



## Short Communication

## Assessment of the Risks of Occupational Diseases of the Passenger Bus Drivers



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## ABSTRACT

**Background:** The working conditions of bus drivers are difficult; they lead to occupational diseases and require careful study, particularly in Ukraine. The objective of the article is the description of occupational health risks of passenger bus drivers that lead to deteriorating health.

**Methods:** The risk assessment was performed using a modified Risk Score method, which allowed determining the generalized level of danger to the driver's health. The hygienic hazards level was assessed as based on Stevenson's law, which was generalized later.

**Results:** Based on the modification of the Risk Score method, it was possible to depart from expert assessments method of the risk level and calculate the general indicator based on the degree of dependence of the impact on the human body on its intensity, proposed by V. Minko. This allows objective determining of the impact of hygiene hazards on the health of the driver and to predict the occurrence of occupational diseases associated with the cardiovascular system, musculoskeletal system, and partial or complete disability due to the accumulation of emotional fatigue. The hazard assessment was carried out for three brands of passenger buses common in Ukraine, in which the driver is exposed to the dangers of fever, vibration, noise, harmful impurities in the bus cabin, and emotional load.

**Conclusion:** The health of drivers in the cabins of passenger buses is most affected by hygiene hazards: fever, vibration, and emotional stress. The generalized level of risk is calculated by the modified method of Risk Score is 0.83;  $-0.99$ ,  $-0.92$  respectively.

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## 1. Introduction

The passenger motor transportation plays an important role in satisfying the traveling needs of people. Its efficiency depends directly upon the reliability of the professional skills of drivers and their working conditions.

Driving a passenger bus is rather a sensitive and stressful job, which is characterized by a considerable number of such harmful factors as: weather conditions; increasing density, intensity, velocity of the traffic flows; possible traffic jams; ignorance of the transportation schedules; nonstandardized working days; complex routes, and so on [1]. Their effect results in the drivers' occupational diseases. The most frequent of them are as follows: diseases related to the development of a cardiovascular pathology, neuropsychic disorders, gastrointestinal disturbances, diseases related to the problems with the musculoskeletal system mobility, disorders

stipulated by the sedentary lifestyle and dysmetabolism, as well as allergic and oncologic diseases (Fig. 1).

The drivers are also affected by the harmful sanitary and hygienic factors: noise, vibration, increased temperature, harmful admixtures in the bus cabin, and nervous tension [3,4]. Under the certain conditions, they may result in the serious changes in a human organism [5,6]. Thus, the analysis of the scientific studies makes it possible to specify three potential consequences of that effect negative emotions, deterioration of the physical and psychical state of a human health [2,7]. As a result, there may be different cardiovascular pathologies, neuropsychic disorders [8,9], problems with the sense of hearing [10], feeling of constant fatigue [11], carbon monoxide poisoning, and development of allergic and oncologic diseases [7,12].

Different European legislative normative documents on the problems of labor safety stipulate the necessity of the evaluation of

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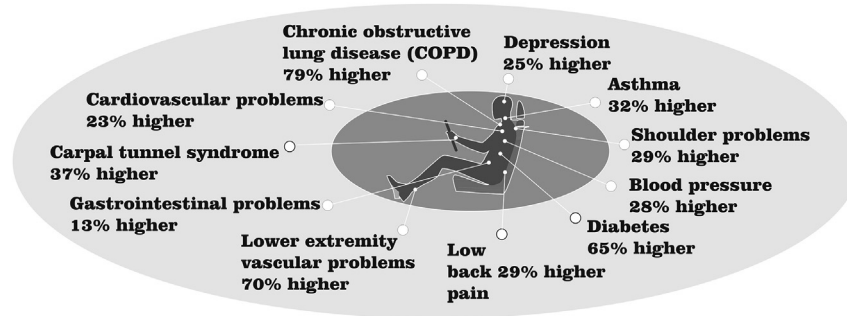


Fig. 1. The risk of the occupational disease manifestation for a passenger bus driver due to the effect of the harmful factors [2].

the occupational risks at any workplace (The Directive of the Council 89/654/EES, ISO 45001, ISO 39001). Thus [13], it indicates the basic principles to prevent the risks during a working process; and ISO 45001 gives the requirements to control the risks in companies for the reduction of the occupational diseases and injuries. There are also the requirements for the transportation duration, breaks, and rest time for the drivers [14]. However, the majority of companies restrict themselves to the assessment of the risks related to the technical conditions of a vehicle, behavior and psychophysical condition of a driver, and road conditions [15]. In this context, the hygienic risks are often neglected due to the long-term effect and difficulty of their control.

The occupational risks are assessed in terms of the specified algorithm [16]. The procedure includes identification of the risks, evaluation of the occupational risk development, and implementation of the measures to reduce the occupational risks, analysis of the efficiency of the proposed solutions, and their improvement [17]. Some researchers expand the list of the problems and provide the detailed explanation of each step required to provide the transportation safety [18]. It is important for an employer to apply the reliable and substantiated methods of the determination of the occupational risk level at any workplace, that helps reduce the probability of the occupational risks occurrence. In addition, this makes it possible to control the risks aimed at the reduction of the financial losses.

It should be noted that in terms of the European Union countries, legal basis to assess the professional risks is represented by the Guidelines for the implementation of measures to improve legislation in the sphere of health protection and labor safety [19]. According to them, the assessment of risks means thorough study of the factors, which, under certain activities, may do harm to people. The assessment objective is either to evaluate the sufficiency of the taken decision or to implement some additional measures to prevent the injuries. Moreover, to strengthen the labor safety positions in Europe, new ISO 45001 Standard was introduced in March 2018; the Standards recommended the employers to be more responsible for the elaboration of risk-oriented systems to control the labor safety and hygiene. The working conditions for the passenger bus drivers are regulated by the corresponding legislative acts, industry standards, and norms; however, in most cases, the drivers do their job with certain risks for their life and health [20–23]. The problem is of special topicality during the organization of the passenger transportations because there is a possible effect upon the traffic safety while transporting passengers. Weak responsibility of the authorities of the automobile operating companies as for the problem of control of the physiological and psychological state of the driver's health results in the accidents involving both drivers and passengers during the transportation operations. There should be also highlighted that recently psychological load on the drivers has increased considerably due to the intensification of traffic, the incoming information for decision-

making, the responsibility for the corresponding transportation type, the increasing trip complexity, and so on. Thus, the studies aimed at the improvement of the system of labor protection in the automobile operating companies to reduce the risks of occupational diseases in the bus drivers are urgent. The analysis of different scientific publications dealing with the assessment of the occupational risks has demonstrated their considerable number. One of the reasons of such great interest to the problem is in the fact that there are no unified methodological approaches to be applied while assessing the professional risks. Thus, every author tries to explain their own view as for the solution of the problem under consideration.

However, it is possible to single out a specific feature identified during the analysis: the authors emphasize the necessity of clear understanding what occupational risks should be assessed and why. Two basic problems are focused on as follows:

- the evaluation of the occupational disease risks of the workers taking into consideration the severity of the consequences for their health [24]; and
- the assessment of the economic efficiency of the preventive measures to stimulate the employers as for their investing into the labor protection [25].

The majority of the published scientific articles deal with the solution of the first problem study of the influence of one dangerous factor on the human organism: development of the cardiovascular diseases, problems of the musculoskeletal system, nervous disorders. For instance, it is possible due to the stressful situations of a driver while performing their duties, excessive everyday load [26], lack of time for having rest, sleep need [27,28], and lack of proper nutrition [29]. Much attention is also paid to the problems dealing with the reduction of the accumulated fatigue during a day and its control. That problem can be solved both by working hours planning and by implementing certain instruments to monitor the physical conditions of a driver. The ergonomic problems are also considered quite often, as the driver's job is characterized by a monotonous working posture and numerous repetitive hand operations [30,31].

While solving the second problem, great attention is paid to the solution of certain social problems (implementation of new standards, development of the means of control/monitor of the driver's behavior and health) which are aimed at the traffic safety improvement [32–37].

Unfortunately, not so many articles are dedicated to a complex assessment of the effect of the sanitary and hygienic factors on the drivers' occupational disease risks. Thus, there arises the necessity to consider this problem in a more thorough way. The topicality of that problem is emphasized by the fact that much more people worldwide die of different occupational diseases than of injuries [38].

<b>EVENT PROBABILITY</b>	<b>6</b>	<b>HIGHLY PROBABLE</b>	<b>6</b>	<b>12</b>	<b>18</b>	<b>24</b>	<b>30</b>	<b>36</b>
	<b>5</b>	<b>PROBABLE</b>	<b>5</b>	<b>10</b>	<b>15</b>	<b>20</b>	<b>25</b>	<b>30</b>
	<b>4</b>	<b>MODERATELY PROBABLE</b>	<b>4</b>	<b>8</b>	<b>12</b>	<b>16</b>	<b>20</b>	<b>24</b>
	<b>3</b>	<b>MODERATE</b>	<b>3</b>	<b>6</b>	<b>9</b>	<b>12</b>	<b>15</b>	<b>18</b>
	<b>2</b>	<b>HARDLY PROBABLE</b>	<b>2</b>	<b>4</b>	<b>6</b>	<b>8</b>	<b>10</b>	<b>12</b>
	<b>1</b>	<b>EXCEPTIONAL</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
		<b>RISK</b>						
		<b>LOW</b>						
		<b>MEDIUM</b>						
		<b>HIGH</b>						
		<b>CRITICAL</b>						
		<b>SLIGHT</b>	<b>LOW</b>	<b>MODERATE</b>	<b>HIGH</b>	<b>VERY HIGH</b>	<b>INTOLERABLE</b>	
		<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	
		<b>SEVERITY OF CONSEQUENCES</b>						

Fig. 2. The table to assess the risks of the occupational diseases in accordance with the method of BS8800 Standard, Risk score.

Moreover, in accordance with ISO 31010 Standard for risk analysis, the labor protection systems may involve two types of the risk factors assessment: quantitative or qualitative (e.g. minor risk, tolerable, critical, catastrophic or other assessments like that).

The problem of the determination of the bus drivers' risks occurrence is related to the fact that most recommendations are given based on the qualitative methods of their assessment. The methods mean that while determining the harmful hygienic risks, several experts attribute corresponding points to those risks; that attribution is based on the experts' understanding of the problem under consideration. The points characterize the risk effect on the human health. However, such an approach does not allow comparing the risk values in terms of different companies. Moreover, it can influence considerably the managerial decisions since one and the same conditions may be/will be evaluated differently, based on the experts' experience. The determined assessment methods are too complicated; they require special knowledge-based training and corresponding accumulation of the statistic data.

The objective of the work is to describe the hygienic occupational risks in drivers of passenger buses that lead to deteriorating health.

**2. Materials and methods**

To assess the effect of possible occupational risks on the driver's health, we are going to use the data based on the studies of three passenger bus types (Appendix A). The research applies standard

methods to study following hygienic parameters: noise, vibration, harmful gases in a driver cabin, and nervous tension of a driver (Appendix B). Appendix C represents the research results used to assess the occupational risks; those results were previously published in several author's publications [39,40]. The measurement results were processed involving standard Microsoft Office Excel 2010 software package. The obtained data were characterized by the normal probability law; to analyze the data, the parametric Student and Fisher criteria were applied. The number of the observations in terms of one parameter was from 15 to 20 values. Student *t* test was used to compare average values of the quantitative indices in terms of normal distribution of a characteristic. Significance point *p* < 0.05 with 95% reliability was considered to be true.

To assess the risks of the occupational diseases for the drivers, we use the method developed in accordance with BS8800, Risk score [21–23,41], being well approbated and adopted in the EU countries. The essence of the method is in the determination of the severity of the harmful factors influence upon the human organism due to a dangerous situation and identification of the possible health hazard. Thus, the risk value will be:

$$R = S \cdot P, \tag{1}$$

where *R* is the risk; *S* is the consequences severity; *P* is the possible hazard.

Fig. 2 represents the table to assess the risks of the occupational diseases based upon the method of BS8800, Risk score.

The unfavorable harmful work-related factors affecting the driver's health in a passenger bus cabin while transporting passengers include the following: noise, vibration, increased air temperature, dust, and gas at the workplace.

We determine the severity of the effects on the human body from the effects of hygienic hazards, based on the manifestation of occupational diseases and in accordance with the hygienic classification of labor [42]. Thus, the acceptable working conditions without serious driver's health consequences will have two points; the harmful working conditions belonging to certain classes (according to [43]) will be evaluated as follows: 3.1–3 points; 3.2–4 points; 3.3–5 points; 3.4–6 points (Table 1).

The next stage involves the calculation of the occupational disease probability. To calculate that probability, we used a well known approach proposed by V.M. Min'ko, assuming that the effect of the irritant agents upon the human organism may be assessed according to the Stevenson function:

$$x = K \cdot S^n, \tag{2}$$

where  $x$  is the risk assessment,  $K$  is the constant depending upon the measurement unit,  $S$  is the value of stimulus (or irritation),  $n$  is the psychophysical factor of the level calculated from 0.2 to 3.5 for different irritant agents.

Table 2 shows formulas for determining the scores, based on the degree of dependence of the impact on the human body of danger on its intensity, proposed by Professor Minko V.M taking into account Stevenson's law, which can be used to assess the probability of disease.

### 3. Results

Table 3 represents the calculation results of the probable severity of various harmful factors affecting the driver's health. The data to calculate the probable occupational diseases of the passenger bus drivers were taken from [40]. The obtained result was rounded to the integer number.

Table 4 shows the results of the calculation of the value of the probable occupational disease risk of the passenger bus drivers caused by the effect of different harmful work-related substances based on formula (1) and based upon the analysis of Fig. 2.

In accordance with the obtained results, it is also possible to calculate the generalized level of the risks in terms of the passenger bus driver' workplace using the following formula:

$$R_{pc} = 1 - \prod_{i=1}^n S_{pci}, \tag{3}$$

**Table 1**  
The effect of the harmful work-related factors upon a human and the determination of the corresponding points for their harm severity

No.	Harmful work-related factor	Consequences of the effect upon the human organism	Determined value of the harmful work-related factor	Corresponding points
1.	Noise	Deteriorates the sense of hearing, results in the loss of hearing, causes stress, increases blood pressure, may result in the hypertonic disease	78–82 dB	3
2.	Vibration	Results in the vibration disease, disorders in the cardiovascular system and the musculoskeletal system	75–85 dB	3
3.	Harmful substances (CO)	Results in the acute intoxication due to the oxygen blocking with the following hypoxia; damages the oxidizing reactions resulting in the biochemical unbalance in tissues	7–18 mg/m <sup>3</sup>	3
4.	Temperature	Results in the disturbed thermal regulation, fluid-and-electrolyte imbalance, organism overheating, oxygen deprivation, headaches, tachycardia	2–30°C	4
5.	Nervous tension	Drowsiness, weakness, indifference, signs of depressed state, nervous breakdown	80%	4

**Table 2**  
The formulas for determining scores to assess the likelihood of disease [26]

Harmful work-related factor, reference	Unit of measurement	Computational psychophysiological formula	Value of psychophysiological factor $n$
Noise, $L$	Hz	$x = x_0 \cdot 1010^{\frac{n}{10} \cdot (L - L_{BAC})}$	0.3
Vibrations, $L$	dB	$x = x_0 \cdot 1020^{\frac{n}{10} \cdot (L - L_{BAC})}$	0.77
Harmful substances (CO), $C$	mg/m <sup>3</sup>	$x = x_0 \cdot \left(\frac{C}{C_{BAC}}\right)^n$	0.55
Temperature, $T$	°C	$x = x_0 \cdot \left(\frac{T}{T_{BAC}}\right)^n$	1.6
Nervous tension, $N_T$	%	$x = 10 \cdot N_T^n \cdot (10^{-3.9})$	1.57

Note:  $x_0$  – corresponds to BAC for different harmful work-related factors; it is taken as a minimal value in points.

where  $n$  is the number of the harmful factors in the working environment of a passenger bus driver being considered,  $S_{pci}$  is the safety level based on the corresponding harmful substances at the driver's workplace:

$$S_{pci} = \frac{(x_{max} + 1) - x}{x_{max}}, \tag{4}$$

where  $x_{max}$  is the maximum scoring,  $x_i$  is the scoring according to the  $i$ th harmful work-related factor of the driver's workplace determined on the formulas (Table 1).

Tables 5 and 6 represent the results of the calculation of the safety level in terms of the corresponding harmful work-related factor of the driver's working environment and the generalized level of the risk level within the driver's working environment.

The proposed method to assess the occupational risks for the passenger bus drivers' health is a complex one. It unites the experimental measurement of the parameters of the action of different harmful factors, the calculation of the occupational risk index, and the evaluation of its priority. That helps compare the drivers' working conditions in different passenger bus types, as the scoring procedure is typical.

### 4. Discussion

Causes of the occupational disease occurrence due to the effect of the hazardous hygienic factors in a driver's cabin are well known and described in numerous scientific articles. In accordance with

**Table 3**  
The calculation results of the probable effect of the harmful work-related factors

Harmful work-related factor	Bus type		
	"MB sprinter"	"RUTA"	"BOHDAN"
Noise	3	3	3
Vibration	5	6	6
Harmful substances	3	3	5
Temperature	3	4	4
Nervous tension	5	5	5

the data in [42–45], numerous chronicle obstructive respiratory diseases, cardiovascular problems, musculoskeletal system disorders, and diabetes are the most widespread diseases (Fig. 1). There is certain correlation between the hazardous factors at a driver's workplace and their manifestation. This is complicated by the long-term effect of the disease, as well as the need for significant financial costs [46–48].

The obtained results correlate with the conclusions of other scientists. The studies [48,49] inform that in terms of vibration, the drivers start having certain physical discomfort, which is mostly the manifestation of the musculoskeletal system diseases. Similar conclusions are obtained in article [50,51], where the authors define the interrelation between the musculoskeletal system diseases and the effect of vibration characterized by the backache. Another research deals with the deterioration of vision caused by hygienic hazards, which may result in the road accidents.

Increased air temperature in a bus may also result in the serious health problems. In particular, cardiac failure, hypoxia, and other physiological reactions [52], caused by the expansion of blood vessels and the increasing load on heart muscles, are the most widespread problems [53]. There are even recorded cases of the drivers' death during their bus driving due to a sudden heart attack; that is already a serious danger not only for a driver but also for the road safety and passengers' lives [54,55]. Moreover, sultry air in a bus may cause a heat stroke.

Nervous strain (stress), determined by the performed calculation, is one of the major effects on the drivers' health and road safety. While studying the interaction between a stress and the accidents, it has been specified that they are a part of a dynamic system, which may have negative effect on the driver's behavior, his/her feeling sick, and the development of cardiovascular diseases [7, 56–58]. Stress is the main factor favoring the development of hypertonic disease, disfunctions of the hypothalamic hypophysial paranephros axis [59] and the sympathetic nervous system [60].

It is known that psychological stress occurs when people feel that the requirements for them are higher than their adaptive capabilities [61]. The metaanalytic surveys have shown that, either cumulatively or separately, the severe requirements and a limited decision-making range (ability to define the skills combined with the decision-making powers) are the important risk factors, which may result in the negative evidence in terms of physical and psychic

**Table 4**  
The calculation results of the occupational disease risks in the drivers caused by the action of different harmful substances

Harmful work-related factor	Bus type		
	"MB sprinter"	"RUTA"	"BOHDAN"
Noise	9 (medium)	9 (medium)	9 (medium)
Vibration	15 (high)	18 (high)	18 (high)
Harmful substances	9 (medium)	9 (medium)	15 (high)
Temperature	12 (high)	16 (high)	16 (high)
Nervous tension	20 (high)	20 (high)	20 (high)

**Table 5**  
The calculation results of the safety level in the driver's working environment

Harmful work-related factor	Safety level of the working environment of a bus driver		
	"MB sprinter"	"RUTA"	"BOHDAN"
Noise	0.67	0.64	0.60
Vibration	0.30	0.16	0.20
Harmful substances	0.72	0.66	0.36
Temperature	0.63	0.56	0.53
Nervous tension	0.41	0.41	0.41

health [62]. Besides, the highest risk of the stress-related disease occurrence [63] is connected with a high level of nervous tension (i.e., with the severe requirements for the job and limited decision-making powers), which has a low level of social support (from the colleagues and administrative managers). That is rather characteristic for the drivers' job.

The increased noise level results in the growing stress load [64]. A study carried out in terms of more than 200 public passenger transport drivers analyses the effect of noise on a driver's organism. It shows that the increased noise level is the ergonomic factor of discomfort resulting in the development of tinnitus, headache, and increased irritation [65].

The assessment carried out has made it possible to control the occupational risks by implementing the corresponding measures aimed at the improvement of the working conditions and preservation of the passenger bus drivers' health. The following measures may be highlighted:

- to transport passengers by means of new vehicles, which meet the requirements for safety, ergonomics, and comfort;
- to transport passengers with the help of the vehicles equipped with the advanced driver assistant systems. There may be such systems as: a system to assist while stationary driving, a system of adapted cruise-control, a parking aid system, a system of road sign information, a system of traffic lane tracking, a system of headlight beam control, a system of driver drowsiness detection, a brake assist system, and so on;
- to improve a system of proper organization of the maintenance and repair of the available vehicles taking into account the compulsory diagnostics and repair of a suspension system, a ventilation systems, a climate-control system and an air

**Table 6**  
The calculation results of the generalized risk level within the driver's working environment

Calculation results	Type of the harmful factors				
	Noise	Vibration	Harmful substances	Temperature	Nervous tension
Generalized safety level, $S_{pci}$	0.261	0.009	0.172	0.187	0.068
Generalized risk level, $R_{pci}$	0.739	0.991	0.828	0.813	0.932
Maximum admissible level of the generalized risk depending upon the work experience, $S_{max}$	0.830	0.830	1.000	0.680	0.750
Deviation of the actual level of occupational risk from the maximum admissible one, %	11	22	17	20	24

conditioning system along with their maintenance in good working order;

- to implement an efficient up-to-date and periodical system of medical examinations for the drivers, medical checkups, introduction of the measures to reduce the risks of the occupational disease occurrence (the *DISC* [Dominance-Influence-Steadiness-Conscientiousness] behavioral assessment of the emotional state of the driver, the *MBTI* personality type test, and so on);
- to intensify the driver's state control during the transit, e.g., the eye movement control and its comparison with the physiological changes involving the *PERCLOS* or *EyeQ* systems;
- to control the transportation schedule and the compulsory rest time, e.g., by controlling the driver's performance on the basis of a driver's cardiac cycle or the vehicle movement.

Moreover, the obtained research results not only help assess the effect of the harmful factors on the driver's health (the factors arising during the passenger transportation operations) but also make it possible to evaluate their effect on the driver's performance, his/her state of fatigue, and the biological age. We consider that the most important thing is that the effect of the indicated harmful factors results in the accelerated state of fatigue being the significant factor for the occurrence of road accident risks.

## 5. Conclusions

Based on the modification of the Risk Score method, it was possible to depart from the method of expert assessments of the risk level and calculate the general indicator based on the degree of dependence of the impact on the human body on its intensity, proposed by professor Minko VM This allows you to objectively determine the impact of hygiene hazards on the health of the driver and to predict the occurrence of occupational diseases associated with the cardiovascular system, musculoskeletal system, and partial or complete disability due to the accumulation of emotional fatigue.

The hazard assessment was carried out for three brands of passenger buses common in Ukraine, in which the driver is exposed to the dangers of fever, vibration, noise, harmful impurities in the bus cabin, and emotional load. Risk reduction is envisaged through the strengthening of medical control over the health of drivers, regular checkups during the performance of professional activities on the control indicators: blood pressure, pulse, nervous excitement, and monitoring the schedule of traffic and mandatory rest.

The health of drivers in the cabins of passenger buses is most affected by hygiene hazards: fever, vibration, and emotional stress. The generalized level of risk is calculated by the modified method of Risk Score is 0.83;  $-0.99$ ,  $-0.92$ , respectively.

## Conflict of interest

All authors have no conflict of interest.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.shaw.2020.07.005>.

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