ARPN Journal of Engineering and Applied Sciences

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INFLUENCE OF ELEMENTS OF THE "DRIVER-CAR-ROAD-ENVIRONMENT" SYSTEM ON EMERGENCE OF THE TRANSPORT JAM

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ABSTRACT

The article deals with the traffic intensity indicator as one of the factors influencing the risk of traffic congestion. On transport delays, which, with increasing duration, are transformed into transport congestion, various factors affect the geometric parameters of the road, the mode of operation of traffic lights, the presence of parked cars on the carriageway, the geographical scheme of the road network, traffic accidents, the psychophysiological state of the driver, the level of his professional training and others. The combination of these factors has a significant impact on traffic intensity and throughput of highways. The change in intensity is described by the times of the year, by the days of the week and by the hours of the day. An example of the change in traffic intensity by the seasons on the central part of the Saratov road network in 2016-2017 is given. A model for calculating the risk of traffic congestion at regulated intersections is presented, on the basis of which the dependence of this indicator on the magnitude of traffic intensity is displayed. The results obtained and the physical meaning is compared with the data of the main transport flow diagram. The maximum risk values for each category of traffic conditions are shown taking into account the risk of traffic congestion, the result of which defines the categories of conditions of traffic flow. Based on the obtained data, the average speed of the transport stream is determined, at which its state can be characterized as congestion. As an example, the cartogram of the section of the surveyed street-road network is shown. A description is given of the mutual influence of the psychophysiological characteristics of the driver, road and meteorological conditions on the traffic regime.

Keywords: traffic flow, traffic congestion, traffic intensity, risk, street-road network, "driver-car-road-environment" system.

INTRODUCTION

One of the factors that have the most significant effect on the risk of traffic congestion is traffic intensity. This indicator can be uneven, both in time and in space.

The annual intensity of the traffic flow is variable. It depends on the level of motorization of specific areas, the category of roads, the time of year, time of day and other factors. At the moment, the growth in intensity in Russia is associated with the growth of motorization of the population while maintaining the old street-road network (SRN).

In rural areas, the level of traffic intensity, as a rule, is low and does not exceed 1000 cars/day. On the most part of the street-road network of cities (with the exception of the main thoroughfares), an average traffic intensity of 4,000 cars/day is observed. On the busiest sections of the road network, there is a high traffic intensity - about 10,000 cars/day or more [1, 2].

The intensity of movement by season varies according to the known patterns. On most roads, the highest level of traffic intensity falls on the summer and autumn seasons. The intensity of the movement depends largely on the days of the week. The highest level of traffic intensity is observed on Friday. It reaches 125% of the average daily. The lowest level of traffic intensity falls on Sunday (72%) [3, 4].

With the passage of the day, the magnitude of the traffic intensity also undergoes a change and has, as a rule, one or two maxima on a working day. On the road of the fifth category one maximum corresponds to 12-14 hours of the day. On the roads of the third category there are two maxima corresponding to 10-11 and 18-19 hours of the day. On the roads of the first category, too, two maxima (10-11 and 19-20 hours of the day). The intensity of traffic on the street-road network of cities within a day varies faster, and it depends both on the location of a particular section of the road network, and on the mode of operation of enterprises [5].

Together with the parameters of the traffic flow, the probability of traffic congestion is also affected by the mode of movement of vehicles in particular and the transport stream as a whole, which in turn depends on the psychophysiological state of the driver, road and meteorological conditions [6].

MATERIALS AND METHODS

According to the result of the study of the average hourly traffic flow (morning, afternoon and evening hours) on weekdays at a local site in the central part of the city of Saratov in the winter and summer periods of 2016-2017, it was revealed that in this section of the street-road network, the intensity level movements in summer and winter are approximately the same (Figure-1). This is due to the fact that the main transport hubs and highways of the city pass through the central part of the city.

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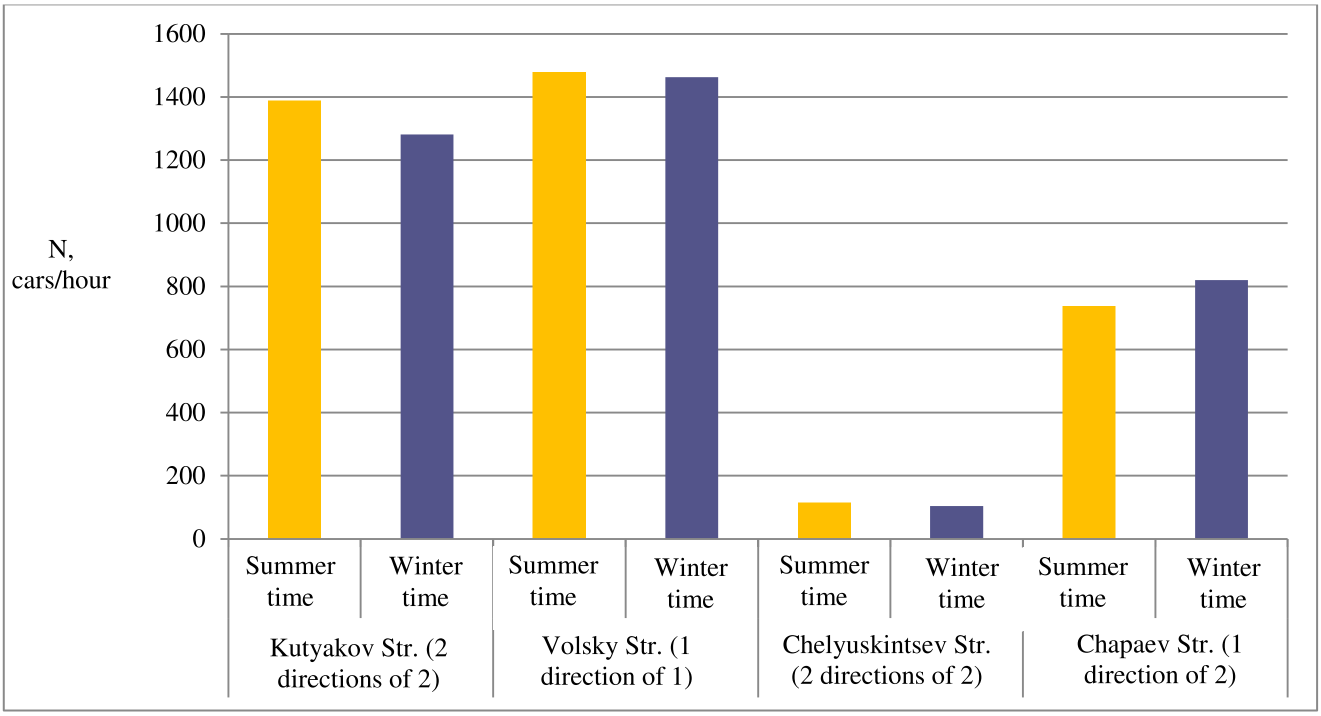

Figure-1. The average hourly traffic flow during weekdays on a local section of the central part of the city of Saratov during the winter and summer periods.

The dependence of the risk of traffic congestion on the traffic intensity on the regulated traffic is calculated as [6, 7, 8, 9, 10, 11, 12]:

$$r_{TJ}(N) = 0.5 - F\left(\frac{d_{cr} - \left(\frac{A}{1-EN} + \frac{B}{\frac{1}{N} - K}\right)}{\sqrt{\sigma^2_{d_{cr}} + \sigma^2_{d_f}}}\right); \qquad (1)$$

Where

r_{TJ} (N) - the risk of transport jam from traffic intensity; d_f - the average value of the calculated or actual value of the transport delay at the regulated intersection at "rush hour", s; d_{cr} - the average value of the limiting (critical) value of the transport delay at the regulated intersection at the "rush hour", at which the probability of the occurrence of the congestion will be 50%, s; $A = \frac{0.9C(1-\lambda)^2}{2}$ - coefficient, depending on the duration of the control cycle and the effective fraction of the green signal, s/auto; $\lambda = \frac{g}{C}$ - the effective fraction of the green signal; $B = \frac{0.9K^2}{2}$ - coefficient that depends on the coefficient determining the ratio of the cycle time to the maximum number of vehicles that have time to leave the intersection in the j-th direction for the effective time of the i-th control phase, s^2/cars^2; $K = \frac{C}{M_S g}$ - coefficient determining the ratio of the cycle time to the maximum number of vehicles that manage to leave the intersection in the j-th direction for the effective time of the i-th control phase, s/cars; $E = \lambda K$ - coefficient that depends on the coefficient determining the ratio of the cycle time to the maximum number of vehicles that manage to leave the intersection in the j-th direction for the effective time of the i-th phase of regulation and the effective fraction of the green signal, s/cars; C - duration of the control cycle, s; g - the effective duration of the green signal, s; M_S - flow of saturation, cars/s; N - intensity of traffic flow arrival, cars/s.

For unregulated intersections, models are used to calculate the actual value of the transport delay at an unregulated intersection at the "rush hour" with its limiting (critical) transport delay at the unregulated intersection at the "peak hour", at which the probability of congestion will be 50%.

RESULTS AND DISCUSSIONS

Based on the result of the study, traffic intensity at regulated intersections in the central part of the city of Saratov (to determine the influence of the speed of the traffic flow on the risk of traffic jams), taking into account the model (1), the influence of the speed of movement on the risk factor was obtained (Figure-2) [6].

VOL. 14, NO. 5, MARCH 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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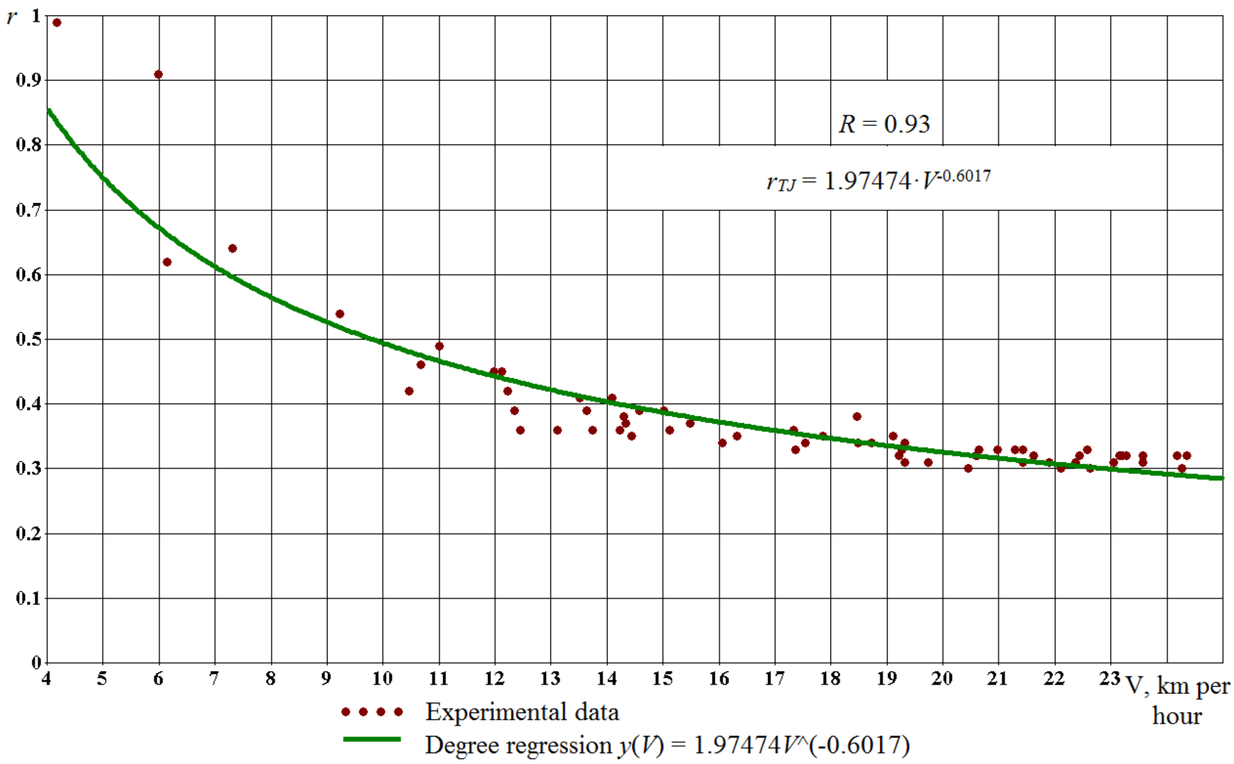

Figure-2. Dependence of the risk of traffic congestion (r_{TJ}) on the traffic intensity of the traffic flow (V) on the Rakhov Street in the opposite direction of the crossing Moscow St.-Rakhov St. on weekdays of the week (with an effective width of the carriageway of 6.5 m).

Thus, judging by the graph of the calculated dependence $r_{TJ}(V)$ according to the formula (1) under identical conditions (Figure-2), the risk of traffic congestion tends to a value of "1" with a decrease in the speed of the traffic flow and a simultaneous increase in traffic intensity (Figure-3) [6], which tends to the maximum level of road capacity, resulting in a density of traffic flow will increase, which does not contradict the main diagram of the transport flow (Figure-4) [2].

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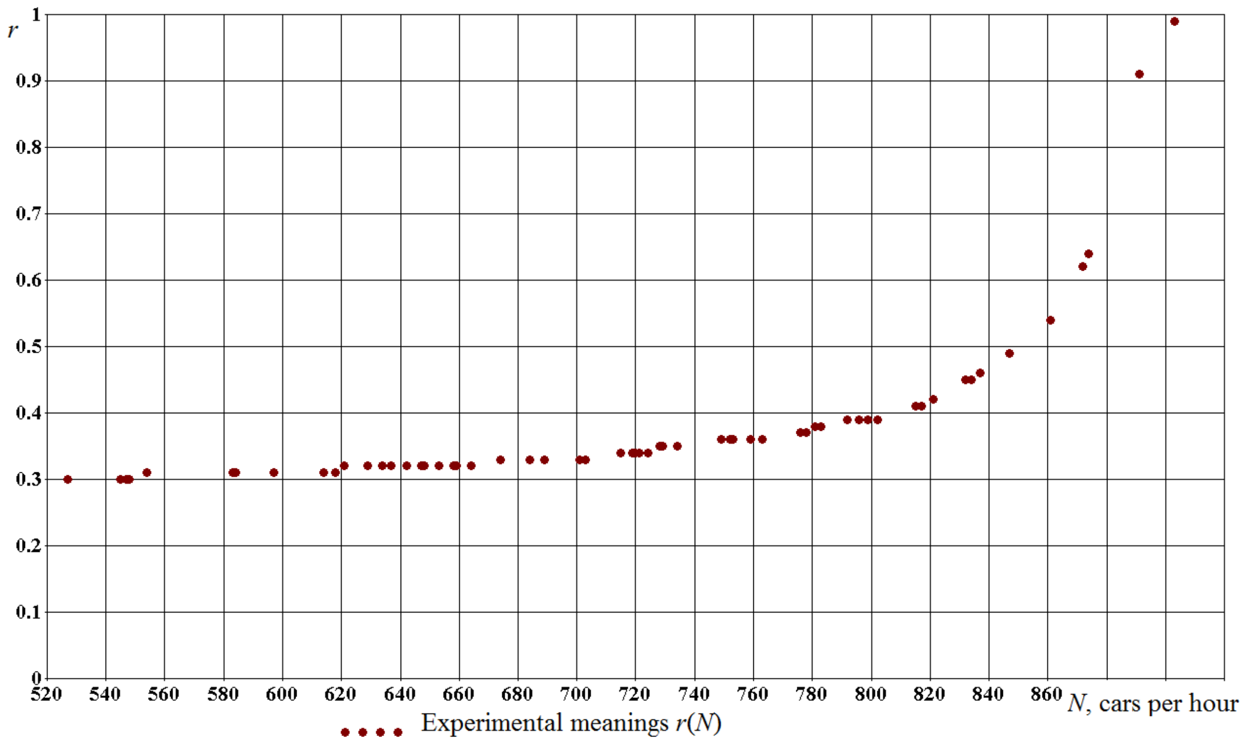

Figure-3. Experimental (calculated) values of the risk of traffic congestion (r_{TJ}) from traffic intensity of traffic flow (N) on the Rakhov Street in the opposite direction of the crossing Moscow St.-Rakhov St. on weekdays of the week (with an effective width of the carriageway of 6.5 m).

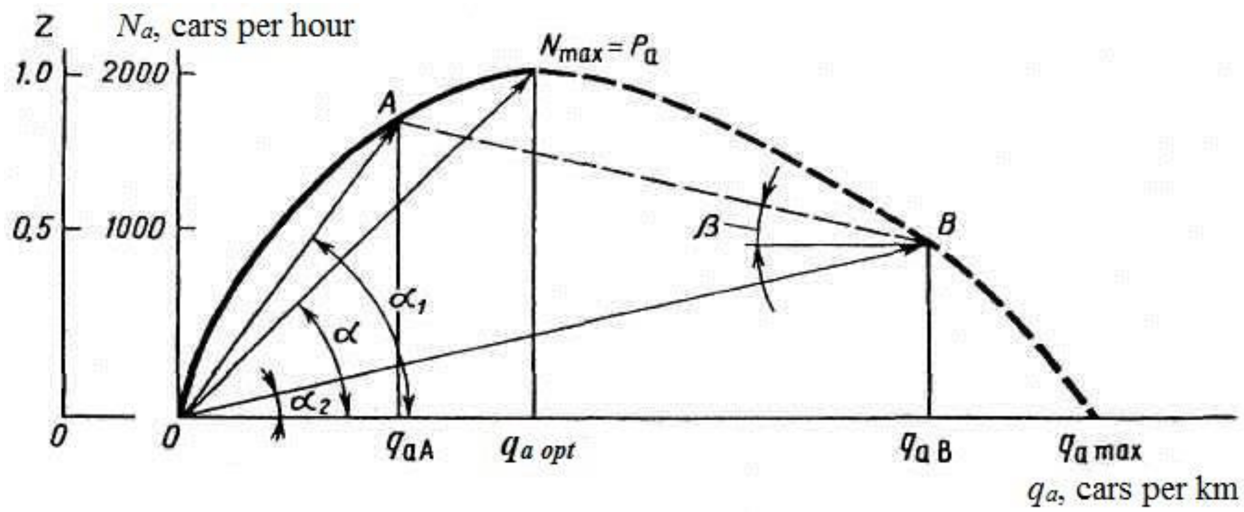

Figure-4. The main diagram of the transport stream: Z - load factor (level).

The reason for this process is a forced reduction in the dynamic dimensions of vehicles [13] as a result of an increase in the flux density on one lane, which in turn forces drivers to reduce traffic from the point of view of traffic safety. In real conditions of the urban environment, such a mechanism operates within the entire direction of movement, regardless of the number of lanes, because on a city street-road network in conditions of a dense traffic flow vehicles evenly move within the limits of the entire effective width of the carriageway of their direction.

For the purpose of carrying out an experimental study of actual transport delays, a SRN site was identified in the central part of the city of Saratov [7].

Taking into account the totality of the approximated dependences $r_{TJ} = f(V)$ obtained under the same conditions, the categories of traffic conditions were identified that take into account the risk of traffic congestion. Each of the categories is limited to a speed interval corresponding to a value of 5 km/h. The limiting risk values are indicated by dots (Figure-5) [14].

VOL. 14, NO. 5, MARCH 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Judging from Figure-5, the state of the traffic flow, which can be characterized as traffic congestion occurs at an average speed of 4.1 km/h. As a result, 7 categories of traffic conditions were identified depending on the speed characteristic of the traffic flow, at which the limiting risk values of the traffic congestion appear at the regulated intersections (Table-1).

Based on the results of the study, a cartogram of the risk of traffic congestion during the peak hours of weekdays of the surveyed SRN site in the central part of the city of Saratov was obtained. Areas identified with the risk of transport jams I and II category [2], that is, above 47% (Figure-6).

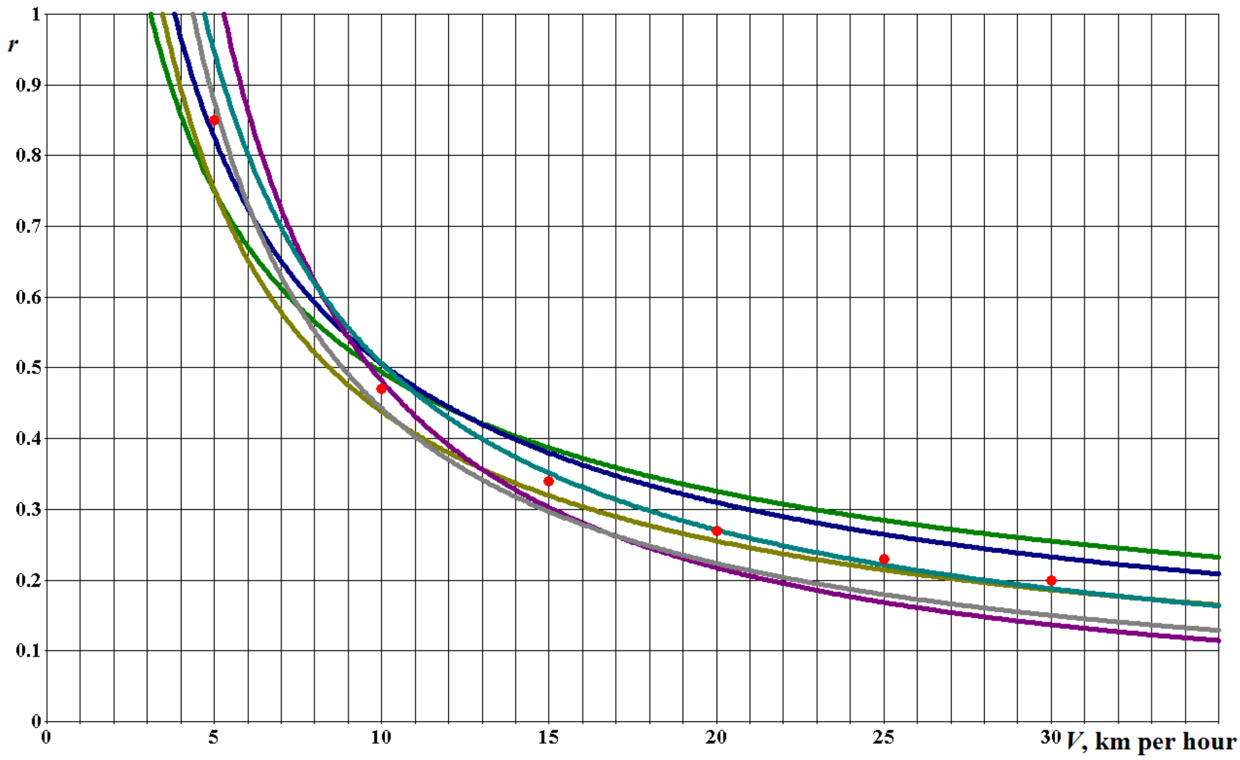

Figure-5. Maximum risk values for each category of traffic conditions, taking into account the risk of traffic jams.

Table-1. Categories of traffic conditions taking into account the risk of traffic congestion.

Category	Speed, km/h	Risk of traffic jam occurrence
I	0-5	0.85-1
II	5-10	0.48-0.85
III	10-15	0.34-0.48
IV	15-20	0.27-0.34
V	20-25	0.23-0.27
VI	25-30	0.19-0.23
VII	> 30	< 0.19

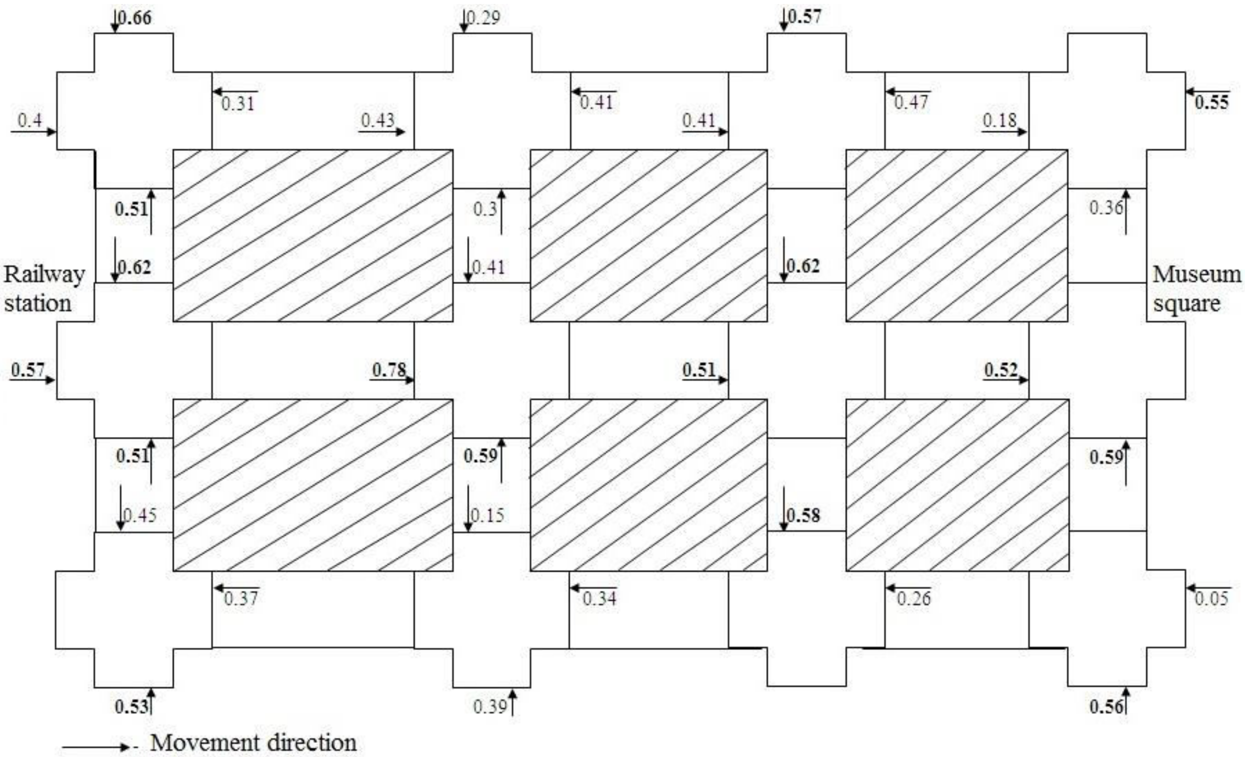

Figure-6. Cartogram of the risk of traffic congestion during the peak hours of weekdays in the surveyed area of SRN.

In addition to the traffic flow parameters, the traffic congestion is also affected by the psychophysiological state of the driver (influenced by road and meteorological conditions), on which the choice of traffic regime depends and the likelihood of road accidents.

There are the following types of loads on the driver: physical, mental, emotional.

Due to the constant improvement in the design of vehicles, the physical stress on the driver is constantly reduced. The driver's work is characterized by the monotony of working movements with insignificant physical exertion (with the exception of trucks and buses) with a forced inactive position. Studies have shown that truck drivers in many cases note unpleasant sensations and pains in the lumbar region and back. Inconvenient planting, as a rule, is the cause of excessive muscle strain and premature fatigue of the driver. Physical fatigue also occurs when driving off-road, snow-covered, slippery and mountain roads, with prolonged driving, especially in difficult road conditions [15].

Mental fatigue is caused by a prolonged movement at high speed or in conditions of intensive traffic flow, the reception of complex traffic information and its processing to make timely and accurate decisions. While driving, the driver must constantly compare this information with such specified parameters as the purpose and direction of the trip, the requirements of the "Traffic Rules", the technical and economic parameters of the car, the accumulated experience and professional skills. Taking into account the analysis of this information, the driver builds his own situational model that meets the current road conditions, and makes a decision that ensures road safety [16].

Emotional fatigue causes hypertrophied positive and negative feelings, outbreaks of vegetative nervous reactions that occur during conflict or emergency situations, when traveling in difficult meteorological conditions, on a slippery, uncomfortable road, when traffic rules are violated by other participants in the movement, euphoria [17].

Under the influence of general fatigue, the sensitivity of the analyzers (sensory organs) decreases in the driver, which in turn leads to a deterioration in night vision and muscular-motor feelings, impaired coordination of movements, the appearance of unnecessary movements, a decrease in the intensity of attention, as well as the speed and accuracy of response motor responses. All this is the cause of an incorrect or belated reaction to the constantly changing road and transport situation.

CONCLUSIONS

In this paper, the greatest attention is paid to the influence of the parameters of the traffic flow and its evaluation on the probability of occurrence of harsh situations. Using the developed model of the risk of traffic congestion, there is an additional possibility of planning a route for the most optimal shortest distance, in which the economic effect will be primarily due to the urgency of delivery. For example, the activities of fire brigades can be cited. The arrival time of fire trucks should not be more than 10 minutes for the urban environment and 20 minutes for the countryside [18]. Based on the research of N.N. Brushlinsky [19, 20], more than three-quarters of those killed in the fires died in the first 5-7 minutes of the fire, mainly due to poisoning by combustion products. Along with this, almost 50% of the material damage accumulates by the time the first fire brigade arrives at the fire site, which on average equals 8-9 minutes. During this time, the first firefighters manage to reach the fire site in approximately 60% of all cases.

The study of the causes and conditions of the traffic jam requires detailed consideration of the mutual influence of the system "Driver-Car-Road-Environment".

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