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Effect of Driver Behaviour on Traffic Jams



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ABSTRACT

Driving in a traffic flow implies involvement in difficult traffic situations that adversely affects response time of a driver, which in turn is considered when estimating stopping distance of a vehicle and determines road safety. This relationship shows the effect of driver behaviour in traffic flow on the road traffic situation.

The objective of the study was to study behavioural factors that influence driver's decisions. The study used methods of driver behaviour modelling, mathematical modelling, experimental studies of the mental and psychological functions of drivers.

Modelling the driver's behaviour, considering various combinations of many behavioural and other factors, leads to a large number of options for mathematical description of driver behaviour, which makes it difficult to use this approach to describe behaviour of drivers under the conditions of a real street-road network.

The research has analysed several works devoted to the study of control action of drivers, using unknown coefficients, describing a model of movement of vehicles considering accuracy of their control. Driving through an unregulated intersection is considered as the most complex and informative version of driver's behaviour. It is found that when modelling a traffic flow, it is necessary to take into account the degree of resoluteness of drivers (through determination of a coefficient of resoluteness which is a random variable that takes into account the probability distribution of the coefficient's value in conjunction with the probability distribution of the function of traffic flow intensity). The distribution of the coefficient of resoluteness of drivers, obtained from experimental data, was subject to analysis.

It is determined that the driving style affects formation of traffic congestion. The assessment of the driving style is made through conditional classification of driver behaviour on the road, namely marked by manifestation of aggression and timidity. When studying the behaviour of timid and aggressive drivers, several pairs of trajectories and the dynamics of the corresponding traffic flow density, were considered and calculated based on Edie's model. It has been confirmed that traffic congestion has the greatest negative effect on choleric drivers and sanguine drivers. Besides, there is a relationship between the response time of a driver and the change in his functional condition.

It is concluded that to improve road safety thanks to a more accurate assessment of possible risks of formation of congestion situations, it is necessary to consider behavioural characteristics and temperaments of the drivers.

Keywords: *road transport, traffic congestion, traffic flow, street-road network, behavioral factors of drivers, driving styles, temperament, determination of drivers, road safety.*

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Background. Drivers are an essential element in traffic flow models (TF). The behavioural factor in the field of decision-making in most cases is determined by traffic conditions in a TF. The decision-making process itself includes an indefinite number of components that depend on driving experience, gender and age of a driver, psychophysiological features of a driver, weather and climate conditions, technical and operational condition of a road, technical condition and dynamic properties of a vehicle, traffic flow indicators, road parameters, etc.

Modelling the driver's behaviour, taking into account various combinations of the variety of these factors, leads to a large number of options for mathematical description of this behaviour, which was analyzed by the authors in the work [1]. This fact makes it impossible to apply a mathematical approach to describing behaviour of drivers on a street-road network (SRN) in the framework of modelling traffic flows in a city where tens of thousands of cars move on roads [2, 3].

«Overcoming such «bottlenecks» in a moving flow as intersections, involvement in difficult traffic situations, traffic jams negatively affect the driver's response time» [4]. The response time of a driver has a significant impact on the braking distance length of a vehicle, especially with regard to emergency braking. All these parameters are included in the dynamic dimensions of a car, which is one of the factors that determine road safety.

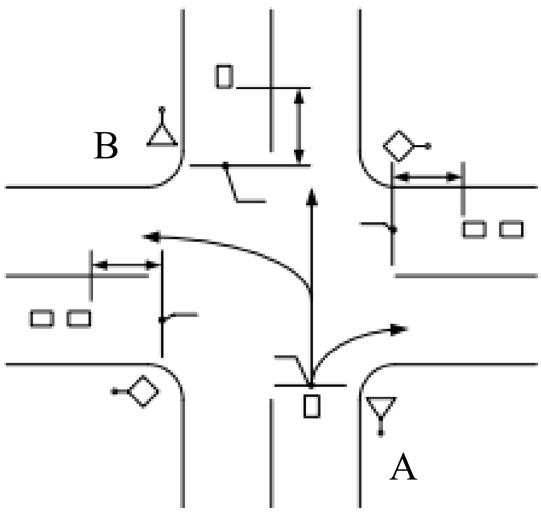
With increasing speed the dynamic dimensions of a car also increase, the reverse state leads to a decrease in transit capacity, and ultimately to formation of traffic congestion due to increase of driver's response time. This relationship shows how the behaviour of drivers in a traffic flow affects the road traffic situation.

Objective. The objective of the study is to determine the influence of various behavioural factors on the actions of the driver of the vehicle, especially on those that cause formation of traffic congestion.

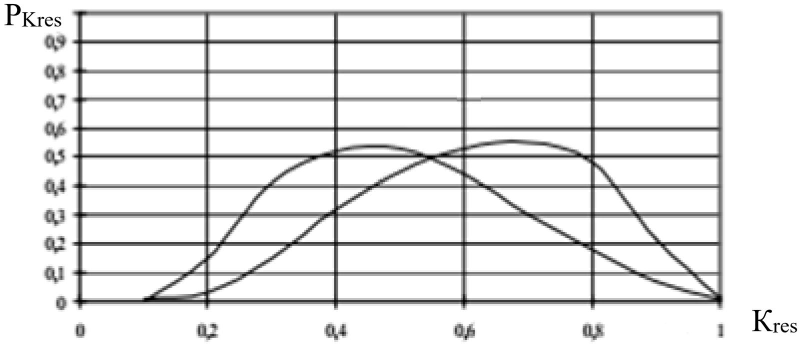
Methods. The authors used general scientific and engineering methods, modelling, experimental studies.

Results. There are many works devoted to the study of the control action of a driver, taking into account various coefficients, which describe vehicle's motion model considering accuracy of its control. This approach has high reliability when analyzing controllability and stability of a car during acceleration (traction mode), braking, and in free-wheeling mode. During simulation of movement of each vehicle in a traffic flow, the above traffic conditions make up a multicomponent model with a dozen unknown coefficients, which are difficult to be used when modelling.

In this regard, for the driver's behavioural factor to be used in traffic flow models, the input information should be simplified, that is, the driver behaviour and decision model can be reduced to *stochastic* transport flow *models* [5].



Pic. 1. Scheme of directions of vehicles at an unregulated intersection.



Pic. 2. The scheme of distribution of the coefficient of resoluteness of drivers.

Stochastic models of transport flow are characterized by a probability that a certain number of cars will pass through a section of the road to which the Poisson distribution applies:

$$P_n(t) = \frac{(t)^n}{n} e^{-t}, \qquad (1)$$

where $P_n(t)$ – probability of transit of the n-th number of vehicles during time t;

λ – distribution parameter (transport flow intensity), car/day;

t – duration of observation segments, sec;

n – number of observed vehicles.

Based on *probability theory*, it is possible to set the probability of making a decision under traffic conditions. The probability distribution of decision making must be determined *experimentally*.

Drivers at an unregulated intersection

The behaviour of drivers when driving through an unregulated intersection will be the most complex and demonstrative (Pic. 1).

«The behaviour of a driver who has approached an intersection on a secondary road, in the case of a right turn, involves a certain margin of time t_{mar}, after which he makes a turn. From the theoretical foundations, the time t_{tt}, necessary to perform a right turn, comprising acceleration to speed of a traffic flow moving in the forward direction, is determined using methods of automotive engineering» [6].

In order to ensure a reserve of response time, drivers, as a rule, overestimate time somewhat, and make decisions about the beginning of a maneuver, subject to:

$t_{mar} > t_{tt}$.

According to the researchers, «the degree of resoluteness of a driver when making a decision can be determined by the following coefficient» [8]:

$$K_{res} = t_{tt}/t_{acttr}, \qquad (2)$$

where $t_{acttr'}$ is actual time redundancy that determines the degree of resoluteness when making a decision, during which a driver must decide on a maneuver.

The change in the coefficient that evaluates resoluteness of drivers can be included in the following range:

$$0 < K_{res} \le 1. \qquad (3)$$

«The probability distribution of K_{res} needs to be obtained experimentally by known methods, for example, by means of photo and video recording of a traffic flow that passes through the intersection under consideration with further statistical processing» [8].

When cars move through an unregulated intersection in the forward direction, a driver must make a decision taking into account time margin:

$$t_{marr} = min(t_{mar}; t_{tt}), \qquad (4)$$

when making a left turn:

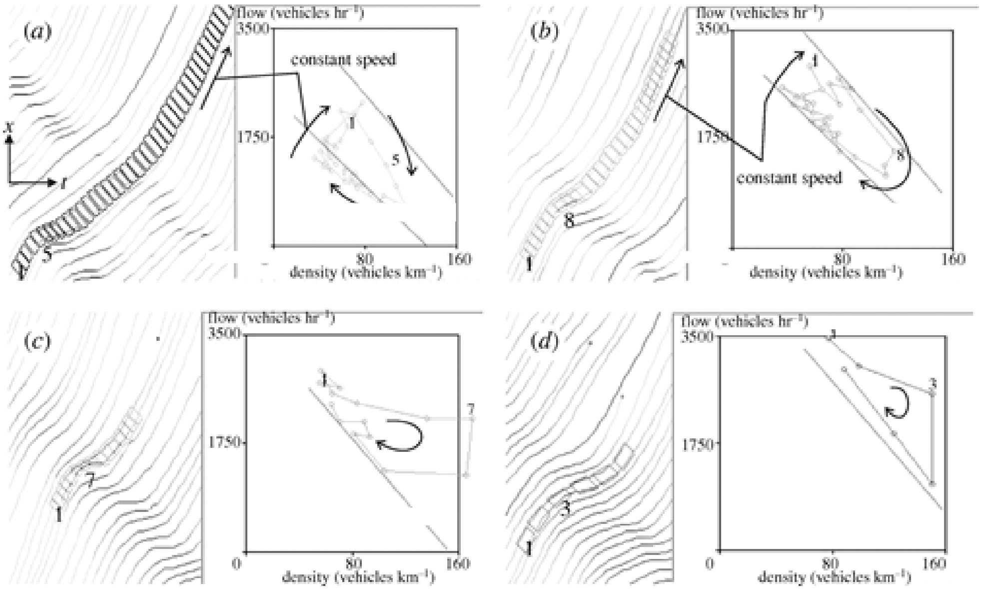
$$t_{marl} = min(t_{mar}; t_{tt}; t_{tr}). \qquad (5)$$

Please note that driver's resoluteness depends on the type of maneuver at the intersection (turning left, right, or driving straight). In this regard, decisive factors must be calculated for each maneuver separately. The distribution of the coefficient of determination of drivers has the form shown in Pic. 2.

«The experimental data on a traffic flow through an unregulated intersection largely depend on parameters of a traffic flow, especially on traffic intensity, the greater is intensity, the more decisively drivers must act» [7].

This can be seen on the curve (Pic. 2) that shows the shift of the distribution curve to the right with increasing traffic intensity. The change in traffic intensity also needs to be analyzed using experimental data.

That is, in the process of modelling the parameters of a traffic flow, it is necessary to take



Pic. 3. The trajectory of cars, the dynamics of density flows:
a), b) – timid drivers; c), d) – aggressive drivers.

into account the behavioural factor of a driver, which can be determined using the «coefficient of resoluteness of drivers». It is a random variable considering the probability distribution of its value in combination with the probability distribution of TF intensity function» [8].

Aggressive and timid drivers

Studies were carried out that determined the dependencies of the risk level of congestion formation, increasing with an increase in the number of agressive drivers who keep close to the vehicle in front and move as fast as possible as compared to timid drivers who keep a great distance and low speed» [10].

To study the behaviour of timid and aggressive drivers Pic. 3 shows several pairs of trajectories and dynamics of the corresponding density of a traffic flow. They are calculated based on the Edies model [11].

For n-cars located in the transport flow inside area *A*, the formula has the following form:

$$k=\sum_{i=1}^{n}\frac{T_i}{|A|},\quad q=\sum_{i=1}^{n}\frac{D_i}{|A|},\quad v=\frac{q}{k}=\frac{\sum_{i=1}^{n}D_i}{\sum_{i=1}^{n}T_i}, \qquad (6)$$

where *k, q* and *v* – density, intensity and speed of the transport flow in the area *A*;

$|A|$ – area *A*;

T_i, D_i – i-th time of movement of the vehicle and the distance traveled within the area *A*.

Each small circle in Pic. 3 corresponds to the flow density within a certain area in the space-time diagram. The unit in the pictures indicates the first dimension, the remaining dimensions are sequentially added and built into the trajectory of motion [11]:

• timid drivers slowed down along the equilibrium branch 1→5*(a)*, and accelerated along the «lower» branch 1→8(*b*), returning to the initial state;

• aggressive drivers slowed down along the «upper» branch 1→7*(c)*, and accelerated along the branch 1→3*(d)*, returning to the equilibrium state.

Soon after such a behaviour of drivers manifests, leading to a nonequilibrium state of the system, speed of vehicles quickly tends to zero, which leads to traffic congestion.

Type of temperament and driver behaviour

«In turn, movement under the conditions of traffic congestion leads to deterioration in the functional condition of a driver due to a temporary distortion of some of his mental and psychological functions» [12].

Given the different types of temperament, drivers behave differently in traffic congestion. «Their functional condition is assessed by analyzing the heart rate and determining the activity index of regulatory systems (according to the method of Professor R. M. Baevsky)» [13].

Studies have found that traffic jams have the greatest negative effect on choleric drivers and sanguine drivers. Traffic congestion does not have a significant effect on drivers of other temperaments.

Experimental studies [14] made it possible to determine an indicator that evaluates the «nature of change in the response time of drivers of different temperaments after leaving a traffic congestion» [15]. The behavior of 100 drivers of a large motor transport enterprise of the city of Saratov during their stay in a traffic jam was analyzed. During the experiment, it was found that for different groups of drivers, the indicator evaluating the nature of the change in the response time of drivers of different temperaments after leaving a traffic jam is different. It was found that it is different for different groups of drivers. For example, the response time of a choleric driver in the first half of the section of the path between the intersections is longer, and in the second section it is less.

This indicates the emergence of hazardous areas in the areas of the transport network [14], where there is a high level of likelihood of traffic jams and traffic accidents.

Brief conclusions. Thus, when optimizing traffic conditions, it is necessary to take into account the behavioral characteristics of drivers and their temperament [16] in order to improve traffic safety by considering risks of congestion situations arising from the fault of drivers.

REFERENCES

1. Baskov, V. N., Rein, A. R. Evaluation of the influence of ergonomic factors on the driver's condition and traffic safety [*Otsenka vliyaniya ergonomiceskikh faktorov n sostoyanie voditelya i bezopasnost' dvizheniya*]. *Nauchnaya mysl'*, 2016, Iss. 3, pp. 102–107.

2. Baranov, Yu. N., Katunin, A. A., Shkrabak, R. V., Braginets, Yu. N. Fundamentals of security in the «man–machine–environment» system [*Osnovy obespecheniya bezopasnosti v sisteme «chelovek–mashina–sreda»*]. *Vestnik NCBZhD*, 2014, Iss. 1, pp. 73–76.

3. Alekminsky, D. E., Kozhin, D. O., Baranov, Yu. N. Factors determining the occurrence of a failure of the «man–machine» system during operation of a vehicle [*Faktory, opredelyayushchie vozniknovenie otkaza sistemy «chelovek–mashina» pri ekspluatatsii transportnogo sredstva*]. *Organization of traffic and safety on the roads of European cities: Proceedings of the international youth scientific practical conference.* Czech Technical University in Prague 2014; UNPK, 2014, pp. 24–27.

4. Gyulev, N. U. On changing response time of a driver due to stay in traffic congestion [*Ob izmenenii vremeni reaktsii voditelya vsedstvie prebyvaniya v transportnom zatore*]. *Bulletin of National Technical University «KhPI»*, 2011, Iss. 2, pp. 117–120.

5. Getsovich, E. M., Lazurik, V. T., Semchenko, N. A., Korol, V. Yu. Empirical-stochastic approach to modeling traffic flows [*Empiriko-stokasticheskiy podkhod k modelirovaniyu transportnykh potokov*]. *Computer Modeling in High Technology: Transport scientific and technical conference with the international participation of Kharkiv National University named after V. N. Karazin*, May 18–21, 2010. Kharkov, 2010, Part 1, pp. 101–104.

6. Umnyashkin, V. A., Filkin, N. M., Muzafarov, R. S. Car Theory: Textbook [*Teoriya avtomobilya: Uchebnik*]. Izhevsk, IzhSTU, 2006, 272 p.

7. Baskov, V. N., Rein, A. R. Influence of operational factors on the psychophysiological state of the driver and his energy consumption [*Vliyanie ekspluatatsionnykh faktorov na psikhofiziologicheskoe sostoyanie voditely i ego energozatraty*]. *Information Technologies and Innovations in Transport Materials of the 2nd International Scientific and Practical Conference.* Ed. by A. N. Novikov, 2016, pp. 139–147.

8. Tryastsin, A. P., Baranov, Yu. N., Lapin, A. P., Katunin, A. A. Theoretical approaches to the strategy of training drivers of vehicles [*Teoreticheskie podkhody k strategii podgotovki voditelei transportnykh sredstv*]. *Mir transporta i tekhnologicheskikh mashin*, 2012, Vol. 2, pp. 123–127.

9. Novikov, A. N., Tryastsin, A. P., Baranov, Yu. N., Samusenko, V. I., Nikitin, A. M. Evaluation of effectiveness of the training system related to traffic safety [*Otsenka effektivnosti funktsionirovaniya sistemy podgotovki kadrov, svyazannykh s obespecheniem bezopasnosti dorozhnogo dvizheniya*]. *Bulletin of Bryansk State Technical University*, 2014, Iss. 4, pp. 188–195.

10. Hennessy, D. A., Wiesenthal, D. L. Gender, Driver Aggression, and Driver Violence: An Applied Evaluation. *Sex Roles*, Vol. 44, No. 11/12, June 2001, pp. 661–676.

11. Laval, J. A., Leclercq, L. A mechanism to describe the formation and propagation of stop-and-go waves in congested freeway traffic. DOI: 10.1098/rsta.2010.0138, Phil. Trans. R. A., 2010, pp. 4519–4541.

12. Efremov, B. D., Overin, Yu. V. Methods for assessing the professional qualities of car drivers [*Metody otsenki professionalnykh kachestv voditelei avtomobilei*]. *Technical and technological problems of service*, 2011, Iss. 16, pp. 95–97.

13. Kramarova, M. I. The role of driver temperament in ensuring traffic safety [*Rol' temperamenta voditelya v obespechenii bezopasnosti dorozhnogo dvizheniya*]. *Technological audit and production reserves*, 2012, Iss. 1, pp. 33–34.

14. Öz, B., Özkan, T., Lajunen, T. An investigation of the relationship between organizational climate and professional drivers' driver behaviours. *Safety Science,* 2010, No. 10, pp. 1484–1489.

15. Kozhin, D. O., Alekminsky, D. E., Evgrashin, V. V., Baranov, Yu. N. Study of factors determining the probability of failure (hazardous action) of motor vehicle drivers [*Issledovanie faktorov, opredelyayushchikh veroyatnost' otkaza (opasnogo deistviya) voditelei avtotransportnykh sredstv*]. *Alternative energy sources in the transport and technological complex: problems and rational use prospects,* 2014, Iss. 1, pp. 235–239.

16. Belonozhko, A. A., Gamayunov, P. P. Implementation of tests determining the psychophysiological characteristics of a novice driver [*Vnedrenie testov, opredelyayushchikh psikhofiziologicheskie osobennosti nachinayushchego voditelya*]. *Scientific and Methodological Electronic Journal «Concept»*, 2015, Iss. 35, pp. 21–25.