VACUUM TRAIN: FINDING A NICHE IN THE PASSENGER TRANSPORTATION MARKET

Nesterov, Sergey B., *JSC Scientific Research Institute of Vacuum Technology named after S. A. Vekshinsky, Moscow, Russia.*

Vorobiev, Ivan A., *JSC Scientific Research Institute of Vacuum Technology named after S. A. Vekshinsky, Moscow, Russia.*

Kondratenko, Rim O., *JSC Scientific Research Institute of Vacuum Technology named after S. A. Vekshinsky, Moscow, Russia.*

ABSTRACT

The necessity and profitability of creating a transport system with speeds that are multiples of 1000 km / h (up to 6000 km / h) is constantly being discussed by the world scientific community. Today, the only way to increase the speed of rail transport to such values is seen in replacing the wheel-rail system with a magnetic suspension system and replacing the natural environment with an artificially created one, in which the aerodynamic resistance for transport will be small. The article considers the niche of the transport market, which can be occupied by a vacuum train in a competitive struggle with high-speed and air transport.

Keywords: vacuum train, comparative analysis, competition, niche search, maglev, air transport, railway transport, high-speed trains.

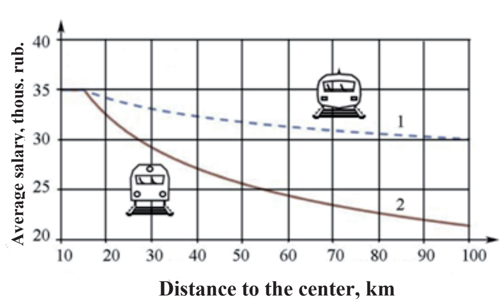
Background. *According to UN estimates, the number of inhabitants of the planet will reach 9,2 billion by 2050. This is a record high figure, considering that in 2009 the figure was 6,8 billion, in 1950 it was 2,5 billion. In addition, 70 % of earthlings are crowded in cities, to save the communication between which high-speed transport networks are now called.*

The American transnational oil and gas corporation ExxonMobil forecasts that by 2040 the demand for transportation services will increase by more than 40 %, mainly due to business travelers.

The scale of the territory of Russia and the nearest countries, the length of their potential highways force us to seek ways to increase the speed characteristics of transport [1–3]. For example, the length of Moscow–Beijing route is 7769 km (and the journey at projected speeds of the high-speed railway (HSR) will take at least 32,8 hours).

The problems at short distances are worth noting. Today, in Moscow and the Moscow region, a significant inequality between the center of the megapolis and its periphery remains at the labor market. Obviously, labor market integration tools (one of which is a developed transport system) do not work with the same efficiency as in the labor markets of European megacities.

Comparative graphs of the calculated dependence income–distance to the center for Moscow region and Europe are shown in Pic. 1.



Pic. 1. Estimated dependence salary (income) – distance: 1 – Europe (Germany, Sweden, Netherlands); 2 – Moscow region. The data source is Rosstat [1].

With the improvement of public transport efficiency, one should expect the integration of labor markets and the smoothing of the income–distance curve. Ideally, when the development of our transport system overtakes the European level, there will be a redistribution of people in space, the Moscow agglomeration with intensive production, transportation and cultural ties will expand, the population density in the middle and far areas of Moscow region will increase. In the limit, the development of the transport network to the European level can reduce the income elasticity of the time en route to the European level, which will increase the average salary in the middle areas of Moscow region by 1,5 times.

Speed characteristics of a vehicle, be it an airplane, train, car, depend on its ability to change, adapt to the environment:

– to change the geometric shape (the shape of the aircraft fuselage, the shape of the high-speed train is changed to suit aerodynamics);

– to change the shape of the movement of its parts (change in sweep, slats and flaps of the aircraft);

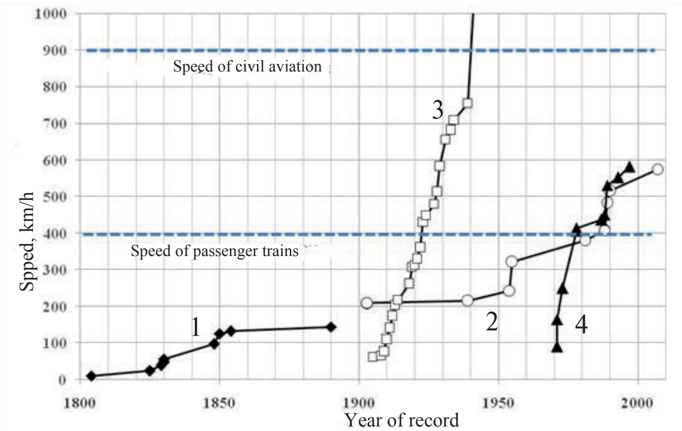
– to change the transmission (replacement of the wheel-rail system by the magnetic levitation system to reduce the friction on the rails).

However, there are cases when further adaptation to environmental conditions is impossible or too time-consuming.

For example, the usual speed in civil aviation is about 850 km/h, although the speed records are above several thousand km/h, and the trains carry passengers at speeds of 80–350 km/h, although the speed record is near 600 km/h.

In both cases, the increase in speed is impeded by aerodynamic drag. It grows as a square of speed, and energy costs as a speed cube. Let's say that with an increase in speed by 2 times, the aerodynamic drag will increase by 4 times, and the energy consumption – by 8 times.

A possible solution to this problem for rail transport is the replacement of the environment by an artificially created one, in which the aerodynamic resistance will be small, for example, by placing the train in a pipeline with a reduced pressure. This solution is not new, it was proposed more than a hundred years ago, the first experiment in the world with the movement of the body in a vacuum tube due to the electromagnetic field was put in 1911–1913 by



Pic. 2. Speed records for some types of transport (until 2010): 1 – train; 2 – electric locomotive and diesel locomotive; 3 – civil aviation; 4 – maglev trains.

Table 1

City express Moscow–New Moscow (40 km)

	Vacuum train	Maglev	HSR
Distance between stops, km	40	40	40
Time rate of change, m/s^2	1	1	1
Maximum speed, km/h	720	603	350
Travel time, min	7	7,5	8,5
Embarkation-disembarkation time, min	5	5	5
Distance of speeding-up, braking (assumed equal), km	20	7,8	4,7

the Russian professor Boris Veinberg at the Tomsk Institute of Technology. In addition, it is not so as a man is the only creature on Earth that does not adapt to the environment, but changes it for himself.

«I cannot forget that stunning impression that this bold and original project made on the cold Petersburg public when the inventor in a brilliant lecture drew a picture of the future struggle against space before the audience», Ya.I. Perelman wrote in «Entertaining Physics» [4].

Let's consider the niches that a vacuum train can take.

Objective. *The objective of the authors is to consider possibilities for using a vacuum train in the Russian passenger transportation market.*

Methods. *The authors use general scientific and engineering methods, economic analysis, comparative method, statistical analysis.*

Results.

1. The Metropolitan. The niche cannot be occupied. *The limiting speed of communication between underground stations, which in the future subway cars, which will be technically better than today, will be able to provide, will not exceed 50 km / h [5]. It is limited to the maximum permissible for the passenger acceleration and deceleration of cars, the conditions of stability and safety of train traffic, etc. The stability of traffic here means the possibility for trains to realize the speed of the traffic logged in the traffic graph steadily, even with occasional delays at the stations. If the train is delayed, the train must ensure that the lost time is overtaken directly at the next haul. If it fails to do this, then at the next station more passengers will wait for it than usually, and the probability of another delay will increase. A consequence of this situation may be a traffic schedule failure. Unplanned train delays at stations during peak hours occur regularly and range from 5 to 10 seconds. The need to have a 10-second run-time reserve for overtaking random delay in the most restricts the possibility of plotting the schedule of trains with speeds of more than 50 km / h.*

2. City express and aeroexpress. The niche cannot be occupied. *Today, there are news about the possibility of using a vacuum train as an aeroexpress [6]. This type of transport is needed to provide accelerated transport links with large suburban areas, airports or satellite towns with a minimum number of stops on the route. For example: city express Moscow–New Moscow, distance 40 km. However, due to the short distance between stops, the travel time for the vacuum train will be comparable to HSR or maglev. This niche is perfect for them, and the problem of noise can be solved in a more economical way – installation of soundproof shields (Table 1).*

3. Suburban electric trains. The niche cannot be occupied. *Suburban electric trains are designed for transport connections of cities with the nearest suburbs, as well as between neighboring settlements, they are designed for distances of up to about 200 km. The average distance between stops on the routes served by suburban electric trains is usually from 2.5 to 5.0 km. Due to the small distance between stops, this niche cannot be occupied by a vacuum train either.*

4. Interregional electric trains (local). The niche can be partially occupied. *Interregional trains are used on routes of suburban and long-distance traffic with stable passenger flow for distances from 100 to 1000 km between cities with stops only in large populated areas or without intermediate stops. Table 2 shows a variant of an interregional communication with stops every 100 km and a distance of 1000 km.*

5. Long-distance trains. The niche can be occupied. *Trains of this type move to a distance of 700 km with stops only in large settlements or without intermediate stops on the route. Table 3 shows a variant of a long-distance train following a distance of 1000 km without stopping. This can be a route*

Table 2

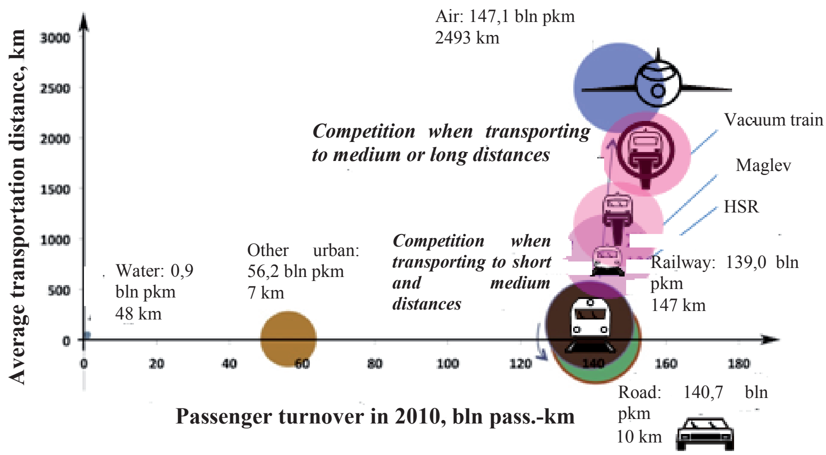
Interregional communication with stops every 100 km

	Vacuum train	Maglev	HSR
Total distance, km	1000	1000	1000
Distance between stops, km	100	100	100
Time rate of change, m/s²	1	1	1
Maximum speed, km/h	1000	603	350
Travel time between stops, min	10,6	15,5	18,7
Total travel time, including time for embarkation-disembarkation, min/h	161/2,6	210/3,5	242/4
Embarkation-disembarkation time, min	5	5	5
Distance of speeding-up, braking (assumed to be equal), km	38,6	7,8	4,7
Time of speeding-up, braking (assumed to be equal), min	4,6	2,1	1,6

Table 3

Long-distance trainsя(1000 km)

	Vacuum train	Maglev	HSR
Total distance, km	1000	1000	1000
Distance between stops, km	1000	1000	1000
Time rate of change, m/s²	1	1	1
Maximum speed, km/h	1000	603	350
Travel time between stops, min	55,4/0,92	135,4/2,3	173/2,9
Total travel time, including time for embarkation-disembarkation, min/h	85,4/1,4	165,4/2,6	203/3,4
Embarkation-disembarkation time, min	30	30	30
Distance of speeding-up, braking (assumed to be equal), km	38,6	7,8	4,7
Time of speeding-up, braking (assumed to be equal), min	4,6	2,1	1,6



Pic. 3. Interspecific competition in passenger transport. The data source is Rosstat [1].

between large cities with large population, for example, Moscow–Saint Petersburg, Moscow–Kazan, etc. This will create a new generation transport infrastructure that will closely connect megacities and regions of the Russian Federation.

As a result, the considered transport system taking into account the specificity of speeding-up can occupy the niches of:

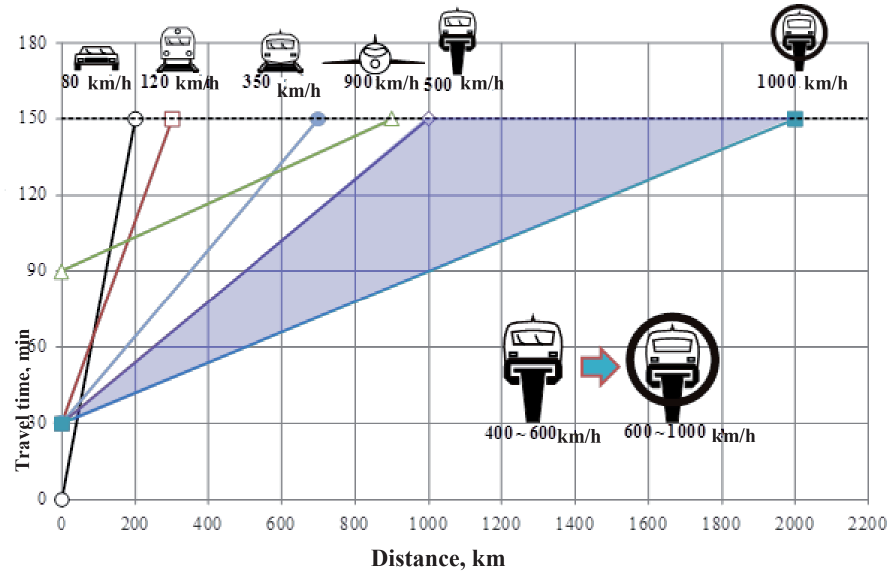
1. Inexpensive high-speed transportation with a large passenger flow for medium distances (100–1000 km). At the same time, competition will be with both air and suburban high-speed transport (Pic. 3, 4).

2. High-speed transportation for long distances (from 1000 km/h). At the same time, competition will be with air transport (Pic. 3, 4).

It should be noted that it is possible to use one track for all transportation. The difference is only in the traffic schedule and equipment of cars.

Despite the obvious prospects for the use of a vacuum train, in some niches of the transport infrastructure, in Russia, unlike the US, the project is perceived very skeptically, partly due to the lack of detailed technical and economic analysis of the new system and the associated risks. These issues are only just beginning to be worked out [7, 8].

Conclusions. *Our preliminary analysis shows that when creating a transport system with a length of 1000 km, about 90 % of all costs will go specifically to the design and laying of a vacuum pipeline. Therefore, without the introduction of new, really*



Pic. 4. Rational areas for the use of passenger transport on the basis of magnetic levitation in rare medium. From left to right in accordance with pictograms on top of the picture: 1 – personal car; 2 – speed rail ground transport; 3 – high-speed rail transport; 4 – aviation; 5 – maglev; 6 – vacuum train.

high-tech solutions in this area, based, in particular, on reducing the weight of the pipeline, while maintaining the simplicity of construction, strength characteristics and tightness, this project will not go beyond the test track.

In this regard, further cooperation is needed between competent enterprises in the field of magnetic levitation, aerospace, railway transport, as well as specialists in vacuum and cryogenic engineering, aerodynamics with the aim of confirming or refuting the feasibility of the tasks set in the design and direct creation of a vacuum-levitation transport system, evaluation of its feasibility today and in the near future, as well as for the purpose of developing the idea itself and supplementing it with new technical solutions taking into account the technological progress.

REFERENCES

1. Evaluation of large infrastructure projects. Tasks and solutions [*Ocenka krupnyh infrastrukturnyh proektov. Zadachi i reshenija*]. *rzd.ru: website – Russian Railways, 2013*. [Electronic resource]: http://rzd.ru/dbmm/download?vp=1&load=y&col_id=121&id=71716. Last accessed 11.10.2016.

2. RFPI and Russian Railways discuss pilot projects on the use of Hyperloop technology [*RFPI i RZhD obsuzhdajut pilotnye proekty po primeneniju tehnologii Hyperloop*]. *RIA Novosti*, 2016. [Electronic resource]: http://ria.ru/economy/20160622/1449639464.html. Last accessed 11.10.2016.

3. In Russia works on analogues of the vacuum train Hyperloop are in progress [*V Rossii rabotajut nad analogami vakuumnogo poezda Hyperloop*]. *RIA Novosti*, 2016. [Electronic resource]: http://ria.ru/economy/20160520/1436931658.html. Last accessed 11.10.2016.

4. Perelman, Ya. I. Entertaining physics [*Zanimatel'naja fizika*]. [Electronic resource]: http://www.eduspb.com/public/books/nauch_pop_uch/perelman_fizika1.pdf. Last accessed 11.10.2016.

5. Gavrilov, Ya. I., Mnatsakanov, V. A. Metro cars with pulse converters [*Vagony metropolitena s impul'snymi preobrazovateljami*]. Moscow, Transport publ., 1986, 230 p.

6. Hyperloop in Moscow can go to airports and to New Moscow [*Hyperloop v Moskve mogut pustit' v ajeroporty i v Novuju Moskvu*]. *RIA Novosti*, 2016. [Electronic resource]: http://ria.ru/moscow/20160617/1449031333.html. Last accessed 11.10.2016.

7. In Russia it is planned to create the concept of a system of «flying» trains [*V Rossii planirujut sozdat' koncepciju sistemy «letajushhih» poezdov*]. *RIA Novosti*, 2016. [Electronic resource]: http://ria.ru/science/20160318/1392431702.html. Last accessed 11.10.2016.

8. Moscow authorities instructed to study the possibility of using Hyperloop in the capital city [*Vlasti Moskvy poruchili izuchit' vozmozhnost' primenenija Hyperloop v stolice*]. *RIA Novosti*, 2016. [Electronic resource]: http://ria.ru/economy/20160617/1449031025.html. Last accessed 11.10.2016.

Information about the authors:
Nesterov, Sergey B. – D.Sc. (Eng), Deputy General Director for Research at JSC Scientific Research Institute of Vacuum Technology n.a. S. A. Vekshinsky, Moscow, Russia, sbnesterov@niivt.ru.
Vorobiev, Ivan A. – Ph.D. (Econ), General Director of Scientific Research Institute of Vacuum Technology n.a. S. A. Vekshinsky, Moscow, Russia, Vorobiev@niivt.ru.
Kondratenko, Rim O. – Ph.D. (Eng), head of the department of Scientific Research Institute of Vacuum Technology n.a. S. A. Vekshinsky, Moscow, Russia, r.kondratenko@niivt.ru.

Article received 11.10.2016, accepted 22.12.2016.