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Freedom of Movement and Features of Transport Systems

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ABSTRACT

Transport systems are considered in terms of ensuring freedom of movement. Various features of transport systems that are important for ensuring freedom of movement and factors affecting them are studied, main and associated characteristics there-of are highlighted. The similarities and differences in understanding of freedom of movement and of transport mobility are revealed.

It is shown that the existing modes of transport differ significantly in terms of the ability to ensure freedom of movement, and these differences have a significant impact on the choice of individuals in favor of a particular mode of transport.

It is concluded that the need to prioritize the need for freedom of movement is to be considered in development of transport systems. It is proposed particularly to account for the modern emerging trend of hybridization of vehicles. As a perspective for development of this trend, creation of multitransport is foreseen, which best combines various characteristics of vehicles and systems in terms of freedom of movement.

Keywords: *modes of transport, freedom of movement, transport mobility, characteristics of transport systems, hybridization of vehicles, multitransport, terraefficiency.*

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Background. While comparing various modes of transport, it is traditionally accepted to pay attention to such characteristics as throughput and carrying capacity, regularity, speed and cost of transportation, specific capital investments, labor productivity, power intensity, safety level and environmental impact [1].

Currently, the leadership of various modes of transport in the transportation market is estimated based on the degree of compliance of their existing or future features with such global trends in development of the transport system as acceleration and cheapening of transportation, safety, environmental friendliness and energy efficiency, service flexibility, use of low-maintenance and unmanned technologies, multimodality [2, pp. 2–3].

With the absolute importance of all the listed characteristics, it seems necessary to focus on one more, most important characteristic of ensuring freedom of movement. Usually it is not subject to special consideration, possibly due to the fact that ensuring freedom of movement is an immanent task of transport. After all, the very «purpose of transport consists in movement of bodies» [3, p. 69], and the concepts of motion, movement, and freedom are closely related, and that was reflected in the philosophy of Pythagoras [4, p. 51].

The *objective* of the author is to consider freedom of movement, transport mobility within their interrelationship with the features of transport systems.

The author uses general scientific *methods*, statistical method, comparative analysis, evaluation approach.

Results.

The essence of freedom of movement and its transport characteristics

In the Russian Federation, the right to freedom of movement is enshrined in the Article 27 of the Constitution. From a legal point of view, freedom of movement means the ability to move freely, to choose a place of stay and residence in any part of the state, as well as to leave the state and to return to it, subject to certain requirements of the law [5].

For realization of the right to freedom of movement, the social and economic importance of which is very great, it is necessary to develop adequately the transport infrastructure [6] and the means of transport.

The entire evolution of human society is associated with spatial movement of people, and the spatial accessibility is one of the key conditions for socio-economic development [7, pp. 45–46]. Indeed, in order «to make... an exchange of activities with other people in the material world, we need two very important general conditions: ...space, available to a man, ... and... *movement*», as a result of which human territorial independence from spatial environment is achieved [3, pp. 102, 106]. Obviously, it's about moving not only people, but also material goods. It is not by chance that one of the founders of the Austrian economic school, Eugen Böhm Ritter von Bawerk, stated that «*the ability to spatial transfer of matter*» is the key to all human success in production, to human domination over nature and its forces [8, p. 40].

Taking into account all the above, the question should be posed: what should be understood under freedom of movement as a characteristic of the transport system?

In our opinion, from the point of view of provision of transport services, freedom of movement can be defined as the ability of a person to move or move material goods from one point of spatial environment to another during an acceptable (from the point of view of both the beginning and the total duration of movement) time, with an acceptable level of cost, safety, passenger comfort or goods safety. From this definition it follows that freedom of movement is determined by a number of characteristics of the transport system.

The first of features is the possibility of choosing the direction (route) of movement, which in turn is determined primarily by development of transport infrastructure. If we take the example of the Russian Federation, it is important that the connection between development of transport infrastructure and implementation of freedom of movement is highlighted in the Comprehensive plan for modernisation and expansion of mainline infrastructure for the period up to 2024, approved by the Government of the Russian Federation. In particular, it is stated that «the growth of such a social good as freedom of movement meets the legitimate interests of population and will contribute to improvement of the quality of life» [9, p. 31].

The second most important characteristic is the offer of transport services, exceeding the demand, which depends on the state of infrastructure and of vehicles and rolling stock and can exist only in a developed market economy that is in a surplus economy [10, 11].

The third set of features comprises traffic regularity and frequency, allowing to start moving at the desired (acceptable) time.

The fourth one is speed of movement, ensuring its acceptable duration. The particular importance of travel speed for passengers is due to the fact that time is the most valuable resource in the modern economy. In turn, acceleration of delivery of material goods allows to reduce the amount of capital embodied in them, «frozen» in the process of transportation [12, p. 3] and, thereby, to increase the efficiency of the economy. Increasing the speed of movement of both people and material goods should be achieved, first of all, on the basis of minimizing vehicle downtime in the process of transit along the route [13].

The cost of moving goods and passengers is determined by many factors [14]. They comprise the general level of technical development of transport systems and the characteristics of specific technical means which are rolling stock and infrastructure elements; transportation technology that determines the quality and efficiency of the use of infrastructure and rolling stock, of labour and fuel and energy resources [15, pp. 8–9]; volumes and range of movement of goods and people. External factors, including the economic environment of the transport market, also significantly affect the cost of moving [16, 17].

As for ensuring the safety of movement, «*a fatal inevitability of an accident, a catastrophe is no longer characteristic of modern transport*. Achievements in science and technology, ... which ensured improvement of ... means of transport, the entire diverse system of traffic safety, created together a broad base for driving vehicles with a high degree of reliability. But the probability of dangerous situations (including accidents and catastrophes) in transport system is not completely excluded, the weight of human (personal) factor in many modes of transport is still significant» [3, p. 118] as the cause of such situations. It is not by chance that the main vectors for improving vehicle traffic safety pass through building a safety culture among people involved in the transportation process, and minimizing the influence of the human factor by developing automated means of monitoring and control of the conditions of transport infrastructure and rolling stock, and of people controlling them, as well as by developing systems that partially or completely replace the person in the course of implementation of the transportation process.

The safety of material goods is an indispensable condition for the freedom of their movement and is determined by a combination of the characteristics of technical means of transport, and transportation technology, as well as of measures to prevent theft of material goods during transportation. The safety of material goods is ensured if they are delivered to their destination point in full and without loss of their properties.

Movement of people requires more sophisticated terms, as it is not sufficient for people to get to their destination alive and healthy. «Since for a person the state experienced while traveling is very different from that while maintaining [his spatial – *author's note*] position» [3, p. 119], the discomfort caused by movement significantly limits freedom of movement itself. After all, one cannot assume that a person is free if he or she is forced to experience severe discomfort.

The factors that cause discomfort (and can sometimes cause harm to health) during transportation are very diverse. Traditionally, these include, first of all, acceleration, vibration, noise, unpleasant or harmful emissions arising from movement of vehicles [3, p. 121]. Besides, discomfort is a limitation to meet the usual needs, the range of which is expanding. Now it is not reduced to nutritional needs, thirst quenching, sanitary and hygienic requirements, comfortable temperature conditions, but comprises also, for example, free use of electronic devices and the Internet.

Ensuring travel comfort, i.e. leveling or minimizing the impact of factors causing discomfort, should be taken into account initially, from the very start of designing and building (manufacturing) transport infrastructure and rolling stock, and, of course, during transportation itself.

Of all the characteristics that determine freedom of movement, the comfort parameters are probably the most subjective ones: for a person, the comfortable temperature is of +19°C, for another one it is of +23°C; someone almost does not experience discomfort during takeoff or landing of the aircraft, and someone feels them very hard. This implies the need to individualize the conditions of carriage, and therefore the use of a wide range of vehicles and technologies.

Each of the listed characteristics is provided by some modes of transport with greater success, and other modes fail to do that. However, these characteristics are not equally important. In our opinion, based on the definition of freedom of movement proposed above, its main, pointed characteristics should be considered as follow:

Table 1

Dynamics of passenger transportation volume and passenger turnover in the Russian Federation by mode of transport, 2017 to 2010 (%)

Mode of transport	Index of passenger transportation volume growth	Index of passenger turnover growth
Railway	118,4	88,6
Bus	83,3	87,8
Passenger taxi	144,7	166,7
Tram	63,8	64,2
Trolleybus	62,4	73,2
Metro	100,1	104,0
Water	141,1	79,1
Air	183,1	176,3
Total	83,8	115,8

Source: Calculations of the author based on Federal Statistics Service (hereinafter referred to as Rosstat) data [21, p. 36].

Table 2

Dynamics of passenger vehicle availability in the Russian Federation, 2017 to 2010 (%)

Type of vehicles	Growth index
Working park of railway passenger cars	103,6
Public buses	107,6
Passenger cars, total	136,3
including owned by citizens	137,4
Trams	87,5
Trolleybuses	84,7
Metro cars	123,8
Sea passenger and cargo-carrying transport vessels	96,4
River passenger and cargo-carrying transport vessels	81,0
Civil aircrafts (all types)	116,7

Source: Calculations of the author based on Rosstat data [21, p. 32].

freedom of choice of route and time (speed) of movement. The ability to move from one point of spatial environment to another of one's choice in a short time means freedom of movement as such. The remaining characteristics are concomitant or limiting (as, for example, cost).

Differences in the dynamics of transportation by mode of transport, taking into account the characteristics that determine freedom of movement

From the point of view of the main characteristics of freedom of movement, automobile transport and civil aviation have significant advantages. And, despite high cost and significant level of danger, many individuals make a choice in favour of these modes of transport. Thus, in the European Union's countries, personal motor transport dominates in domestic passenger transportation. For example, in Germany its share in the domestic passenger turnover steadily exceeds 80 % [18, p. 11].

In Russia in recent years, air transport and passenger taxi are leading in terms of the dynamics and volumes of passenger turnover and passenger transportation (Table 1). Federal Statistics Service [Rosstat] does not provide data on the volume of transportation and passenger turnover of personal vehicles, but an indirect characteristic of the dynamics of those indicators can be translated through the increase in the number of passenger cars owned by citizens that is the maximum number among all types of vehicles (Table 2). With this in mind, decline in passenger transportation by buses, trams and trolleybuses, the low dynamics in the metro become understandable. It is obvious that part of passenger traffic is switching to personal vehicles, despite the problems encountered in major cities and agglomerations due to traffic jams [19, 20].

Air and road transport were also leading in terms of freight turnover dynamics (Table 3). By the way, the number of trucks owned by citizens increased very significantly during the period under review, by 34,5 % [21, p. 52].

Thus, the statistics confirm the introspective conclusion that the need for freedom of movement

Table 3

Dynamics of cargo transportation volume and cargo turnover in the Russian Federation by mode of transport, 2017 to 2010 (%)

Mode of transport	Index of cargo transportation volume growth	Index of cargo turnover growth
Railway	105,5	124,0
Automotive	103,2	128,1
Pipeline	107,3	109,8
Water	103,6	73,4
Air	118,2	168,1
Total	104,1	115,4

Source: Calculations of the author based on Rosstat data [21, p. 33].

(including freedom of movement of material goods) is a significant factor affecting distribution of transportation volumes between modes of transport, and one of the reasons for preferences given to air and road (above all to passenger vehicles) transport.

At the same time, personal vehicles are much less energy efficient and terraefficient [22] than bus and, especially, train transportation.

Terraefficiency [*original spelling and meaning is different from land use efficiency – ed. note*] of the transport system is an economic category that characterizes the ratio of the volumes of transportation and of the economic results, to the land surface used for deployment of the transport system. Terraefficiency can be defined, e.g., as:

– Ratio of passenger turnover to the area of land used by transport, thous. p-km/sq. km. (for passenger transport systems);

– Ratio of cargo turnover to the area of land used by transport, thous. t • km/sq. km. (for freight transport systems);

– Ratio of adjusted transportation work to the area of land used by transport, thous. of adjusted t • km/sq. km. (for combined, freight and passenger transport systems);

– Ratio of revenues of transportation to the area of land used by transport, thous. currency units (e.g. rubles)/sq. km. (for any transport systems) [22].

Thus, according to the calculations of French specialists, passenger transportation by personal transport requires the use of a territory which is by 5 times larger than when passengers are transported by buses, and almost by 20 times larger than when passengers are transported by metro trains. The corresponding differences in energy efficiency reach 2- and 2,5-times difference respectively [23, p. 40]. It seems that these differences may even be much higher.

Modern high-speed railway system significantly exceeds both road and air transport in terms of energy efficiency, environmental friendliness and terraefficiency [24, p. 23].

Attention should also be paid to differences in the level of safety of transportation by modes of transport (Table 4).

The number of fatalities in air transport is by several times higher than in railway and water transport, and for road transport this number is higher than for any other mode of transport by several orders of magnitude.

Nevertheless, people actively use both air and road transport, which have significant advantages in ensuring the basic characteristics of freedom of movement. And this desire for freedom of movement must be taken into account when choosing priorities for developing transport systems.

Freedom of movement and mobility

It is necessary to note the connection of freedom of movement as of a characteristic of the transport system with the concept of «transport mobility of the population», but at the same time to differentiate them.

Transport mobility of population means usually the intensity of spatial movement of people, expressed by such indicators as the average number of trips or the number of passenger-kilometers per inhabitant over a certain period [1, 25]. In the general case, expansion of freedom of movement contributes to the growth of population mobility, the connection between them is undoubted. But there are significant differences.

Firstly, freedom of movement is determined by the *opportunity to make* a movement (travel), characterized by certain qualitative terms. And transport mobility in the above understanding is characterized by movements that have already been made, and only in quantitative

Table 4

The number of traffic accidents and number of injured persons in the Russian Federation, 2017

Mode of transport	Number of accidents, thousand	Died, thousand people	Injured, thousand people
Public railway transport	0,014	0,003	0,024
Water	0,054	0,008	0,002
Air	0,039	0,050	0,029
Automotive	169,4	19,1	215,4

Source: Rosstat [21, p. 86].

terms. Variants are quite realistic when expanding freedom of movement will lead not only and even not so much to an increase in quantitatively measured transport mobility, but to its geographical diversification.

Secondly, the concept of transport mobility refers only to movement of people, while freedom of movement (in the interpretation proposed in the article) covers movement of material goods as well.

Another interpretation of transport mobility is closer to freedom of movement. It implies that «transport mobility is *a process* [*italics of the author*] of safe, comfortable, fast, accessible and economically expedient movement of a person or group of people using one or several modes of transport» [26, p. 32]. In this definition, one can find a wide range of qualitative characteristics, close to the characteristics of the transport aspect of freedom of movement, although not identical to them. However, here it is not the *opportunity* that is being considered, but the *process* of movement itself, and again it is only a matter of moving people, but not material goods. At the same time, it is important to indicate the use of several modes of transport. The importance of multimodality for ensuring freedom of movement will be noted below.

Thus, understanding of the essence of transportation provision of freedom of movement, associated on the one hand, with the widely used concept of transport mobility, and on the other hand, having fundamental differences as compared to it, significantly enriches the categorical apparatus of the theory of transport and allows to consider the priority implementation of one of the key human needs when developing transport systems.

Development of transport systems' openness and multimodality as a factor ensuring freedom of movement

The main lines of harmonization of the main and associated (in terms of freedom of movement) characteristics of transport systems consist in development of open access transport systems [27] and of multimodal transportation. The current stage of development of transport equipment and technology is characterized by hybridization of vehicles [28, p. 53]. At the same time, synergetic innovations arise, allowing to form the corresponding socio-economic effects thanks to combination of advantages of different vehicles and technologies and to emergence of new opportunities for passengers and commodity owners [29, 30].

We should note among them vehicles that combine the properties of an aircraft and a car, which are to allow to effectively solve the transport problems of megalopolises, providing acceleration of trips and elimination of traffic jams on highways. Another concept of interest is a «train-plane», the implementation of which will make it possible to harmonize the interaction of air and railway transport [31].

The radical acceleration of transportation, which means expansion of freedom of movement will be facilitated by implementation of projects of ultra-high-speed ground and air vehicles [2, 32].

All this taken together will raise multimodal transportation to a new level. It seems that the development of hybridization of vehicles will constitute a basis for a possible transition from multimodal transport systems to multitransport, which best combines various characteristics of transport vehicles and systems in terms of freedom of movement.

Conclusion. Process of multitransport development will require fundamentally new combinations of existing technical and technological solutions, as well as of those that have yet to be invented. To advance in this direction, it is crucially important to realize the urgency of finding harmonious transport solutions to increase freedom of movement, which will have significant social and economic effects.

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