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TRAFFIC STREAM STATE QUANTITATIVE ANALYSIS THEORY BASES

Summary. The analysis of existing traffic streams requires a simultaneous account of a considerable quantity of factors characteristic of drivers, vehicles, street and road geometric elements, as well as the environment. For multi-factor analysis we will apply the method of generalizing analysis on the basis of complex variables and dimensionality theory. The methods for obtaining structural relations for various types of tasks of traffic flow conditions in the space of city streets and roads have been developed. The analysis of basic quantitative relations in time form, and also taking into account traffic stream state change under the influence of traffic density increase as a growing probability of road traffic accidents occurrence, and sluggishness at road traffic conditions, improvement has been carried out.

ОСНОВЫ ТЕОРИИ КОЛИЧЕСТВЕННОГО АНАЛИЗА СОСТОЯНИЯ ТРАНСПОРТНОГО ПОТОКА

Аннотация. Анализ состояния существующих транспортных потоков требует одновременного учета значительного количества факторов присущих водителям, автомобилям, геометрическим элементам улиц и дорог, а так же окружающей среде. Для многофакторного анализа применим метод обобщенного анализа на основе теории размерностей и комплексных переменных. Разработаны методы получений структурных соотношений для различных типов задач состояний транспортных потоков в пространстве городских улиц и дорог. Выполнен анализ основных количественных соотношений во временной форме, а также с учетом изменения состояний транспортных потоков под влиянием увеличения напряженности как возрастающей вероятности возникновения дорожно-транспортных происшествий, и инерционности при улучшении условий движения.

An effective application of positions of transport stream conditions theory in practical purposes becomes possible only in that case when theoretical representations get a concrete and exact character in the quantitative form. Thus, completeness of the quantitative information, sufficient for technical appendices, will be reached, when each of the values essential for the transportation process are defined as the function of arguments, characterizing transportation process movement. In the overwhelming majority of cases the attempt in practice to find the analytical decision in problems of movement organization and designing of roads and streets encounters on considerable, and sometimes insuperable difficulties caused by the complexity of transportation process and mathematical process bulkiness. Effective application of positions of the transport stream theory of conditions in the practical purposes becomes possible only in that case when theoretical representations get concrete and exact character in the quantitative form. Thus, completeness of the quantitative information, sufficient for technical appendices, will be reached when each of the values essential for the transport process is defined as the function of arguments characterizing the movement of the transport process. In the overwhelming majority of cases the attempt in practice to find the analytical decision in problems of traffic organization and designing of roads and streets encounters on considerable, and sometimes insuperable difficulties caused by the complexity of the transport process and bulkiness of the mathematical apparatus. Therefore results which at the best have the character of approached estimation, in the worst-are wrong in essence and consequently are the reason of deep errors. The isolated private experimental dependences connecting with each other separate variables (intensity-speed, intensity quantity of road and transport incidents, speed-intervals etc.), are not united by the general equation and cannot lead to a full and distinct picture.

The experience of the given method application for an estimation of conditions of a transport stream are not reflected in the publications.

Numerical methods can be essentially strengthened by means of other means of research based on the analysis of the physical mechanism of a transport stream and leading to the important parities which do not manage to be received in other ways. As the experience shows, synthesis of these parities and data of the numerical decision or experiment appears extremely fruitful [1-6].For the definition of quantitative parities we will replace usual variables of the transport stream by complex type values which are made of the same variables, but in certain combinations, depending on the transport stream nature. Complex variables, according to [1-2], are generalized variables and are defined on the basis of the dimensions theory or the method of generalized analysis. This method is based on consecutive application of dimensionless sizes-criteria of similarity and relative variables.

The criteria of parametrical type, representing simple relations of parameters with the same name, and the criteria of complex type uniting in diverse parameters. Relative variables represent private from division of variables into constant parameters.

On the specified basis we will define generalized criteria Z_r which will be used further both as parameters, and as transport stream variables, presenting them as the product of various degrees of dimensionless values. Thus, as the basic units of the transport stream measure we will accept fundamental measuring instruments:

The-car [*A*], that is what its geometrical and dynamic parameters are generalized by;

-Extent [*L*], (meters, km) roads, the vehicle, dynamic dimension, road cross-section etc.;

-Time [*T*], (second, hour).

Dimension of any size will be expressed through the basic units of measure, i.e.

$$[p_i] = [L][A][T] \quad \mathrm{i} = 1, 2, \ldots, \mathrm{n}\,. \tag{1}$$

The less the number of parameters defining the studied size in the transport stream is, the more limited the form of functional dependence is, hence, it will be easier to conduct the research.

A number of problems of the transport stream with view of establishment of generalized criteria characterizing the transport process condition have been considered.

As it was specified above, for the decision of transport problems in the quantitative form consecutive application of dimensionless values is required, that is criteria of similarity and relative variables. Thus, "the problem decision is represented in the form of equations in dimensionless sizes by which required relative variables are defined as unequivocal functions of independent relative variables and similarity criteria playing the role of constant parameters" [1]. Hence, the general type of the equation will be

$$\mathrm{Y} = \mathrm{f}\,(\mathrm{x}_1, \mathrm{x}_2, \ldots, \mathrm{z}_1, \mathrm{z}_2, \ldots, \mathrm{Z}_1, \mathrm{Z}_2 \ldots), \tag{2}$$

where: *Y* - required variable of the transport stream; *x* - independent variable; z - complex type criteria; Z - parametrical type criteria.

The kind of function (2) in final expression is not defined. The greatest completeness of knowledge of transport stream movement process at quantitative research will be reached when distributions of variables are found in space and in time. Set of instant values, continuously distributed in space, in Physics is accepted to be referred to as the field [1].

Let's consider a number of consistently becoming complicated problems of vehicles movement in a transport stream and the stream itself. We will reveal at the beginning the process of vehicle dynamic dimension change (accordingly and distances) in a transport stream because of cars affinity on driveway spatial axis. The sizes of dynamic dimension *S* we will define by the following values:

V - vehicle speed, km/h; km/s; *Q* - stream density, aut/km: aut/m;*x* - lane site extent, km/h; m/sec;
a - vehicle acceleration, km/h;m/sec; *N* - stream intensity, aut/h; aut/sec; or by formula:

$$S = f(x, V, Q, N, a)\,. \tag{3}$$

It is quite clear that analytically obtaining of a kind of dependence (3) is inconvenient, experimental definition is extremely labor-consuming, as it is required to define the connection between the six values. However, passing to criteria, instead of *к* = 6 values, we will obtain n-m = 6-3 = 3 criteria. To find communication between the three values is much easier. Let's accept as core independent values *x*, *V*, *a*.

Let's find the required criteria:

$$z_2 = \frac{N}{VQ},\ Z_1 = SQ,\ z_3 = \frac{xa}{V^2}\,. \tag{4}$$

Whence for a dynamic dimension it is possible to write:

$$S = \frac{1}{Q} f\left(\frac{N}{VQ}, \frac{xa}{V^2}\right)\,. \tag{5}$$

Let's analyze the obtained criteria (5) under condition when they are constant.

From the first criterion Z_1 it is visible that the dynamic dimension of vehicles in a stream depends in inverse proportion only on the density of the transport stream Q ($S=Q^{-1}$).This is a criterion of parametrical type; it is widely used in applied calculations. The second criterion - $\mathbf{z}_2$ specifies that to increase the sizes of intensity *N* of a transport stream on a lane site is possible either with reduction of stream speed *V*, or with distance reduction between vehicles, i.e. increasing the stream density. The criterion $\mathbf{z}_2$ characterizes the relation measure between the intensity of a stream and throughput possibility of a site. In practical calculations this criterion, as the relation $\frac{N}{N_{\max}}$, is applied for road level of loading estimation and level of movement convenience. That's why the criterion $\mathbf{z}_2$ is a generalized criterion used for the assessment of the transportation process and considers the road condition influence on speed movement reduction. In the transport theory the parity $\mathbf{z}_2$ is the generalized criterion for transport process estimation and considers the influence of roads condition on reduction of speed movement. The criterion $\mathbf{z}_3$ characterizes the relative (in comparison with inertial) size of vehicle dynamic possibilities and consequently it is essential when the vehicle moves in a stream with frequent overtaking and sharp accelerations. It considers the noise of accelerations.

From the requirement of criterion $\mathbf{z}_3$ constancy follows that high-speed possibilities of the car xa should be more than the speed of transport stream V_i. The criterion $\mathbf{z}_3$ considers the transport stream influence on the speed of vehicle movement in the stream, besides, it specifies that the quantitative value of the transport stream speed essentially depends on the site length on which this speed is defined that is not always considered in experimental supervision.

By consideration of the transport stream process of movement through the road section and "stop" line transport stream parameters and variables at movement through the road section will be:

N - intensity aut/h; *B* - driveway width in section, m; *b* - lane width, m; *Q* - stream density, aut/km; *V* - speed of movement, km/h.

The change of transport stream intensity is function of:

$$N = f(B, b, Q, V)\,. \qquad (6)$$

Let's accept for basic units *B*, *V*, *Q*, where the criteria are:

$$z_1 = z_2 = \frac{N}{QV},\ Z = Z_4 = \frac{b}{B}\ . \qquad (7)$$

In the considered case similarity criterion **п**$_1$ has been defined by us earlier. Its generality has also been specified. Similarity criterion Z_4 characterizes the use of the driveway by the transport stream according to the road width and is, at constant sizes of the lane and driveway width, parametrical number. For a lane in width of 3,5 m Z_4 is within the limits of 0,714-0,73, for a lane of 3,75 m = 0,68-0,594.

For fuller characteristic of transport stream movement condition we will define possible criteria at estimation of movement condition in space and time. We will characterize the transport stream by all the above obtained parameters and variables. Such approach will allow obtaining the greatest version of quantitative parities.

Let's consider:

-Lane extent x, km; $[L]$;
-Time of movement T, hour; $[T]$;
-Stream speed V, km/h $[L]\,[T]^{-1}$;
-Stream density Q, aut/km; $[A]\,[L]^{-1}$;
-Stream quantity q, aut; $[A]$;
-Intensity N, aut/h; $[A]\,[T]^{-1}$;
-Stream capacity M, aut. km/h; $[A]\,[T^2]\,[L]$;
-Quantity of movement D, aut.km; $[A]\,[L]$;
-Stream Work H, aut.km/h; $[A]\,[L]\,[T]^{-1}$;
-Dynamic dimension S, km/aut, $[L]\,[A]^{-1}$;
-Stream inertia J, aut.h/km, $[A]\,[T]\,[L]^{-1}$;
-Intensity of movement C, km.h/aut, $[L]\,[T]\,[A]^{-1}$;
-Dimensional length of the vehicle la, m, $[L]$;
-Vehicle acceleration a, m/s, $[L]\,[T]^{-2}$.

Now the intensity of the transport stream on one traffic lane will be defined as the function of the above-stated values:

$$N = f(x, T, V, Q, q, M, D, H, S, J, C, l_a, a)\,. \qquad (8)$$

From the specified 14 values we will obtain n - m of various criteria. As m = 3, the number of criteria will be 14 – 3 = 11. As basic units we accept extent *x*, speed *V* and stream quantity *q*. Generalizing, we will define the intensity in spatial representation:

$$N = \frac{qV}{x} f\left(\frac{TV}{x}, \frac{Qx}{q}, \frac{Mx}{qV^2}, \frac{D}{qx}, \frac{H}{qV}, \frac{Sq}{x}, \frac{JV}{q}, \frac{CqV}{x^2}, \frac{ax}{V^2}, \frac{l_a}{x} \right). \tag{9}$$

In time representation instead of base parameters *x* it is necessary to accept time *T*, therefore a number of criteria will change. Then:

$$N = \frac{q}{T} f\left(\frac{x}{TV}, \frac{QVT}{q}, \frac{MT}{qV}, \frac{D}{qVT}, \frac{H}{qV}, \frac{Sq}{VT}, \frac{JV}{q}, \frac{Cq}{VT^2}, \frac{aT}{V}, \frac{l_a}{VT} \right). \tag{10}$$

Apparently from the equations (9) and (10), all the relations standing in the right part, represent complex and parametrical criteria.

The doubtless scientific and practical interest has the analysis of the obtained quantitative parities itself, as there is a possibility to consider from the quantitative aspect the transport stream movement condition on various sites of streets and roads with the account of simultaneous influence of many factors.

The received quantitative parities more fully, than coefficients of loading, acceleration and movement delay defined as the relation of current values intensity, speed and density to their maximum values [5, 6], allow to estimate the quality and conditions of movement in a transport stream, that is levels of movement conveniences and how to operate its quality in the automated systems of ASTM type.

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