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ABOUT THE THEORY OF CONGESTED TRANSPORT STREAMS

Summary. Talked about a theory, based on integrity of continuous motion of a transport stream. Placing of car and its speed is in a stream - second. Principle of application of the generalized methods of design and new descriptions of the states of transport streams opens up. Travelling and transport potentials are set, and also external capacity of the system a «transport stream» is an exergy, that allows to make differential equation and decide the applied tasks of organization of travelling motion. Efficiency of application theory of waves is underlined with the new parameters of streams for management and increase of carrying capacity.

О ТЕОРИИ НАСЫЩЕННЫХ ТРАНСПОРТНЫХ ПОТОКОВ

Аннотация. Говорится о теории, основанной на целостности непрерывного движения транспортного потока. Размещение автомобиля и его скорость в потоке - вторичны. Раскрывается принцип применения обобщенных методов моделирования и новые характеристики состояний транспортных потоков. Установлены дорожный и транспортный потенциалы, а также внешняя работоспособность системы «транспортный поток» - эксэргия, что позволяет составлять дифференциальные уравнения и решать прикладные задачи организации дорожного движения. Подчеркивается эффективность применения теории волн с новыми параметрами потоков для управления и повышения пропускной способности.

The modern transport stream theory, based on numerous methods of auto traffic modeling as a process of probability with attraction of considerable by volume experimental material, does not reveal relationships of cause and effect, laws and properties which are peculiar to dynamics of the stream of vehicles. Therefore the objective necessity for studying and description of the transport stream condition as a dynamic system, with disclosing of its new qualitative features, definition of properties, structures, relationships of cause and effect, dynamics of stay change in city streets and roads for the search of new laws, the phenomena, methods of quantitative representation and for the account of the established laws in traffic management and methods of traffic automatic control has matured.

The author in the course of many years has been developing this important scientific direction connected with investigation and working out of transport stream identification as a dynamical object of management with determination, solution and analysis of a class of differential equations which describe the condition, relationship of cause and effect and the movement of congested transport streams within time limits by means of roadway crossing; a class of differential equations which describe the transport stream movement in the space of streets and roads, with the qualitative and quantitative analysis of transport stream conditions and city traffic, with working out of a spectrum of new measurers, characteristic of the transport stream as a complex system with a return negative association that has allowed to improve the methods of streets and road systems designing, methods of transport estimation of town-planning areas, methods of definition, calculation and throughput increase of city highways and different types of crossings in one and different equations [3-5], methods of feasibility reports on design decisions [3], recommend methods of public land transport throughput increase, and efficiency of operating technological transport systems and lay down the theoretical base for further applied researches directed on the decision of actual transport problems [1].

In the given work the theory of transport streams which includes methods of characteristics measurement, statistical laws of traffic characteristics arrangement, stream model "intensity-speed-density", dynamic, hydrodynamic and kinematic models of traffic models, model of vehicles turns, model of stream imitating modeling, information models of decision-making by drivers, is structured into the following sections:

1. The theory of system measuring instruments “transport stream" and estimation of its external work capacity according to hauling;
2. The theory of transport streams conditions in concentrated parameters on planned elements of streets and roads;
3. The theory of transport streams conditions in distributed variables and parameters on highway network;
4. The theory of qualitative and quantitative estimations of conditions; connecting known and new, created theoretical positions.

For disproportion liquidation between the condition of city traffic and objective necessity for the decision of city transport problems the theory of transport streams develops in a qualitative direction, as more important for the description of possibilities, structure, conditions and movement of different according to congested transport streams in the most characteristic generalized conditions of traffic on city streets and roads within time limits and space. For the decision of the specified purpose applied methods of modern mathematics, system methods of research modeling of physical stream systems are widely used.

The stream of vehicles and the roadway are considered as a complex system, connected by the concept "transport stream", to which the feedback is inherent, carried out by drivers and the system of traffic management.

The main principle in the theory that is being developed is the acceptance of integrity of a continuous process of transport streams movement, that is primary is the stream integrity, and secondary is the position and speed of vehicles in the stream. Therefore the condition and vehicle movement in a stream is described proceeding from the integrity of the whole stream.

The qualitative model of transport streams is developed on the basis of fundamental physical laws of interaction, saving and symmetry.

The methodical basis for generalized transport stream model development is "the tetrahedron of conditions" by Painter /cited on [2]/, fig. 1, and methods of energy modeling. The presence of energy communications between the cross-section intensity N(t) and extended change speed V(t) demanded for conclusion of equations of transport streams movement to apply the method of Lagrange.

Energy characteristics of the stream defined as the road and transport potentials, power functions are intensity N(t) and speed V(t), and the basis of movement-density Q(t) of the stream, therefore the equation of vehicle movement in a stream and stream quantity changes have been obtained in a differential form. Interrelation of parallel and cross-section variables with the speed of their change and integral characteristics has allowed establishing new changes of the transport stream.

On the basis of theoretical positions, conducted full-scale supervision and experimental data of other authors the analysis of parameters and transport stream variables, both known, and established has been made, and ways of their applied use in designing of streets, roads, highway systems and traffic organization have been specified.

Methods of building of differential equations of transport streams movement and conditions, their linearization, general and private decision methods for various applied problems have been obtained.

Difficulties of nonlinear differential equations solution have defined their qualitative analysis on the phase areas of "road-speed" and "quantity of stream-intensity" conditions that has allowed to analyze the periodicity, different forms of counterbalanced conditions to reveal fluctuations in a transport stream and recommend developed methods for practical use in traffic organization.

Transport stream nature of probability also refers to qualitative properties.

It has been established that the reason of non-uniform intervals distribution, speed and other changes of a continuous stream is an oscillatory character of their conditions with different frequency and amplitude concerning average values.

For the real account of stream probability features casual processes in the transport stream, certain stochastic characteristics of condition and movement equations solution have been considered, besides values of initial conditions probability (free movement speed, safe distance etc.) have also been taken into account.

The meters of transport flows have the fundamental importance both for design of urban transport systems and for estimation of transport process efficiency (transportation of freights and passengers). Therefore, well-known meters of transport work are particularised and added on base of trends of the theory of meters of transport flows by following indices and their parameters:

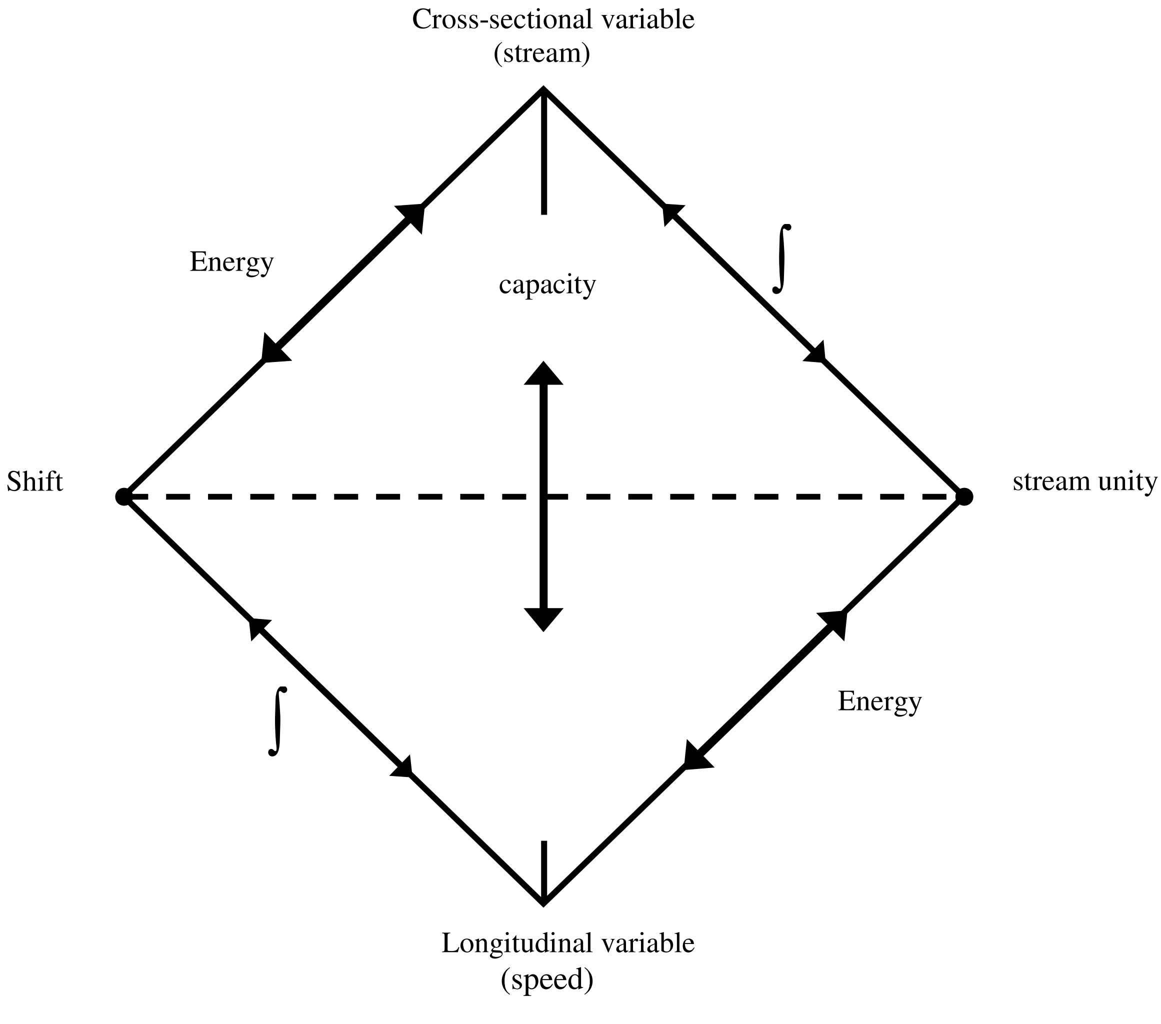
1. Stream - Intensity (N, car/h) - characteristic of a flow in road section, Nm – capacity.
2. Speed - Velocity (V, km/h) - spatial characteristic of a flow, Vo - speed of free traffic of a car.
3. k_1 - Density (Q=N/V, car/km - momental loading of a road) Qm - density under congestion.
4. k_4 - Dynamic clearance (S=V/N, km/car) - space between vehicles in movement, S_{min} - minimum space under congestion - two length of a car.
5. $\int dt$ - Quantity of flow ($\lambda=\int Ndt$, car) - unit of a flow and quantity of vehicles in a group, the main characteristic for transport systems design.
6. Quantity of traffic ($D=\lambda L$, car km) - is known as work, but it is only quantity of accomplished movement of a flow
7. k_3 - Sluggishness of a flow ($l= \lambda / V$, car h/km) - characteristic of gradual, but not momental change of car speed in a flow,
8. k_6 - reciprocal quantity (B=1/I , km/car h) - transient of change of flow state.
9. k_2 - Rate of traffic on road length $\hat{L}$ (C=L/N , km h/car) - characteristic of accumulation of vehicles in a street.
10. k_4 - reciprocal quantity (U=1/C ,car/h km) - specific intensity.
11. Road potential per unit of a street $\hat{L}$ (E_d =C/D=0.5IV² car km/h) - qualitative and quantitative characteristics of a designed street.
12. Transport potential (E_t=0,5CN², car km/h) - quantitative characteristic of road loading with transport.
13. Work of a transport flow (H= N L= λV, car km/h).
14. Exergy (E =E_d+E_t, car km/h) - external serviceability of the system «transport flow-road».
15. Traffic volume (M=NV, car km/h²) - powerful characteristic of the system «transport flow-road».

Constant fluctuations of stream variables within days, weeks are characteristic of city traffic conditions that are considered by stationary casual processes. Possibilities and borders of the theory of mass service use for the description of transport stream conditions have also been determined.

The development of transport stream theory requires an adequate description of its movement in the stream. For these purposes methods of "the theory of waves" have been used. The speed of the vehicle in the stream is described by the wave movement, as fashions of speed arrangement, and stream movement- by the superposing of these fashions.

The scalar wave equation of the transport stream has been deduced, hyperboloid waves of speed and kinematic waves of stream density have been analyzed. Return waves of different transport stream characteristics which starts to find application in traffic management by automated systems have been especially investigated. For fuller description of the transport stream movement in open space wave equations in the reason of density distribution in open space of streets that has allowed revealing "transport diffusion" have been analyzed. Theoretical positions have been confirmed by experimental calibration.

Interrelation of main variables of physical systems.



Interrelation of longitudinal and cross-sectional variables

Speed = k_1 stream, stream = k_4 speed,

Speed = $k_2 \frac{d}{dt}$ stream, stream = $k_5 \frac{d}{dt}$ speed,

Speed = $k_3 \int$ stream dt, stream = $k_6 \int$ speed dt.

Fig. 1. Generalized diagram (“tetrahedron of conditions’’ by Painter)
Рис. 1. Обобщенная диаграмма («тетраэдр состояний» Пэйнтера)

The specified approach has allowed to develop a number of practical recommendations and to plan ways of further theory development.

For applied use of positions and conclusions of the transport stream qualitative theory methods of quantitative parities reception on the basis of the collected variables have been considered.

The received number of indicators which are recommended to be used for the analysis of movement reasons on the existing and projected streets and roads and for calculation of algorithms and programs of mathematical provision for traffic ASTM (Automatic System of Traffic Management). Methods and examples of city highways throughput calculation with different modes of movement, methods of streets and roads throughput increase and freight capacity of public land transport, methods of traffic quality estimation with the account of environment preservation requirements and management of algorithms, and also recommendations concerning the structure of highway systems and new positions on improvement of norms and methods of streets and roads designing and traffic organization have been presented.

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