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CHANGE OF DRIVERS FUNCTIONAL CONDITION WHILE MOVING ALONG HIGHWAYS OF DIFFERENT TECHNICAL CATEGORIES

Summary. *The article analyzes the influence of a human factor on road safety and the main methods of its research. The main indicators of the functional state of the drivers, which most accurately illustrate the change in the neuro-emotional stress while operating the vehicle in different road conditions, are determined. The regularities of changing the functional state of the drivers who were driving the vehicle along different categories of roads were established. It is revealed that the geometric features of the highway that determine its category have a significant impact on the performance of drivers, and, consequently, on the reliability of their work. The results of this research provide an opportunity to predict the functional state of the driver under different road conditions, as well as to adjust the routes of traffic of vehicles and the mode of work and rest of drivers.*

Key words: *highway, driving conditions, environment, functional state, fashion heart rate variability, driver reliability*

1. INTRODUCTION

Road traffic is characterized by a tight link between the elements of the driver-car-road-environment system, in which the first link is the least predictable. The emergency to study this issue is reflected in the works of indigenous authors [1-2], as well as in foreign sources [3-5]. In today's conditions, in Ukraine, there is an uneven development of infrastructure, namely the network of public roads. The allocation of budget financing is carried out in such a way that a considerable part of the funds is allocated for the operation and repair the highways of international and national importance, which belong to the first and second technical categories [6]. Accordingly, motorways belonging to the higher technical (first-second) categories are more sophisticated due to the better geometrical parameters of the plan and profile, besides they are kept in better operating condition. Freight transportation by road is the most popular because of the possibility of their door-to-door delivery, which involves the movement of vehicles on local roads. In such conditions, the influence of the highway parameters and qualities on the drivers functional condition (FC) becomes noticeable, which, in turn, is crucial in assessing the reliability of their work.

2. RESEARCH STATEMENT

The main issue is that freight routes are nowadays evaluated by a number of technological indicators, such as delivery times, technical speed and consumption of lubricants. However, an important factor for a person who depends on traffic safety is omitted, since this factor is associated with a certain group of risks in the traffic [7–9]. On this basis, the standard classification of routes and their comparisons are poorly understood in terms of drivers' performance. First of all, it concerns the influence of road conditions on the FC, which is most noticeable when driving along the highways of different technical categories. The purpose of this research is to identify patterns of change in the performance of drivers' FC, depending on road conditions.

The main objectives of the research are:

- identification of factors that affect drivers FC and substantiation of the methodology of studies of FC change;
- determination of patterns of change of indicators of drivers FC and statistical analysis of their significance;
- a comparative analysis of the results obtained and an assessment of the road conditions impact, determined by the highway category, on drivers FC.

3. METHODS OF RESEARCH

In ergonomic systems that study the interaction of man and technology, the methodology of research is based on determining the main psychophysiological indicators of the driver [10]. Most scientists are of the opinion that data on human FC is best obtained by electrophysiological methods, which include: electrocardiogram, electroencephalogram and skin-galvanic reaction [11]. A number of scientific studies conducted in real-world conditions, when professional drivers were driving vehicles, confirmed that heart rate variability analysis, based on the electrocardiogram recording provides ample opportunity to evaluate the FC of the operator [12–14].

While collecting and processing research results, all indicators that directly or indirectly affect the vehicle's driving process and driving conditions are divided into variables and constants. The sustainable indicators include:

- age and work experience of drivers (age – 35–45 years, work experience – 12–20 years);
- characteristics of vehicles (MAN TGA Euro-5 cars with tilt semi-trailers when transporting goods weighing 18–20 t);
- hydrometeorological conditions (summer, daytime, no precipitation).

Variables include:

- indicators of heart rate variability;
- technical indicators on the route (duration, technical speed on the segments of the route);
- road conditions defined by the technical category of the highway (the quality of the road surface decreases with the change of the road category).

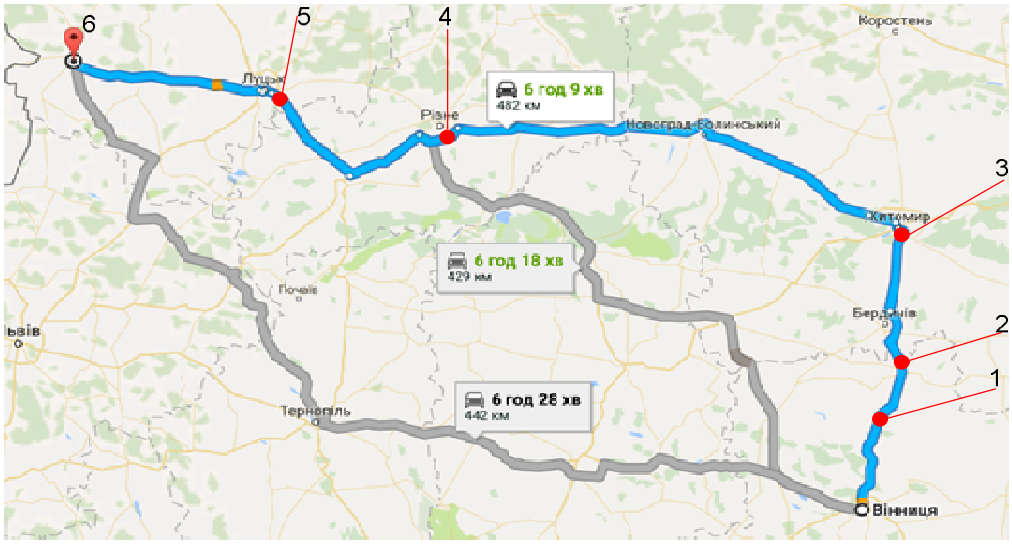
The drivers' FC changes were recorded with the help of a Polar H7 and processed in the CardioMood software environment. The parameters such as vehicle speed and driving time as well as space positions are recorded with the help of a GPS. Statistics were processed in Statistica software.

The research also took into account the general conditions of transportation:

- freight – consumer goods, formed into cargo units (pallets);
- loading and unloading operations were conducted without the participation of drivers;
- the time characteristic is the travel time between the points not the duration of the drivers work;
- vehicles in good technical condition;
- appropriate ergonomics for long-distance transportation (climate control, air suspension, automatic transmission, etc.).

To study the driver's FC, the Vinnytsia-Volodymyr-Volynskyi route was explored as it crosses different categories of roads. The assessment of the change of the driver's FC on different categories of road was made in comparison of the three configurations of this route, which were formed by the orders in the intermediate points.

Route No. 1 passes through such points as: Berdychiv, Zhytomyr, Novograd-Volynskyi, Rivne, Dubno, Lutsk. The total length of 482 km and with a drive time of 6 h 9 min. Graphically the route is shown in Fig. 1. The characteristics of the route by segments, according to the categories of roads and their administrative importance are also described (Table 1).



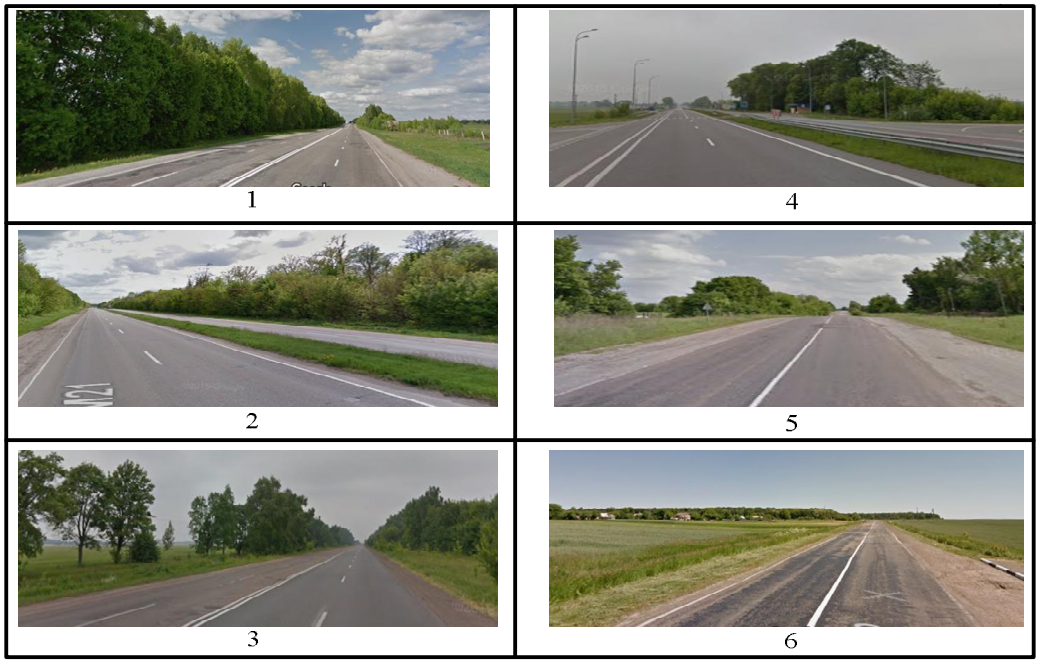


Fig. 1. The investigated route No. 1

Table 1

Characteristics of route No. 1

Starting point	End point	Distance, km	Time, h	Road	Technical category
Vinnytsia	Cordelivka	37.6	0.33	M 21	II
Cordelivka	Mahnivka	25.3	0.18	E583	I
Mahnivka	Zhytomyr	65.8	0.49	M 21	II
Zhytomyr	Rivne	188	2.2	E40	I
Rivne	Lutsk	89	1.13	E40/M19	II
Lutsk	Volodymyr-Volynskyi	75.6	1.8	H22	III

The first route of transportation is the longest, however, it is characterized by rather long sections of roads belonging to the first technical category (213.3 km), the lengths of second and third categories roads are much smaller, accounting for 39.9 and 15.6 % respectively. By analogy with the first one, the characteristics of the other two routes are presented below (Fig. 2–3 and Table 2–3).

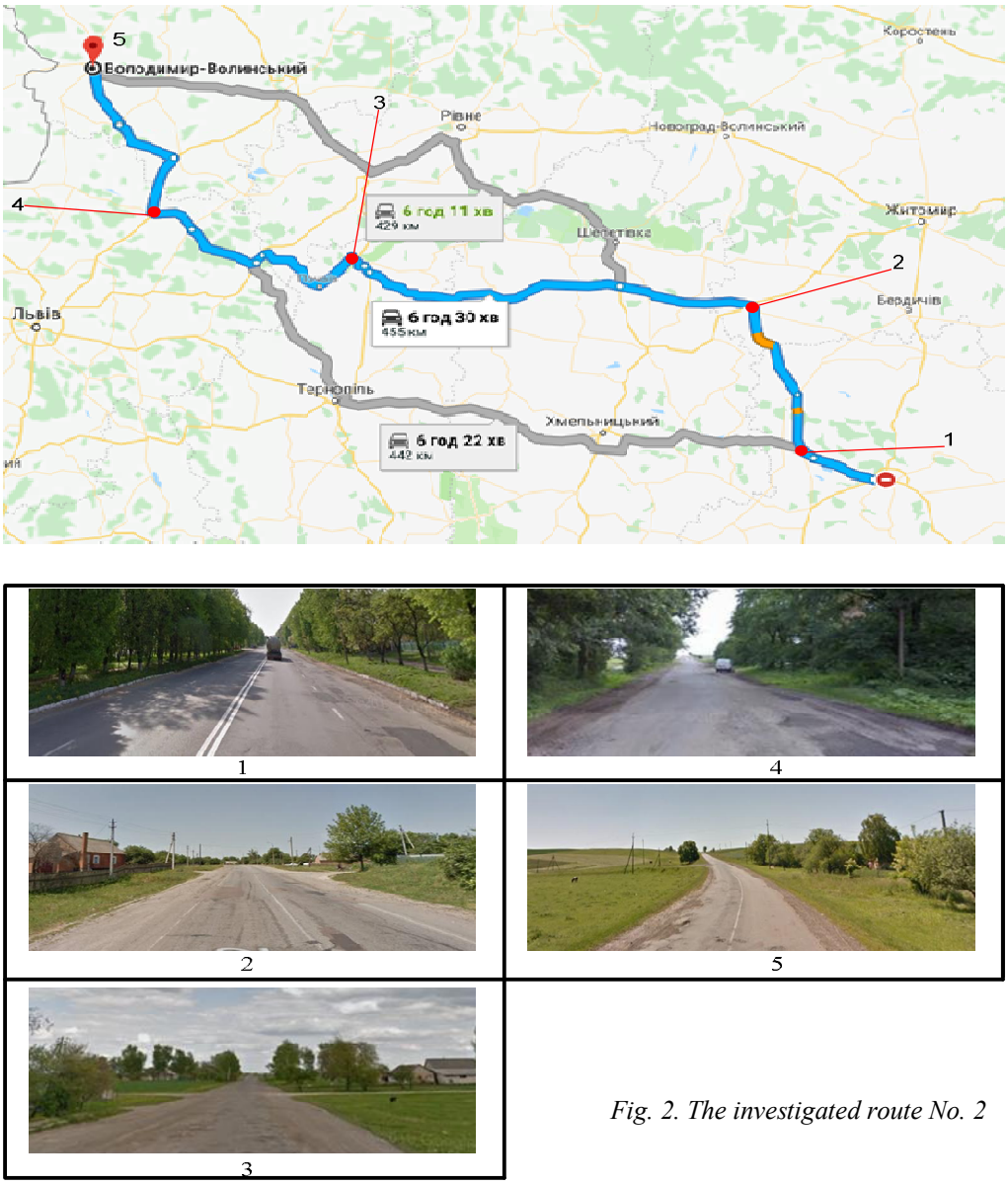


Fig. 2. The investigated route No. 2

Table 2

Characteristics of route No. 2

Starting point	End point	Distance, km	Time, h	Road	Technical category
Vinnytsia	Lityn	31.6	0.32	E50	II
Lityn	Liubar	76.1	1.11	P31	III
Liubar	Kremenets	198	2.58	P32/H03	III
Kremenets	Radehiv	142	1.49	P26	III
Radehiv	Volodymyr-Volynskiy	57.2	0.98	TO302	III

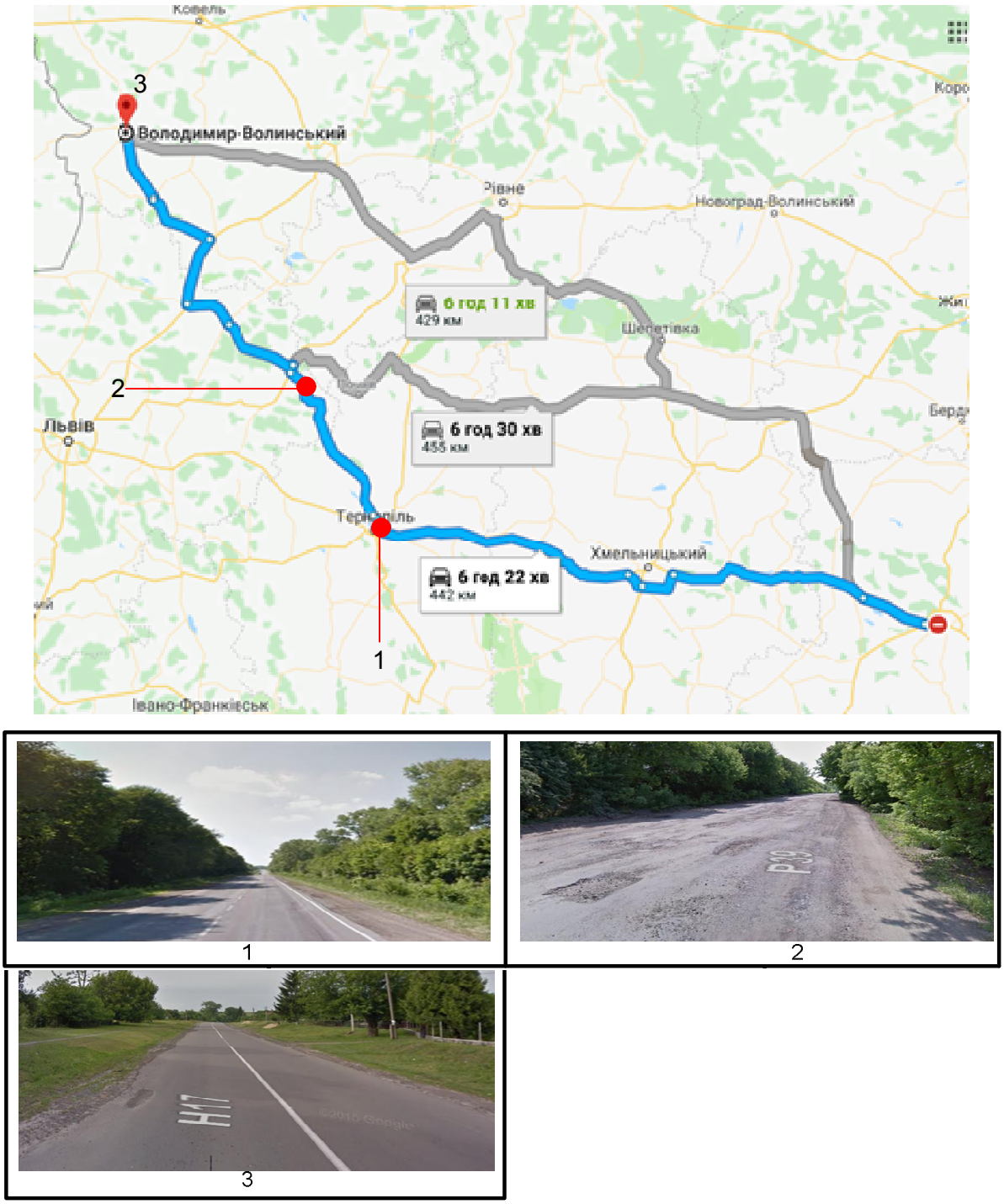


Fig. 3. The investigated route No. 3

Table 3

Characteristics of route No. 3

Starting point	End point	Distance, km	Time, h	Road	Technical category
Vinnitsa	Ternopil	234	3.19	E 50	II
Ternopil	Brody	77.4	1.17	P 39	III
Brody	Volodymyr-Volynskiy	124	2.17	TO302	III

The second route is 30 km shorter, but it ran in worse road conditions, the traffic was mainly carried out by roads of the third technical category (94 % of the total length of the route), a large number of sections of this route had an unsatisfactory road surface, which is typical for lower categories roads.

The third route ran along a road of the second and third technical categories (54 % and 46 % of the total length respectively) with a satisfactory road surface condition (with the exception of a few short sections), but with high traffic intensities.

Routes mostly run along flat terrain with slight differences in altitudes. The categories of roads encountered: from first to third. Because of frequent changes in driving across residential areas and beyond them as well as categories of roads, drivers revealed slight variations in the studied indicators, but there were exceptions.

3. THE RESULTS OF STUDIES DRIVER'S FC

In the framework of this research, stress-index of regulatory systems (SI), which is normally 80–150 c.u, was recorded. This index increases with the deterioration of the FC of the driver and the mode of cardio intervals (Mo), which is normally 650–750 ms and decreases with increasing nervous and emotional tension of the person [15]. Traffic factors such as duration, distance and speed were also taken into account. In order to compare the data for different road categories, the results (Table 4) are displayed for a 100 km long section.

Table 4

The results of studies driver's FC, moving by first road category

L, km	V, km/h	Mo, ms	SI, c.u.	t, h
5	78	655	83	0.06
10	80	687	85	0.13
15	83	680	105	0.19
20	77	722	89	0.25
25	74	749	110	0.32
30	72	728	83	0.39
35	68	744	119	0.46
40	62	701	87	0.54
45	65	704	87	0.62
50	66	664	90	0.70
55	67	692	119	0.77
60	70	702	88	0.84
65	69	672	99	0.91
70	68	690	99	0.99
75	73	693	119	1.06
80	72	703	119	1.13
85	73	742	113	1.19
90	76	692	96	1.26
95	74	715	99	1.33
100	78	705	86	1.39

It is worth noting that, for the correctness of the results, they are given relative to the distance of transportation, which is a multiple of 5 km, and the duration of the movement is variable.

The program Statistica was used to represent the relationship between speed, movement time, mode and voltage index and a correlation matrix was constructed (Table 5).

Table 5

Correlation matrix of the studied indicators, driving first road category

	L, km	V, km/h	Mo, ms	SI, c.u.	t, h
1	2	3	4	5	6
L, km	1.000000	0.142941	-0.180792	0.094266	0.996420
V, km/h	0.142941	1.000000	-0.996420	0.035027	0.061928
Mo, ms	-0.180792	-0.996420	1.000000	-0.064480	-0.089901
SI, c.u.	0.094266	0.035027	-0.064480	1.000000	0.619341
t, h	0.996420	0.061928	-0.089901	0.619341	1.000000

The links between metrics are not tight. The dependence of the change of the voltage index on the time of motion, since the correlation coefficient for these values, in this case, is the largest and is 0.61, is shown in Fig. 4.

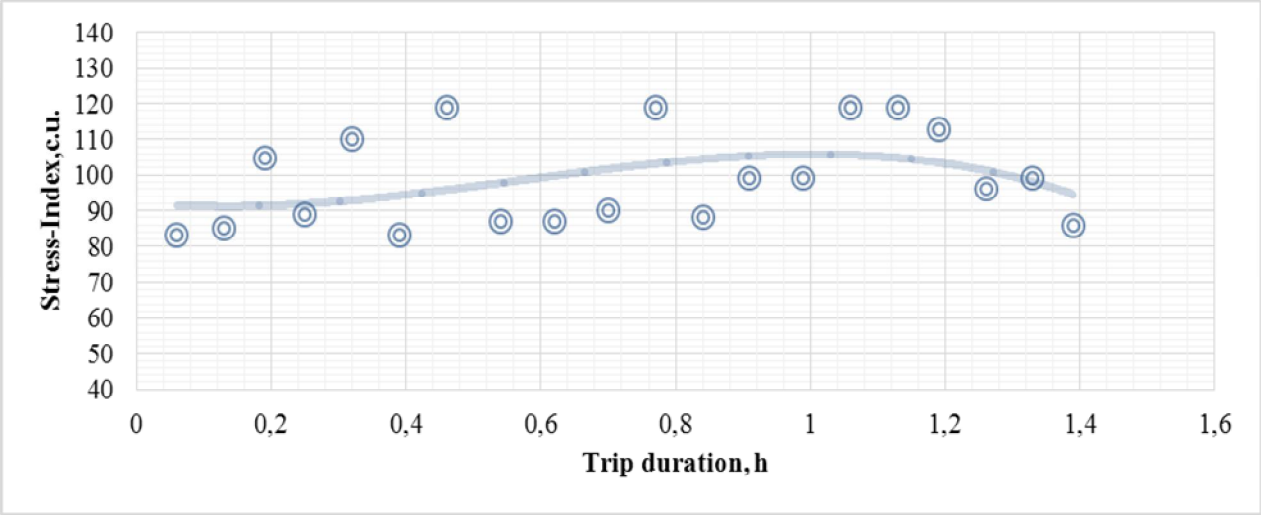


Fig. 4. Dependence of Stress-index change by trip duration on the first category road

The voltage index partially increases with time, but this amplitude is insignificant.

Traffic on the road of the second category differed with the following features:

– fewer lanes;
– absence of dividing strip;
– the smaller width of the roadside;
– smaller radii of curves in plan.

The results of studies of changes in the FC of drivers, when driving expensive second category are presented in Table. 6.

While driving along the second category road, other values of the studied indicators were observed, and a correlation matrix was constructed to represent the relationship between speed, travel time, mode, and voltage index (Table 7).

In this case, there is also no absolute correlation between most metrics. The highest correlation coefficient is observed between the value of fashion and, again, the travel time (0.56). This dependence is shown in Fig. 5.

Table 6

The results of studies driver's FC, moving by second road category

L, km	V, km/h	Mo, ms	SI, c.u.	t, h
5	52	761	122	0.10
10	56	835	182	0.19
15	52	755	129	0.28
20	67	755	176	0.36
25	53	842	174	0.45
30	53	846	103	0.54
35	60	755	195	0.63
40	66	789	168	0.70
45	54	829	184	0.80
50	62	756	176	0.88
55	51	817	173	0.98
60	67	764	161	1.05
65	52	784	140	1.15
70	54	842	114	1.24
75	61	833	169	1.32
80	61	812	173	1.40
85	67	824	183	1.48
90	52	780	197	1.57
95	62	796	103	1.65
100	63	835	137	1.73

Table 7

Correlation matrix of the studied indicators, driving along the second category road

	L, km	V, km/h	Mo, ms	SI, c.u.	t, h
L, km	1.000000	0.291251	0.259990	-0.021117	0.999913
V, km/h	0.291251	1.000000	-0.198206	0.228001	0.283786
Mo, ms	0.259990	-0.198206	1.000000	-0.126343	0.563200
SI, c.u.	-0.021117	0.228001	-0.126343	1.000000	-0.022853
t, h	0.999913	0.283786	0.563200	-0.022853	1.000000

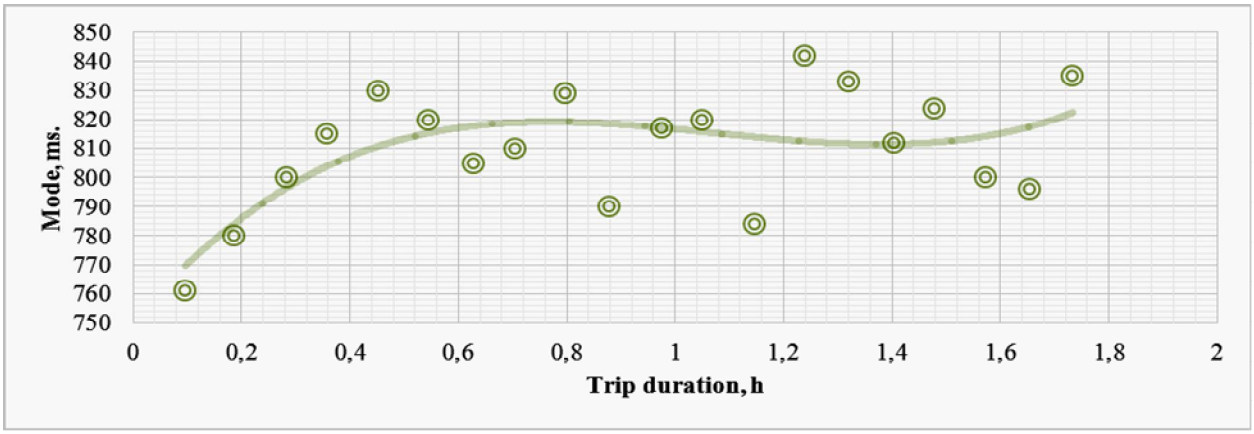


Fig. 5. Dependence of Mode change by trip duration on the second category road

When driving along a second category road, there is a very strong variation in the values of mode, even when comparing the results of previous studies.

Road traffic of the third technical category is the most difficult because there are narrower lanes, more curves in plan and profile than the previous two. Thus, at least lower speeds and higher drivers' FC performance should be expected.

The results of the studies are shown in Table. 8.

Table 8

The results of studies driver's FC, moving by third road category

L, km	V, km/h	Mo, ms	SI, c.u.	t, h
5	47	511	191	0.11
10	41	596	102	0.23
15	45	472	106	0.34
20	35	522	250	0.48
25	53	577	272	0.58
30	48	617	238	0.68
35	43	618	143	0.80
40	35	601	272	0.94
45	40	578	170	1.06
50	35	604	213	1.21
55	42	580	149	1.33
60	53	542	120	1.42
65	51	560	184	1.52
70	54	483	239	1.61
75	43	452	335	1.73
80	41	470	296	1.85
85	47	437	111	1.96
90	53	554	281	2.05
95	55	624	102	2.14
100	45	481	346	2.25

When driving along a third category road, there were clear jumps in some indicators. First of all, it concerns low values of movement velocity and, accordingly, longer travel duration.

The correlation matrix of the obtained values is as follows:

Table 9

Correlation matrix of the studied indicators, driving third category road

	L, km	V, km/h	Mo, ms	SI, c.u.	t, h
L, km	1.000000	0.344514	-0.585752	0.275209	0.999173
V, km/h	0.344514	1.000000	-0.065282	-0.148533	0.329474
Mo, ms	-0.585752	-0.065282	1.000000	-0.270330	-0.281984
SI, c.u.	0.275209	-0.148533	-0.270330	1.000000	0.270866
t, h	0.999173	0.329474	-0.281984	0.270866	1.000000

The highest correlation coefficient is observed between fashion and distance – 0.58, which characterizes fashion for the second time as a more sensitive indicator of driving conditions than a voltage index. Fig. 6 shows the dependence of a pair of fashion values and motion time.

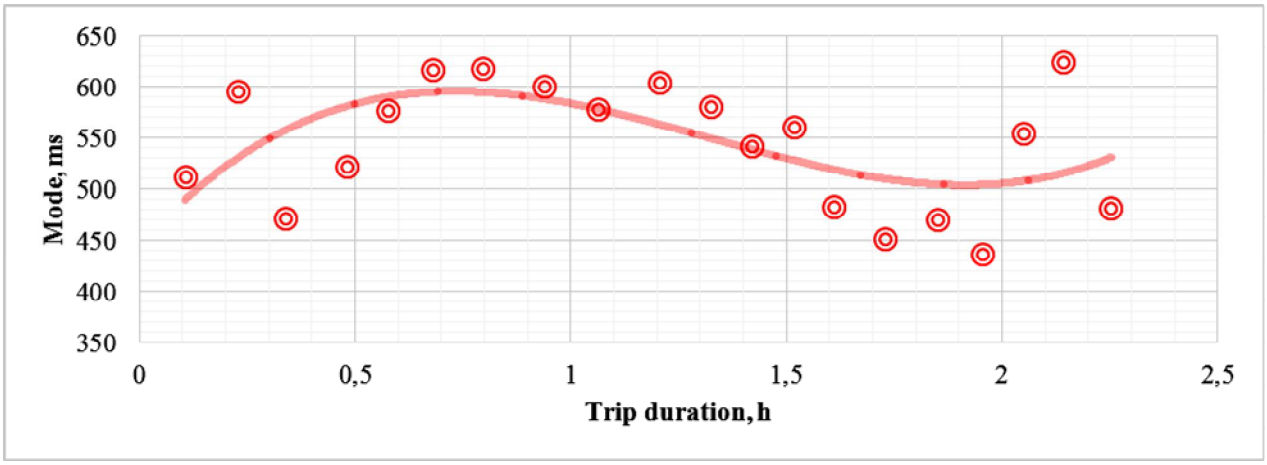


Fig. 6. Dependence of Mode change by trip duration on the third category road

The low values of the correlation coefficients indicate that the obtained dependencies need to be further elaborated by increasing the mass of information. This will be achieved through experiments on other routes to obtain more values and to compare them over longer distances.

Since the correlation coefficients in the three cases are quite small, it is necessary to compare the investigated indicators of the driver's FC by an additional method. It would be better to depict the value of mode on one scale, which will change at certain marks of the traveled distance (Fig. 7).

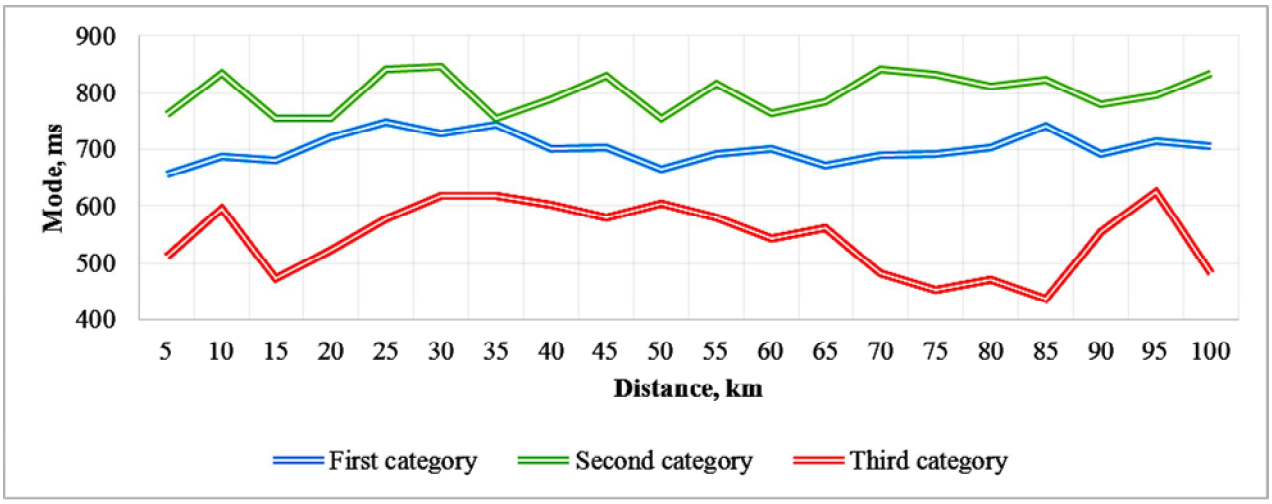


Fig. 7. Changing Mode value by the distance, for different road categories

The results of the studies indicate that when driving along the studied route, under typical road conditions, the driver's FC may vary by 20–25 % depending on the technical category of the highway. There is a clear differentiation of results for first-third road categories. The general trend indicates a deterioration of the FC of drivers, when driving segments of the route that pass the lower categories of highway

4. CONCLUSIONS AND RESEARCH PERSPECTIVES

Studies have shown that there are interrelations between road factors and drivers' FC. This is evidenced by the values of the correlation coefficients between the studied indicators, most of all between the values of fashion, voltage index and time and distance of the trip, which fluctuate within 0.5–0.6. The analysis of the results also showed that the value of the cardio interval mode is the most sensitive to external stimuli and optimally illustrates the change in drivers' FC.

As a result, we can state the following: when driving the motorways of the first and second technical categories, the value of the mode of cardio intervals is within optimal limits. When driving along motorways of the third technical category, the state of the detected neuro-emotional tension of the regulatory systems of drivers is observed – the values of modes lower than 600–500 ms indicate this.

For the development of further studies, it is necessary to carry out a detailed analysis of the traffic situation along the route, namely: to quantify the quality of the road surface, the intensity and the density of traffic. Although the technical category of the road pre-determines certain future driving conditions on it, it is necessary to differentiate the results of the studies in the light of the above factors. This will improve the accuracy of the results obtained.

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