Kazakhstan from 2015 to 2020 are shown in table.

After a four-year period of decline in all major accident rates, the number of road accidents increased in 2019, as well as the number of people killed and injured in them (Table).

According to official statistics, 16 614 road accidents were registered in Kazakhstan in 2019. Compared to 2018, the number of accident increased by 5% [4].

Figure 1 shows the dynamics of changes in the number of accidents and the number of victims for the period from 2015 to 2020.

The driver of a motor vehicle is the main link of the driver-car-road-environment (DCRE) system, the sustainable functioning of which determines the efficiency and safety of road traffic. The driver drives a car in a state of constant stress. As a person drives, he or she continuously perceives and comprehends the rapidly changing traffic situation, the position, speed and condition of the car, and has to instantly make decisions and implement them. Such an active and continuous course of mental phenomena in a rapidly

The main indicators of accidents in the Republic of Kazakhstan						
Year	Road accident		Died		Injured	
	Cases	Growth/decline, %	People	Growth/decline, %	People	Growth/decline, %
2015	18890	-7,3	2453	-5,1	24055	-7,3
2016	17974	-5,8	2390	-2,6	23389	-2,8
2017	17019	-5,3	2086	-12,7	22256	-4,8
2018	15821	-7,0	2096	+0,5	20445	-8,1
2019	16614	+5,0	2405	+14,7	22180	+8,5
2020	13515	-18,7	1997	-19,5	17844	-17

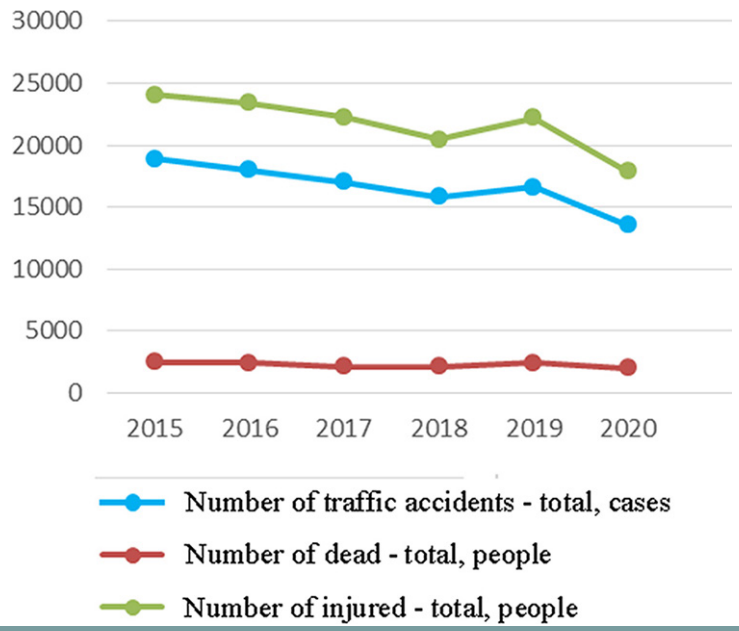

Figure 1 – Dynamics of changes in the number of accidents and the number of victims

changing environment of potential danger increases the tension of the nervous system and causes fatigue and sometimes overwork of the driver [1, 5].

When driving a car, the driver must accept and adequately analyze a large amount of information (road, regulatory means, road signs and markings, control devices and the operation of vehicle systems and mechanisms, weather conditions, etc.). In addition, he or she must be able to predict how the road situation will further develop and choose the safest driving modes. With high dynamism, variability of conditions and strict restrictions on decision-making time, the driver is constantly under great emotional stress.

The driver's poor health and illnesses lead to a decrease in the working capacity and a corresponding increase in the probability of a traffic accident [6].

Analyzing the factors determining the causes of high accidents, we can conclude that the human factor is the key. Poor quality of driver training leading to errors in assessing the road situation, unsatisfactory discipline, inattention and negligence of drivers when driving vehicles – these are the components for road accidents.

The analysis of the majority of road accidents shows that the weakest link of the human-machine DCRE system limiting its effectiveness and reliability is people themselves. Drivers are responsible for 65 to 85% of accidents [1, 4].

The problem of the reliability of the professional activity of the driver is very complex. It covers not only purely technical issues related to the design features of cars and roads, but also issues from other fields such as psychology and human physiology. Identification of people with reduced reliability using professional selection based on psychophysiological qualities will reduce risk levels, and thereby increase the safety of the transport process [7].

To improve the professional training of future drivers, it is necessary to conduct professional selection taking into account the psychophysiological qualities of a person. In this regard, the issue of creating a car simulator for driver training is relevant as its use will allow identifying and weeding out potential traffic violators, who may subsequently be the causes of road accidents due to their limited

psychophysiological capabilities, at the stage of driver training.

At the initial stage of the research work, we conducted an analysis of the existing designs of automobile simulators.

Justification of the concept of a car simulator

Car simulators are software or hardware-and-software complexes that simulate real processes and situations in order to train drivers and develop their driving skills. Simulators that simulate processes associated with risk to life and health have become widespread.

Driving simulators have been successfully used for several decades in researches conducted in the automotive industry. Initially, they were invented in order to develop and improve driving skills. Later, they began to be used to train professional drivers of special vehicles for successful adaptation to difficult driving conditions.

To date, simulators are used both for training drivers and for conducting research in the field of reliability of the interaction of the «car-driver» system [8].

Car simulators are very expensive. Firstly, this is due to high technical and design requirements, and secondly, they are not mass-produced. In most cases, separate samples are assembled, if needed. For this reason, their production requires high costs.

The development and production of car simulators, for the most part, is carried out with the interaction of research institutes, educational institutions and car manufacturers [9].

Based on the results of the analysis, the concept of a car simulator was formed. Structurally, the car simulator consists of parts of the car interior with

During the analysis, we considered simulators from the following countries:

- Republic of Korea

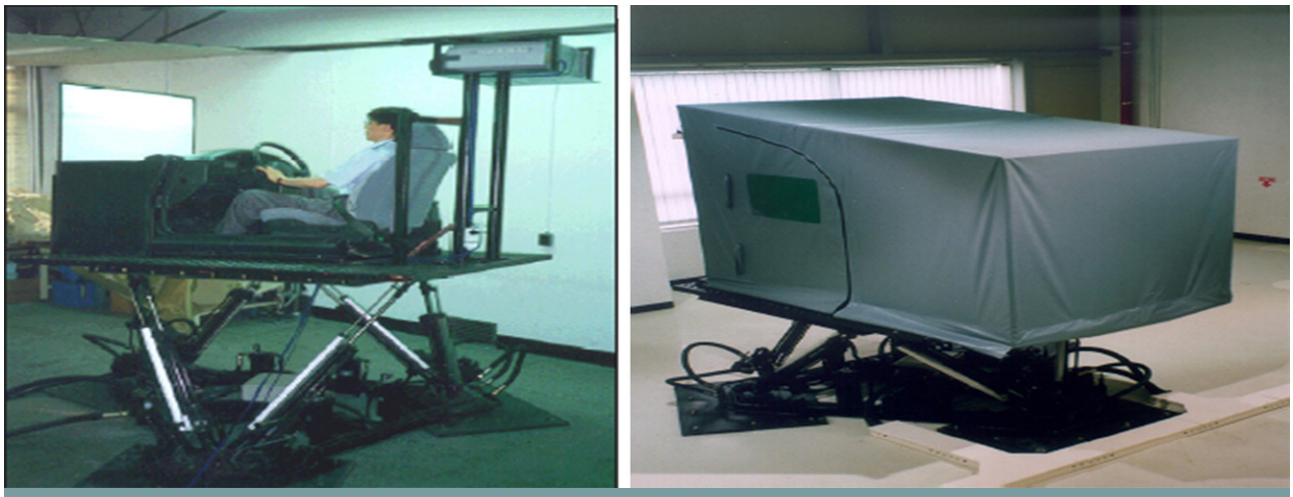

Figure 2 – Hexapod-based simulator

- France

Figure 3 – Advanced simulators on the engine platform in Technocentre Renault (on the right there is the so-called «crossdesk»)

- USA

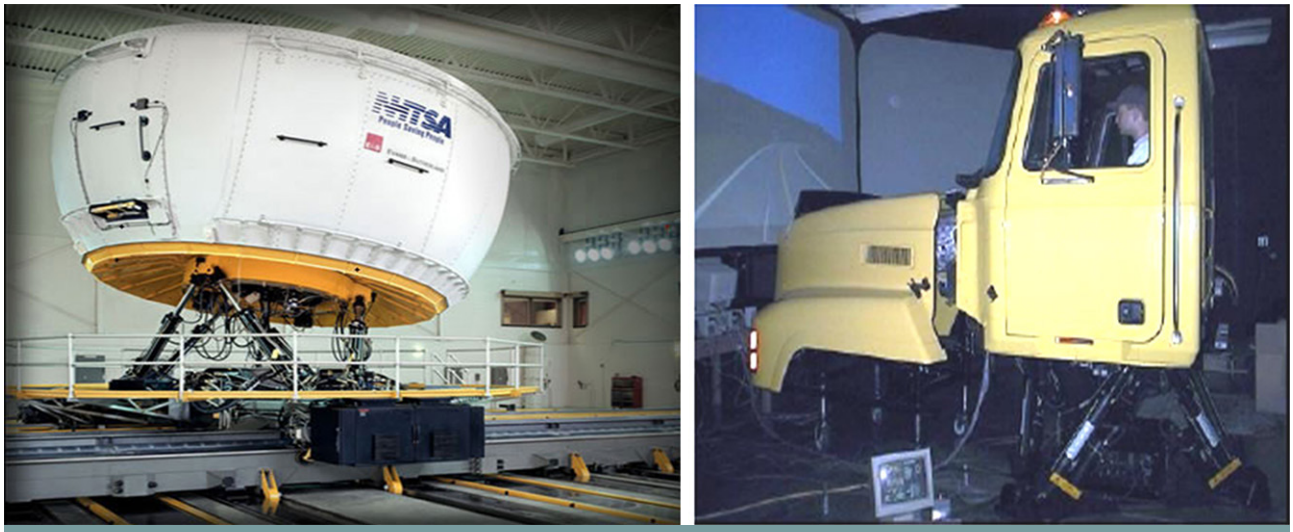

Figure 4 – Advanced system based on the NADS propulsion platform (on the right is a Truck Driving Simulator)

- Sweden

Figure 5 – Hybrid motor platform for VTI stimulator (an inside view is on the right)

- Germany

Figure 6 – A complete car simulator placed on a highly reliable six-legged platform at BMW facilities

- Japan

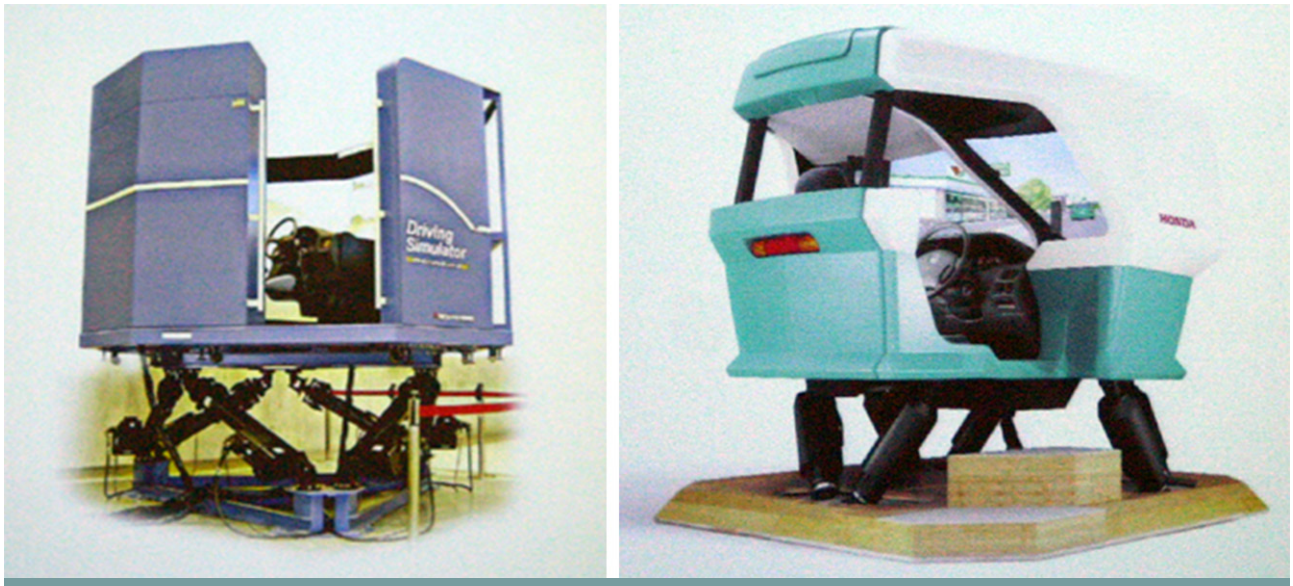

Figure 7 – Driving simulator produced by Mitsubishi Precision (left) and Honda (right)

control system elements (steering wheel, pedals, dashboard) and an adjustable seat borrowed from a real car. It is equipped with a manual transmission, a clutch pedal and a real car control panel [10].

Visualization is provided by a screen located in front of the instrument panel. This concept of a driving simulator is more convenient for implementing the so-called «inside-the-car dynamics», which makes the driver perceive driving skills more realistically. In addition to the aforementioned, the simulator should allow one to simulate the operation of components and assemblies of a real car, provide the ability to create and change a virtual landscape. The described driving simulator is the closest to reality in terms ergonomics of the driver, since elements of a real car are used.

The distinct feature of the car simulator proposed by our team is that it allows us conducting studies of the influence of various stimuli on a driver's condition by the use of non-invasive measuring devices.

In psychophysiological studies, the criteria for assessing the impact of various road conditions on the driver are the values of psychophysiological parameters corresponding to the optimal level of emotional stress. The degree of reliability of a driver's actions is determined based on them [11, 12, 13].

Figure 9 shows the functional structure of the proposed car simulator. The entire system can be divided into four modules. The first module represents the simulator itself. It consists of software and hardware. The simulator software includes a virtual reality engine (3D graphics and spatial sound) and a physics engine. A verisimilar behavior of the simulated vehicle is a prerequisite for good experimental results.

The second module of the simulator is a cabin consisting of parts of a real car and computers connected to the Internet.

The next module is a database of test tracks and passenger cars. To get objective results, it is necessary to produce a certain level of track complexity.

The last module is tools for creating assets that make up tracks. Basically, this is the modeling of 3D objects and tools for automating the process and databases from simulated objects. Each object in virtual reality is accompanied by a texture. Texture is a picture that simplifies the creation of a 3D object. Textures can be of different types.

A helmet with sensors is put on the head of the test operator, which allows one to fully simulate the signals in 3D format. A sensor connected to the head scans the operator's head. These data primarily serve to assess the movement of the projected image through an eye tracking system [14].

Eye tracking is a technology for tracking eye movements around an observed object or scene. To sense these movements without damaging the eyes, non-invasive technologies using infrared light are used. Movements are scanned by special cameras that transmit eye movements to a computer through data set files [15].

Conclusions

The conducted research on the analysis of accidents and detailed information on the number, types and causes of road accidents has shown that the number of accidents is continuously increasing, with 65–85% of road accidents occurring due to the fault of drivers.

Ensuring the reliability of the driver of any vehicle can be achieved by improving the driver training system and the implementation of professional selection. Identification of people with reduced reliability using professional selection based on

Figure 8 – Advanced car simulator

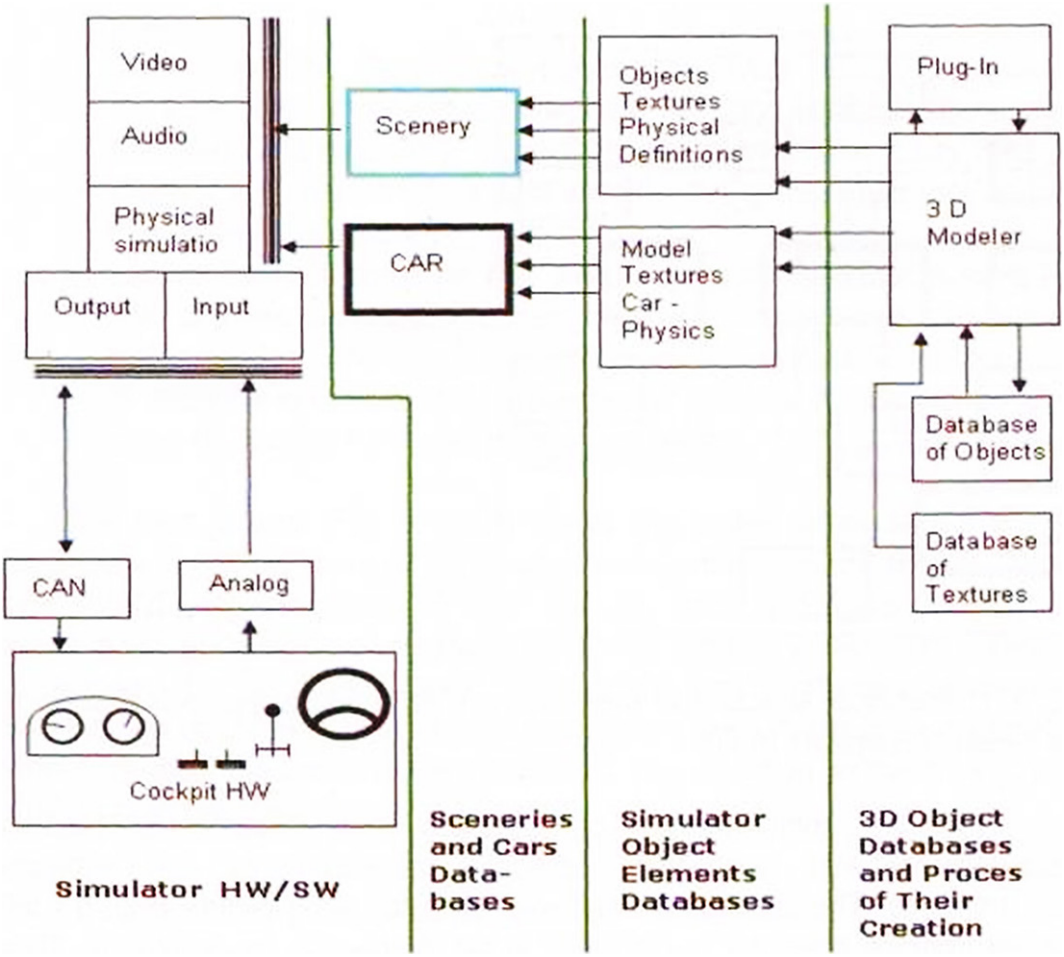

Figure 9 – Functional structure of the car simulator

psychophysiological qualities will in turn reduce risk levels, and thereby increase the safety of the traffic.

For the implementation of these measures a simulator concept based on the analysis of the existing designs of driving simulators was created to study the psychophysiological characteristics of motor vehicle drivers. The distinct feature of the car simulator proposed by our team is that it allows us conducting studies of the influence of various stimuli on a driver's condition by the use of non-invasive measuring devices.

The use of the proposed driving simulator will allow identifying and weeding out potential traffic violators, who may subsequently be the causes of traffic accidents due to their limited psychophysiological capabilities, at the stage of driver training.

REFERENCES

1. Abishev K.K. On the issue of reliability of the driver of a motor vehicle / Bulletin of the Shakarim State University of Semey – No. 2 (70) – 2015. – pp. 3-6 (in Russian).
2. Abishev K.K., Baltabekova A.N. To the question of choosing the scheme of the stand for the study of the psychophysiological condition of the driver // Collection of materials of the XIV International Scientific Conference «Progressive technologies in transport systems». – Orenburg: OSU, 2019. – pp. 5-10 (in Russian).
3. Bekmagambetov M.M., Zhumagulov R.B. The transport system of Kazakhstan in modern conditions. – Almaty, 2008. – p. 432 (in Russian).
4. Official website of the Agency of the Republic of Kazakhstan on Statistics. Online resource: http://www.stat.gov.kz/
5. Stepanov I.S., Pokrovsky Yu.Yu., Lomakin V.V., Moskaleva Yu.G. The influence of elements of the «driver-car-road-environment» system on road safety. Moscow: MSTU «MAMI», 2011. – p. 171 (in Russian).
6. Yarmukhamitova A.I., Alekseeva O.V. Assessment of the driver's influence on road safety // Scientific creativity of youth – to the forest complex of Russia: Materials of the VII All-Russian Scientific and Technical Conference of Students and Postgraduates. – Yekaterinburg, 2011 (in Russian).
7. Organization and road safety: textbook for universities / A.N. Galkin [et al.]; edited by K.V. Kostin. – 2nd ed., reprint and additional – Moscow: «Yurayt» Publishing House, 2020. – p. 229 (in Russian).
8. Došek J., Janda M. and others. Professional vehicle drivers training and performance measurements with use of advanced driving simulator laboratory // Publ. by Czech Technical University in Prague, 2013.
9. Sokolov E.D. Simulator of driving skills: a design solution / E.D. Sokolov, N.A. Razgonyaev, A.A. Savitsky, V.Y. Pischikov // Young scientist. – 2015. – No. 19.1 – pp. 61-64 (in Russian).
10. Rozhdestvenskiy D., Mashko A., Mukanov R. and others. Dynamic Human-Machine Interface for Electrical Vehicle design guidelines / Smart Cities Symposium Prague (SCSP) (June 24-25, 2015). Czech technical university in Prague, 2015. – pp. 58-62.
11. Usoltseva I.V. Psychophysiological foundations of the driver's activity. Moscow: «Academia» publishing center, 2019. – p. 292 (in Russian).
12. Golubikhina Yu.Yu., Goncharova N.A. Comparison of psychophysiological indicators of reliability of female and male drivers // Fundamental research. 2015, No. 2-4. – pp. 815-819 (in Russian).
13. Iskandarova G.K., Shatunova O.V. Consideration of psychophysiological features of future drivers as means of increasing their reliability // «Concept» Scientific and methodological electronic journal. 2016. vol. 11. – pp. 2921-2925 (in Russian).
14. Abishev K.K., Kasenov A.Zh., Baltabekova A.N. Measuring Devices of Non-Invasive Form for the Study of the Psychophysiological State of the Driver of Motor Vehicles // Mechatronics, automation, control. – 2022. – vol. 23. – No. 3. – pp. 152-157 (in Russian).
15. Eyetracking in psychological science and practice / Responsible editor V.A. Barabanshchikov. – Moscow: Kogito-Center, 2015. – p. 410 (in Russian).

Автокөлік құралдар жүргізушілерін даярлауға арналған интерактивті тренажер жасаудың алғышарттары

[1]***БАЛТАБЕКОВА Алмагуль Нурлыбековна,*** *докторант, almagul_bn@mail.ru,*
[2]***БОУХНЕР Петр,*** *PhD, қауымдастырылған профессор, bouchner@lss.fd.cvut.cz,*
[1]***КАСЕНОВ Асылбек Жумабекович,*** *т.ғ.к., профессор, asylbek_kasenov@mail.ru,*
[1]****АБИШЕВ Кайратолла Кайроллинович,*** *т.ғ.к., профессор, a.kairatolla@mail.ru,*
[1]*Торайғыров университеті, Қазақстан, Павлодар, Ломов көшесі, 64,*
[2]*Прагадағы Чех техникалық университеті, Чехия, Прага, Конвиктска көшесі, 20,*

**автор-корреспондент.*

Аңдатпа. *Мақалада апаттық пен жол-көлік оқиғаларының себептеріне талдау жүргізілді. Көп жағдайда жол-көлік оқиғалары жүргізушінің кінәсінен болатыны анықталды. Бұл автокөлік құралы жүргізушісінің кәсіби дайындықтың төмендігіне және психофизиологиялық жағдайының шектелуіне байланысты. Интерактивті тренажер жасау ұсынылды. Автомобиль тренажерларының қолданыстағы құрылыстарына талдау жүргізілді. Талдау негізінде автомобиль тренажерының концепциясы негізделген. Сипатталған автотренажерды пайдалану жүргізушілерді дайындау кезеңінде жол қозғалысы ережелерін ықтимал бұзушыларды анықтауға және іріктеуге мүмкіндік береді.*

Кілт сөздер: *апаттық, жол-көлік оқиғасы, автокөлік құралының жүргізушісі, автомобиль тренажері, психофизиология, концепция, жол қозғалысының қауіпсіздігі, кәсіби іріктеу.*

Предпосылки к созданию интерактивного тренажера для подготовки водителей автотранспортных средств

[1]***БАЛТАБЕКОВА Алмагуль Нурлыбековна,*** *докторант, almagul_bn@mail.ru,*
[2]***БОУХНЕР Петр,*** *PhD, ассоциированный профессор, bouchner@lss.fd.cvut.cz,*
[1]***КАСЕНОВ Асылбек Жумабекович,*** *к.т.н., профессор, asylbek_kasenov@mail.ru,*
[1]****АБИШЕВ Кайратолла Кайроллинович,*** *к.т.н., профессор, a.kairatolla@mail.ru,*
[1]*Торайгыров университет, Казахстан, Павлодар, ул. Ломова, 64,*
[2]*Чешский технический университет в Праге, Чехия, Прага, ул. Конвиктска, 20,*
**автор-корреспондент.*

Аннотация. *В статье проведен анализ аварийности и причин дорожно-транспортных происшествий. Установлено, что в большинстве случаев дорожно-транспортные происшествия происходят по вине водителя. Это обусловлено низкой профессиональной подготовкой и ограниченностью психофизиологического состояния водителя автотранспортного средства. Предложено создание интерактивного тренажера. Проведен анализ существующих конструкций автомобильных тренажеров. На основе анализа обоснована концепция автомобильного тренажера. Использование описанного автотренажера позволит еще на стадии подготовки водителей выявить и отсеять потенциальных нарушителей правил дорожного движения.*

Ключевые слова: *аварийность, дорожно-транспортное происшествие, водитель автотранспортного средства, автомобильный тренажер, психофизиология, концепция, безопасность дорожного движения, профессиональный отбор.*

REFERENCES

1. Abishev K.K. On the issue of reliability of the driver of a motor vehicle / Bulletin of the Shakarim State University of Semey – No. 2 (70) – 2015. – pp. 3-6 (in Russian).
2. Abishev K.K., Baltabekova A.N. To the question of choosing the scheme of the stand for the study of the psychophysiological condition of the driver // Collection of materials of the XIV International Scientific Conference «Progressive technologies in transport systems». – Orenburg: OSU, 2019. – pp. 5-10 (in Russian).
3. Bekmagambetov M.M., Zhumagulov R.B. The transport system of Kazakhstan in modern conditions. – Almaty, 2008. – p. 432 (in Russian).
4. Official website of the Agency of the Republic of Kazakhstan on Statistics. Online resource: http://www.stat.gov.kz/
5. Stepanov I.S., Pokrovsky Yu.Yu., Lomakin V.V., Moskaleva Yu.G. The influence of elements of the «driver-car-road-environment» system on road safety. Moscow: MSTU «MAMI», 2011. – p. 171 (in Russian).
6. Yarmukhamitova A.I., Alekseeva O.V. Assessment of the driver's influence on road safety // Scientific creativity of youth – to the forest complex of Russia: Materials of the VII All-Russian Scientific and Technical Conference of Students and Postgraduates. – Yekaterinburg, 2011 (in Russian).
7. Organization and road safety: textbook for universities / A.N. Galkin [et al.]; edited by K.V. Kostin. – 2nd ed., reprint and additional – Moscow: «Yurayt» Publishing House, 2020. – p. 229 (in Russian).
8. Došek J., Janda M. and others. Professional vehicle drivers training and performance measurements with use of advanced driving simulator laboratory // Publ. by Czech Technical University in Prague, 2013.
9. Sokolov E.D. Simulator of driving skills: a design solution / E.D. Sokolov, N.A. Razgonyaev, A.A. Savitsky, V.Y. Pischikov // Young scientist. – 2015. – No. 19.1 – pp. 61-64 (in Russian).
10. Rozhdestvenskiy D., Mashko A., Mukanov R. and others. Dynamic Human-Machine Interface for Electrical Vehicle design guidelines / Smart Cities Symposium Prague (SCSP) (June 24-25, 2015). Czech technical university in Prague, 2015. – pp. 58-62.
11. Usoltseva I.V. Psychophysiological foundations of the driver's activity. Moscow: «Academia» publishing center, 2019. – p. 292 (in Russian).
12. Golubikhina Yu.Yu., Goncharova N.A. Comparison of psychophysiological indicators of reliability of female and male drivers // Fundamental research. 2015, No. 2-4. – pp. 815-819 (in Russian).
13. Iskandarova G.K., Shatunova O.V. Consideration of psychophysiological features of future drivers as means of increasing their reliability // «Concept» Scientific and methodological electronic journal. 2016. vol. 11. – pp. 2921-2925 (in Russian).
14. Abishev K.K., Kasenov A.Zh., Baltabekova A.N. Measuring Devices of Non-Invasive Form for the Study of the Psychophysiological State of the Driver of Motor Vehicles // Mechatronics, automation, control. – 2022. – vol. 23. – No. 3. – pp. 152-157 (in Russian).
15. Eyetracking in psychological science and practice / Responsible editor V.A. Barabanshchikov. – Moscow: Kogito-Center, 2015. – p. 410 (in Russian).