



Research of Changing the Driver's Reaction Time in the Traffic Jam

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Abstract

In this research the main attention is paid to establishing dynamics of changes in the driver's reaction time in a traffic jam that affects traffic safety.

With the help of the regression model, graphs of driver's reaction time are constructed taking into account different age groups and types of the nervous system depending on the initial level of fatigue at the entrance to traffic jam and duration of traffic jam.

Analysis of these graphs allowed us to establish trends in the driver's reaction time in traffic jams, which indicate an increase in the driver's reaction time with an increase in the time spent in the traffic jam. However, at the beginning of the traffic jam, depending on the initial fatigue level, different combinations of the reaction time change occur at the entrance to the traffic jam: at low values, the reaction time increases, and at high values it decreases. It was also found that the traffic jam has a different effect on the reaction time of drivers depending on their temperament. For the reaction time of the driver-phlegmatic traffic jam does not have a significant impact.

Keywords: Fatigue level; functional state; temperament; reaction time; traffic jam;

1. Introduction

Excess of traffic intensity over the capacity of streets and roads leads to uneven distribution of traffic flows, which leads to the formation of traffic jam. The driver, being in such situation, feels an emotional load, which leads to temporary disturbances of some of his psychophysiological functions, including changing the reaction time [1, 2].

The reaction time plays an important role in the activity of the driver, the braking distance of the vehicle depends on it and, in general, the safety of traffic.

Depending on the emotional state, the psycho-physiological parameters of the driver's work are also changing. Negative emotions caused by excessive restriction of driver's freedom of work and unsatisfactory state of traffic organization considerably worsen the performance, reducing the reliability of their activities. The deterioration of drivers' state in the conditions of intense urban traffic and the result of staying in a traffic jam leads to a change in the time of their reaction. The reaction time of the driver plays an important role in the creation of traffic safety and the probability of a traffic accident depends to a large extent on it [3].

2. Literature Survey and Purpose Statement

A lot of researchers were involved in the organization and traffic safety issues. Many of them note that the safety of the movement depends on the driver's condition, as the main link "driver-vehicle-road environment".

One of the most significant factors that have a negative effect on the driver's functional condition is the traffic jam [3].

Such qualities of the driver as the reaction time, driving experience, temperament were considered by the authors of works in their studies [4–7].

The growth of emotional tension leads to a temporary disorder of some of the drivers' mental functions, increasing the time of their reaction [8–17].

The authors [18, 19] determined the reaction time of young and elderly drivers. However, these studies did not fully address the impact of traffic jams.

3. Methodology of Conducting Experimental Researches

Drivers of all ages and categories participated in the experimental researches. Drivers of all age ranges and types of the nervous system were involved in assessing the impact of traffic jams on the reaction time.

The device consisting of a telescopic antenna, a timer, a pointer and a light signal switch off was used for determination of the drivers' reaction time.

At the same time with the measurement of the reaction time, the functional state of the driver and the level of his fatigue were estimated. The analysis of human functioning of the cardiovascular system is a basis of the level of the operator fatigue definition. Moreover, the unevenness of the heart reduction is analyzed.

According to the concept of cardiovascular system as an indicator of adaptive and applied human activity, first of all the analysis of the heart rate rhythm should be considering, that is universal



reaction of the organism, physical or emotional in the response to any load. Information about the level of human activity has been encoded in the sequences of cardio intervals.

The electric cardiogram is a main indicator of the human emotional state under physical and mental stress in psychophysiology [4].

The electric cardiogram is fixed by a portable cardiograph "Cardiosens" with self-contained power supply (Fig. 1).



Fig. 1: Scheme of connection of electrodes for assessing the functional state.

The sequence of cardio intervals of the electric cardiogram is encoded information about processes which happen not in the heart, but in the different level of control system: nervous plexus, pledges of internal secrets, nervous centers which located at the depth of brain tissue. Condition of the mechanisms of regulation may be estimated by the structure of the cardio rhythm

It is integral estimation of the level of the human fatigue. This methodic is based on the theory of direct proportional dependence of uneven cardio intervals and level of fatigue, which in literary sources is often called an indicator of the activity of human regulatory systems.

It is calculated in the conventional units (according to R.M. Baevsky) by a special algorithm that takes into account statistical indicators, histogram parameters and data of the spectral analysis of cardio intervals. The level of fatigue makes it possible to differentiate the various levels of tension of regulatory systems and to evaluate the adaptive body capacity. It is calculated by an algorithm that takes into account five criteria:

1. the total effect of regulation (on indicators of mathematical expectation);
2. the function of automatism (in terms of the mean square deviation, in the variation scale and in the coefficient of variation) ;
3. vegetative homeostasis (according to a set of indicators: variation scale, amplitude of the mode, tension index and regulating systems);
4. stability of regulation (by coefficient of variation);
5. activity of subcutaneous nerve centers (determined on the basis of relative capacities of respiratory waves and waves of the first and second order with the allocation of states of the expressed and moderate enhancement of activity of sub cortical nerve centers).

The values of fatigue level are given in conditional units from 1 to 10. The analysis of fatigue values allows diagnosing the following

- condition of optimal tension of regulatory systems which is necessary to maintain an active body balance with the environment (the norm of 1–2 units by Baevsky);
- condition of moderate tension of regulatory systems when additional functional reserves need to adapt to the environmental body (3–4 units by Baevsky);
- condition of strong tension of regulatory systems, which is conditioned by the active mobilization of protective mechanisms (Ps = 4–6 units by Baevsky);
- condition of strong tension of regulatory systems, which is conditioned by the active mobilization of protective mechanisms (Ps = 4–6 units by Baevsky);
- condition of exhaustion of regulatory systems, where the activity of control mechanisms is reduced and special signs of pathology appear; specific changes clearly prevail over nonspecific (7–8 units by Baevsky);
- condition of "breakdown" of adaptation mechanisms, when the specific pathological deviations dominate and the ability of adaptation mechanisms to self-regulation is partially or completely disturbed (Pc = 8–10 units by Baevsky).

Experimental researches consist in fixing of a drivers electrocardiogram at the entrance to a traffic jam, in a traffic jam and at an exit from it. At the same time, the reaction time of the driver was also measured.

The reaction time of the driver is determined by the moment when a driver touches by a special pointer the corresponding section of a telescopic antenna after the signal is given. At the moment of signaling, a timer would be activated, and then would be stop after the pointer touches the antenna. To ensure a road safety, a convenient moment to determine the reaction time has been chosen by the driver himself.

4. The Results of the Research

4.1 Model of the Impact of the Driver's Condition at the Time of His Reaction

In order to develop a mathematical model of the impact of traffic congestion on the functional state of the driver and his reaction relevant research was carried out.

The developed model is as follows:

$$\Delta T = 0.029 + 0.022 \cdot (F_2 - F_1)^2 \tag{1}$$

Where

ΔT – change of the driver's reaction time, s;

F_2 – fatigue level when leaving the congestion, conventional units by Baevsky;

F_1 – fatigue level at the entrance to the transport congestion, conventional units by Baevsky.

The calculation results of the model parameters are given in Table 1.

Table 1: Characteristics of the model of change of driver's reaction time depending on changes in its functional state after stay in traffic jams.

Parameters	Designation, dimension	The boundaries of measurement	Coefficient	Standard error	Student's criterion	
					Calculated	Tabular
Coefficient	–	–	0.029	0.001	30.6	2.0
Difference between fatigue level when leaving the congestion and at the entrance to congestion, squared	$(F_2 - F_1)^2$, conventional units	0.01–13.69	0.022	0.0001	130.1	2.0

In the developed mathematical model coefficient and the squared difference between F_2 , F_1 at the entrance and exit of the traffic congestion have proven to be influential. The fact of exceeding the calculated value over the tabular one shows their importance.

4.2. Change in the Time of Reaction of Drivers with Different Temperaments in the Traffic Congestion

Individual typological characteristics and temperament of the driver significantly affect his functional state and, therefore, time of his reactions. To carry out studies on the evaluation of influence of traffic congestion on the reaction time, drivers with different temperaments were selected: melancholic, choleric, sanguineous and phlegmatic.

To assess the impact of traffic congestion on the reaction times of drivers of different ages and temperaments regression models have been developed [21].

Figures 2–7 show the results of studies of changes in reaction time of drivers with different temperaments and age in traffic jams.

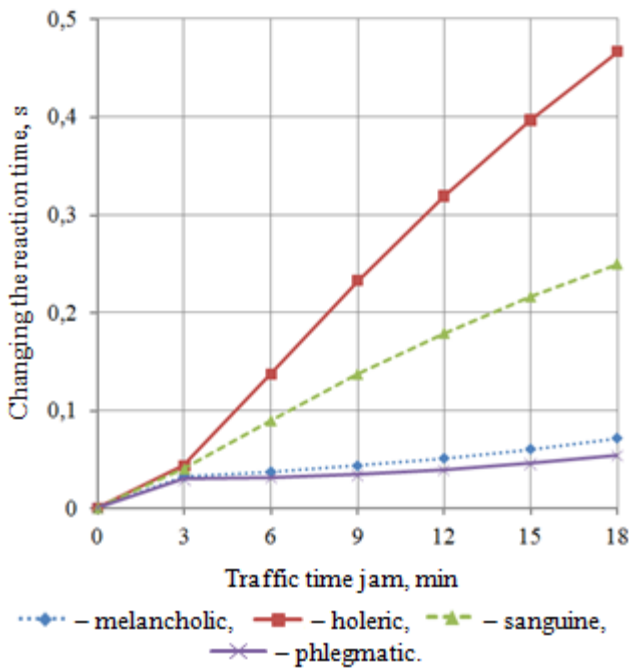


Fig. 2: The dependence of the change of drivers reaction time (aged 30 years) in the traffic congestion where $F_1 = 2$.

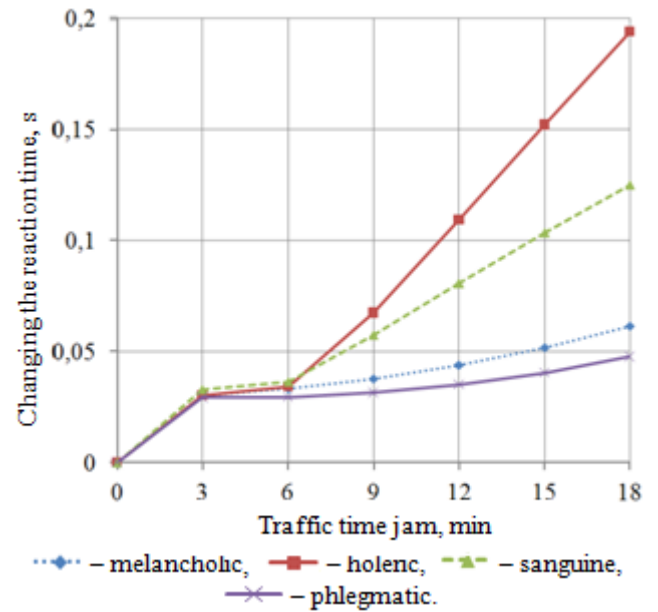


Fig. 3: The dependence of the change of drivers reaction time (aged 30 years) in the traffic congestion where $F_1 = 4$.

As it is seen in Fig. 2, at $F_1 = 2$ points. The reaction time in the transport jam is increased by thirty-year-old drivers of all temperaments. By the end of the transport jam the visually change in reaction time will be as follow: of the choleric driver – 0.47 s, of the sanguineous driver – 0.25 s, of the phlegmatic driver – 0.05 s, and of the melancholic driver – 0.07 s.

At $F_1 = 4$ points. changing of the reaction time of thirty-year-old drivers in a traffic jam are as follow (Fig. 3): drivers of all temperaments, to the third minute of the traffic jam, the reaction time increases slightly, and until the sixth minute it stabilizes. Then the reaction time increases, and change of this time of the choleric driver is 0.2 s, of the sanguineous driver – 0.12 s, of the melancholic driver – 0.06 s and of the phlegmatic driver – 0.05 s.

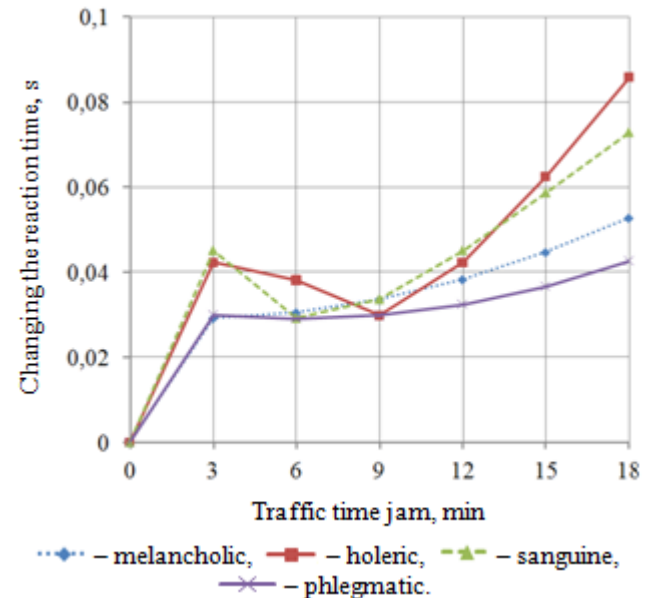


Fig. 4: The dependence of the change of drivers reaction time (aged 30 years) in the traffic congestion where $F_1 = 6$.

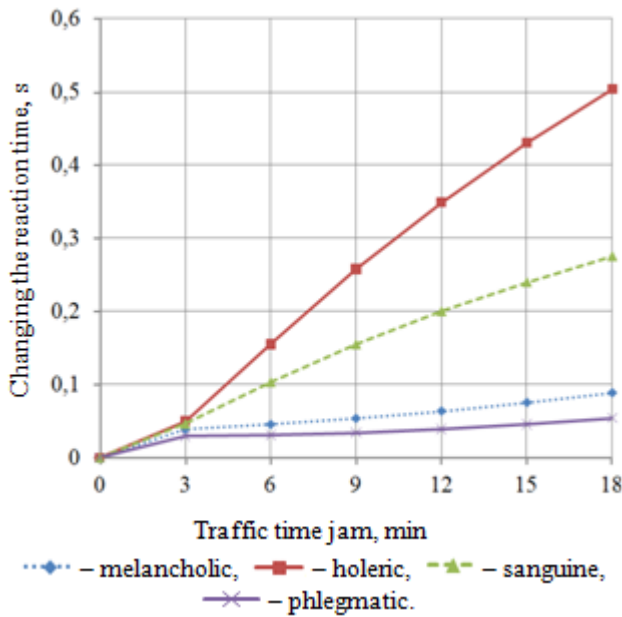


Fig. 5: The dependence of the change of drivers reaction time (aged 50 years) in the traffic congestion where $F_1 = 2$.

At $F_1 = 6$ points. the reaction time of the drivers in the traffic jam to the third minute increases, reaching of the choleric and sanguineous drivers - 0.045 s, of the melancholic and phlegmatic drivers - 0.03 s (Fig. 4).

The reaction time of the sanguineous driver to the sixth minute of the stay in the traffic jam is slightly reduced (by 10–12%), which is observed in the choleric driver until the ninth minute.

Then, the reaction time of drivers increases, reaching in the end of the traffic jam of the choleric driver - 0.09 s, sanguineous - 0.07 s, melancholic - 0.05 s, phlegmatic - 0.04 s.

As it is clear from Fig. 5, when fatigue level is two points, the reaction time in the traffic jam increases of drivers of all temperaments. At the end of the traffic jam change in the time of their reaction will be as follow: of the choleric driver - 0.51 s, of the sanguineous driver - 0.28 s, of the phlegmatic driver - 0.05 s and of the melancholic driver - 0.09 s.

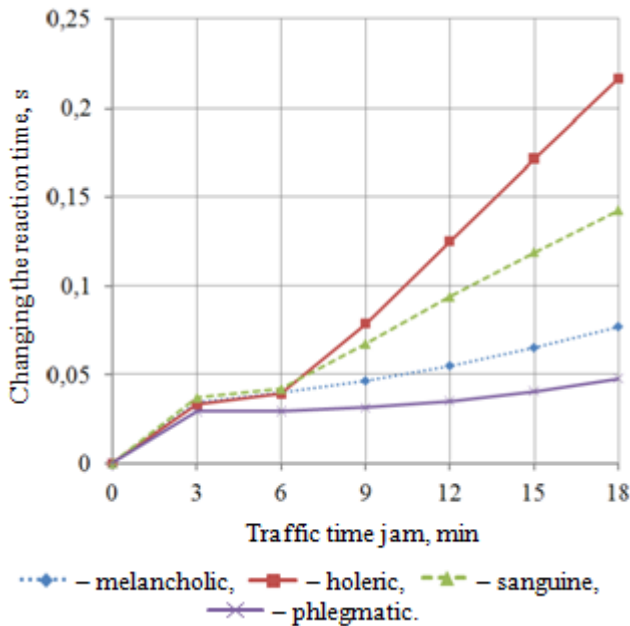


Fig. 6: The dependence of the change of drivers reaction time (aged 50 years) in the traffic congestion where $F_1 = 4$.

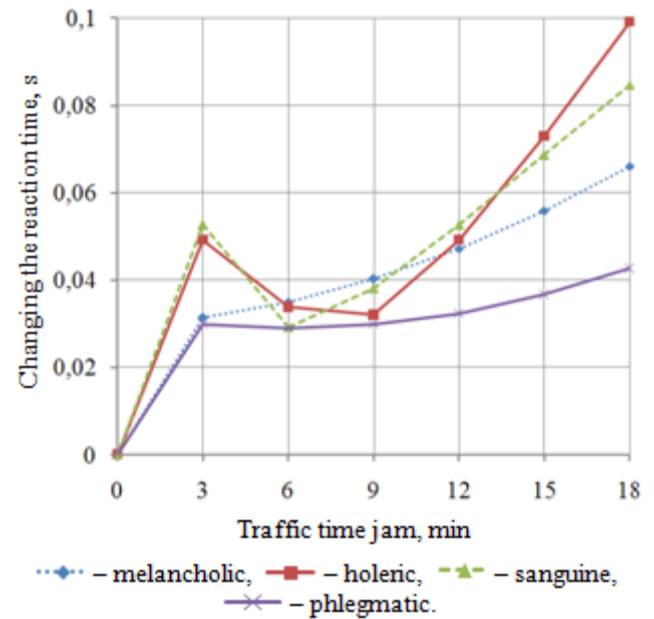


Fig. 7: The dependence of the change of drivers reaction time (aged 50 years) in the traffic congestion where $F_1 = 6$.

At $F_1 = 4$ points. changing of the reaction time of fifty-year-old drivers in the traffic jam will change as follow (Figure 6): drivers of all temperaments until the third minute of the traffic jam the reaction time slightly increases, and until the sixth minute it stabilizes. Then the time of their reaction increases, and change of this time of the choleric driver is 0.22 s, of the sanguineous driver - 0.14 s, of the melancholic driver - 0.08 s and of the phlegmatic driver - 0.05 s.

At $F_1 = 6$ points. (Fig. 7) the reaction time of fifty-year-old drivers in the traffic jam to the third minute increases, reaching the choleric driver and the sanguineous driver - 0.05 s, of the melancholic driver and the phlegmatic driver - 0.03 s. For the sanguineous driver, the reaction time is reduced to six minutes in the traffic jam, and of the choleric driver - up to nine minutes. Then the reaction time of drivers increases, reaching the end of the traffic jam of the choleric driver - 0.09 s, of the sanguineous driver - 0.07 s, of the melancholic driver - 0.05 s and of the phlegmatic driver - 0.04 s.

The reaction time change of thirty-years-old drivers of all temperaments in the traffic jam is showing in Fig. 8–11 in three dimensions.

The change of the reaction time of fifty-year-old drivers of all temperaments in the traffic jam in three dimensions are shown in Fig. 12–15.

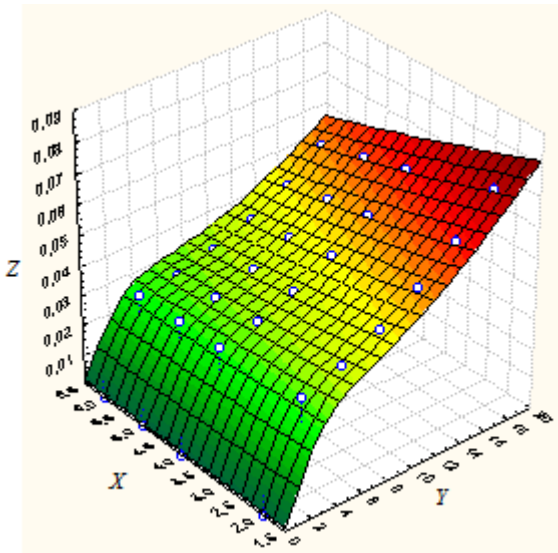


Fig. 8: The dependence of the 30 years old melancholic driver's reaction time changing (Z) is depending on the entry level (X) and the duration of the traffic jam (Y)

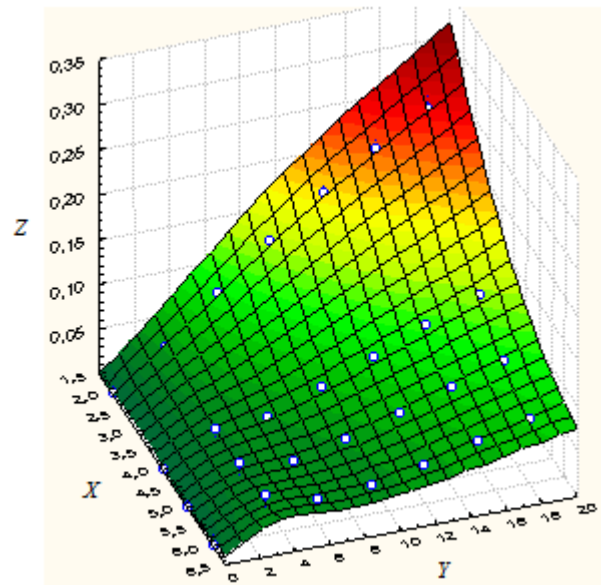


Fig. 10: The dependence of the 30 years old sanguineous driver's reaction time changing (Z) is depending on the entry level (X) and the duration of the traffic jam (Y).

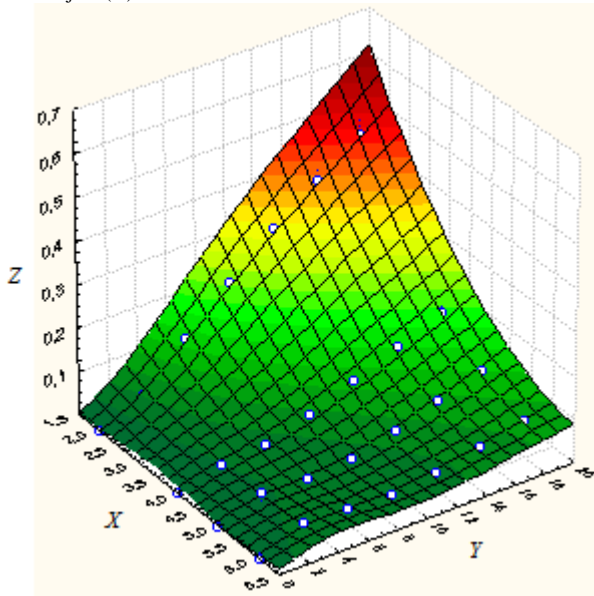


Fig. 9: The dependence of the 30 years old choleric driver's reaction time changing (Z) is depending on the entry level (X) and the duration of the traffic jam (Y).

The reaction time changing of the 30 years old melancholic driver is gradually increasing with increasing the time of staying in the traffic jam regardless of his initial level of fatigue (see Fig. 8). Fig. 9 shows that the value of the initial level of fatigue at the entrance to the traffic jam is the most significant factor which affects the reaction time of the choleric driver in the traffic jam. A similar tendency of the reaction time changing is observed in Fig. 10.

Fig. 11 shows that the reaction time changing of the phlegmatic driver in the transport traffic jam is not significant.

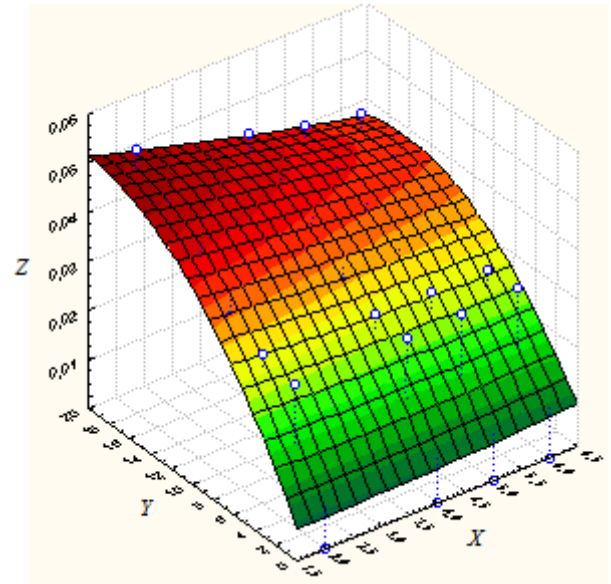


Fig. 11: The dependence of the 30 years old phlegmatic driver's reaction time changing (Z) is depending on the entry level (X) and the duration of the traffic jam (Y).

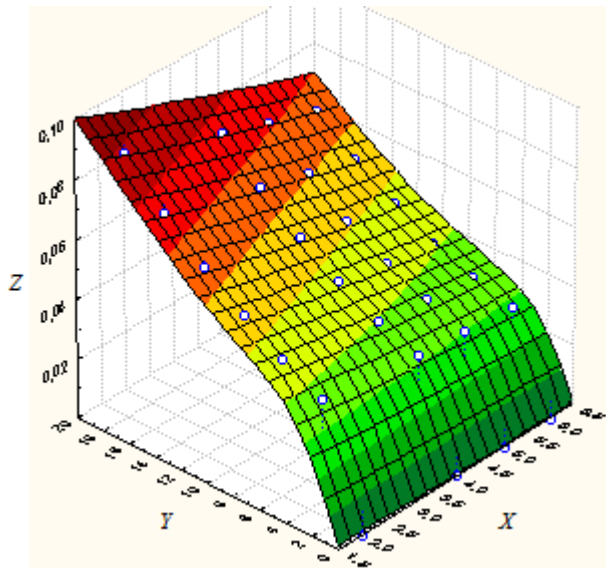


Fig. 12: The dependence of the 50 years old melancholic driver's reaction time changing (Z) is depending on the entry level (X) and the duration of the traffic jam (Y).

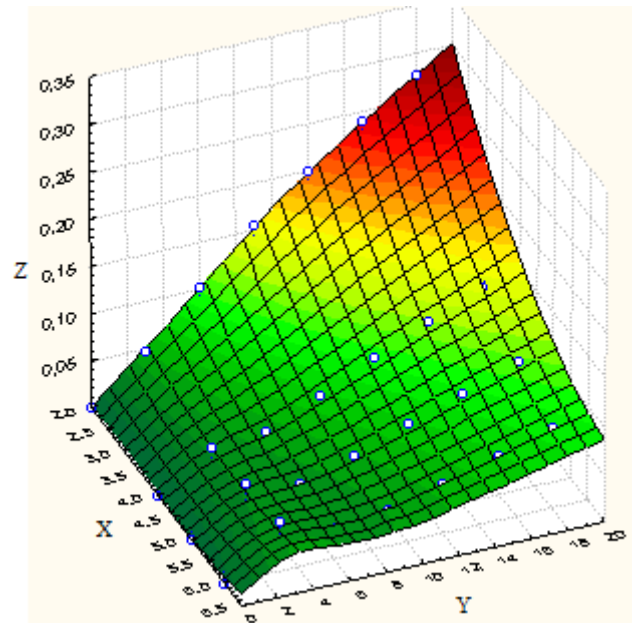


Fig. 14: The dependence of the 50 years old sanguineous driver's reaction time changing (Z) is depending on the entry level (X) and the duration of the traffic jam (Y).

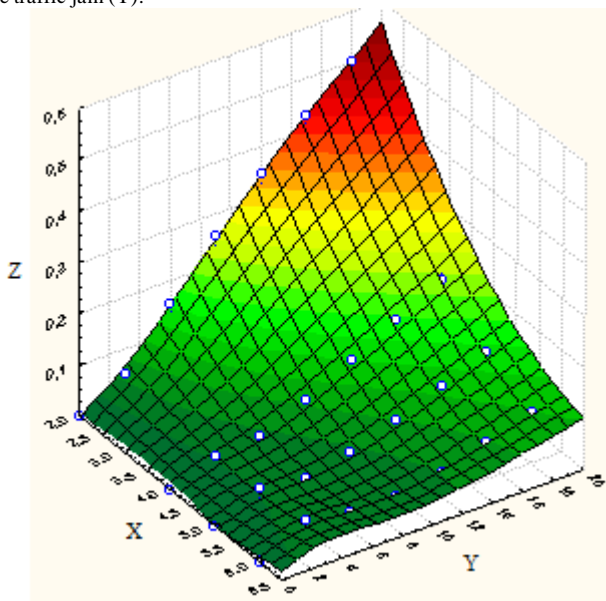


Fig. 13: The dependence of the 50 years old choleric driver's reaction time changing (Z) is depending on the entry level (X) and the duration of the traffic jam (Y).

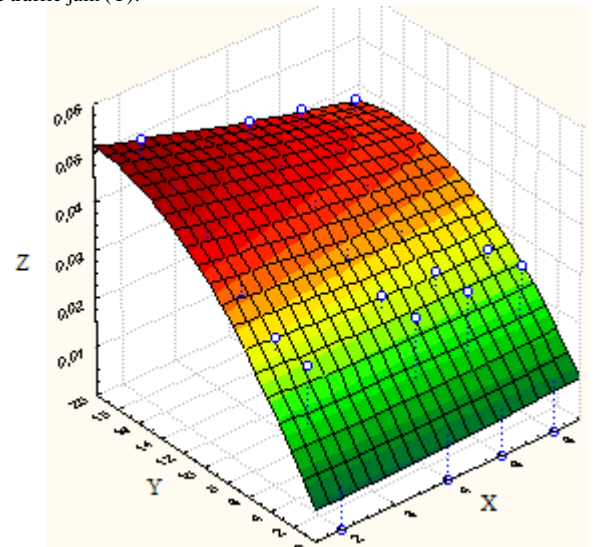


Fig. 15: The dependence of the 50 years old phlegmatic driver's reaction time changing (Z) is depending on the entry level (X) and the duration of the traffic jam (Y).

The tendency of changing the reaction time of 50 years old melancholic driver in Fig. 12 is similar to the reaction time changing in Fig. 11 and gradually increases regardless of the value of the initial level of his fatigue. As it follows from the Fig. 13, the value of the initial level of fatigue at the entrance to the traffic jam is the most significant factor which affects the reaction time of the choleric driver, the same as 30 years old driver, in the traffic jam. With increasing of its value, the reaction time of the choleric driver does not change to the tenth minute of the traffic jam, and then it increases slightly. A similar tendency of the reaction time changing can be seen in Fig. 14. However, at the beginning of the traffic jam the reaction time of the sanguineous driver reduces on its large values.

The reaction time changing of the phlegmatic driver in Fig. 15 is not significant.

5. Conclusion

The changing of drivers' reaction time in the traffic jam depends on their temperament. Drivers react differently to the length of the traffic jams.

With the help of a model influence of the driver's functional state on the time of his reaction it is possible to estimate the reaction time of different ages and temperaments drivers taking into account the traffic jam, when developing and organizing road traffic.

The developed model of traffic jams impact on changing drivers' reaction time has shown that the duration of traffic jams increases the drivers' reaction time with the any type of nervous system directly proportional. Choleric person is the most sensitive, sanguineous person is the least sensitive, melancholic and phlegmatic persons are less sensitive. Driver's age slightly (up to 5%) affects on the reaction time increasing. Moreover, it has been experimentally established that the driver's functional state, which precedes the traffic jam, is significantly affect on the reaction time. So, if during the entrance to the traffic jam the level of fatigue is significant ($X=5-6$), the driver can "rest" from 3 to 9 minutes of the traffic jam. Further, the reaction time increases. It is in varying degrees inherent to drivers of all ages with any type of nervous system.

The regularities of the influence of the traffic jam time and the functional state of the driver in the beginning of the traffic jam on the changing of the reaction time of drivers with different types of the nervous system and age testify to the nonlinearity of these dependences. At the same time, the reaction time changing varies by almost 80–100% among drivers of different types of the nervous system, considering that when applying the above regularities in practice, it is necessary to consider different drivers separately. The received regularities should be taken into account when developing and organizing road traffic.

The purpose of the further studies is identification of regularities of changing drivers' level of fatigue and the probability of road traffic accidents on the sections of the urban transport network after leaving traffic jams.

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