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S. A. Smirnov, O. Yu. Smirnova

EVALUATION OF EFFECTIVENESS OF DIFFERENT TRANSPORT MODES FOR REGULAR MASS FREIGHT TRANSPORTATION

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The article deals with different transport modes for regular mass freight transportation, their efficiency evaluation is conducted on the bases of cost, operational and environmental properties.

Introduction. Due to demand in ensuring mass transportations between Southeastern Asia and Europe, there is a topical issue of efficient application of different types of ground transport. There is a request rising, to use cutting edge achievements in technology, to increase speeds of freight transportation for long distance and their safety and environmental friendliness enhancement.

Analysis. Consideration of cost properties of application of different transport modes for mass freight transportation allows revealing that the lowest infrastructure cost is typical for conventional railway transport; the lowest prime cost of transportation is ensured by maglev transport with permanent magnets of the "RosMaglev" technology; the lowest commercially profitable mode of transport for today's level of science and technology is vacuum transport.

Operationally, the leading project is "RosMaglev", with the vacuum transport having the lowest operational efficiency.

From environmental and carrying safety points of view, railway transport has gone pretty far in the recent two decades. However, a more sustainable and safe one is the maglev and vacuum modes of transport, which is explained by lack of emissions and other types of pollution, including noise pollution.

In terms of safety, maglev transport is the most competitive mode of transport. Whereas, vacuum transport is the most dangerous one.

Results. For mass freight transportation, the most promising mode of transport is the "RosMaglev" permanent magnets maglev transport, according to the authors. The technology allows significant increase of infrastructure construction costs. The second most promising mode is conventional railway transport. However, if the demand in transportation is low and the energy efficient traction rolling stock is implemented, the high-speed freight railway transport may be highly competitive, especially in countries with developed high-speed railway network. The vacuum transport holds firmly the third place.

Conclusion. The relevance of maglev transport implementation for mass freight transportations is obvious. The maglev technologies now in use in many countries for carrying passengers have proved profitable, safe and convenient. Technical "maturity" of these technologies allows considering all points and factors when constructing maglev freight lines which is very topical due to increasing need in searching transport routes alternative to sea routes.

Railway transport, high-speed mainlines, maglev transport, vacuum transport, string transport, regular freight transportation, cost, operational properties, sustainability (environmental friendliness), safety, prospect of implementation, technology "RosMaglev".

Introduction

In the today's world, there are firmly established geographical centres of production and consumption, with the first one located in Southeast Asia including, but not limited by China, and the second one – in Europe, predominantly its western part. There is a steady goods turnover between these two centres, showing dynamical growth in recent years. Due to demand in ensuring regular mass freight transportations between these centres, there arises a topical issue of consideration of application efficiency of various ground transport modes.

Despite a more dense goods flow from Southeast Asian countries to European ones, their reverse transportation also takes place (fig. 1). Decrease in amount of turnover caused by global economic down turn lasting from 2008, could not break the common tendency, which is indirectly confirmed by active elaboration of projects of the New Silk Road, the Silk Wind and other projects by China.

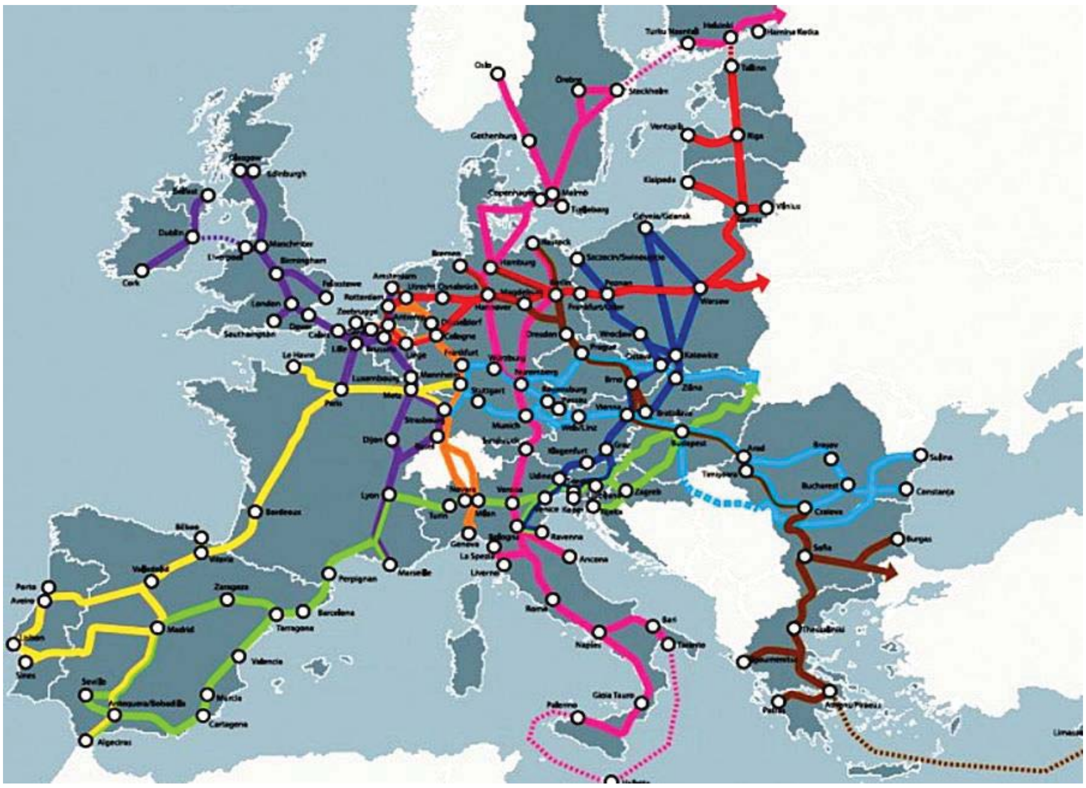

Fig. 1. World transport flows

The most capacious cargo route, the Deep Sea route, also known as the South Sea Route which passes through the Suez Canal, does not meet the conditions for acceleration of the movement of the commodity and money supply (fig. 2). This provides opportunities for the development of new modes of transport and new modes of transportation [1].

Fig. 2. The Northern Sea and the Suez Canal Routes

In European countries, despite a relatively low length of freight transportation routes, there also arose a demand in breakthrough technologies of freight transportation. This demand, on the one hand, is driven by environment protection ideas and policies. From the other hand, a number of states, including Switzerland, are in need of transit efficiency enhancement. On the part of Southern Europe states, in their turn, there is a demand to increase the speed of freight transportation over long distances - to the countries of Northern and Eastern Europe, and to Russia.

Analysis

Based on the existing level of technologies and prospects of their further development for comparison of their application efficiency for mass freight transportation, the following types of transport are determined:

- conventional railway transport;
- HSR, high-speed railway transport;
- maglev transport (EMS, EDS, permanent magnet suspension);
- vacuum transport;
- string transport.

Assessment of efficiency of transport modes has been carried out in accordance with the following parameters:

- cost parameters (more precisely, in cost of infrastructure construction, prime cost of transportation);

- operational properties;
- environmental properties and safety.

Railway infrastructure construction costs are highly dependent on construction and local conditions. Thus, in Russian conditions the cost of new non-electrified line starts from 500-600 million (approximately 8.5-10.3 million USD) rubles per one kilometre of track. The electrification of this line will increase the initial cost by more than 30 %.

Prime cost of freight transportation by conventional railway transport in Russia does not exceed 600 kopeck (approximately 0.11 USD) per 10 tonnes per kilometre [2].

Expenditures for construction of passenger HSR are much higher. Thus, the cost of construction of the HSR-1 between Moscow and Saint Petersburg at each of two options of financing makes more than 1 trillion (17.2 billion USD) rubles or 1.52 billion (17.2 million USD) rubles per one kilometre (as of 2012) [3], HSR Moscow − Kazan (HSR-2) – 1.26 trillion (21.6 billion USD) rubles or 1.64 billion rubles (28.1 million USD) per one kilometre (as of 2017) [4].

Cost of regular freight traffic designed HSR is higher than the cost above, but there is no precise data, since the real projects are being developed. JSC “RZD” (Russian Railways) and the Italian Railway Engineers Association express their utmost interest in this type of transportation [2, 5]. Drawing parallels with passenger transportation, we are sure that freight HSR will demand higher costs compared to conventional railways’ ones [6].

The cost of construction of maglev mainline for different projects varies from 500 million rubles (8.6 million USD) to 1.4 billion rubles (24 million USD) for one kilometre of track. Infrastructure deploying permanents magnetics has a higher cost. The cheapest mode in this case is light-rail metro on electromagnetic or electrodynamic suspensions.

The peculiar feature of maglev lines is that they can be installed in the form of flyovers, giving the possibility to divide the infrastructure into active and passive. The passive part is similar to non-electrified railway line [7, 8]. Thus, the Scientific and Engineering Cluster “Russian Maglev” (“RosMaglev”) estimates one kilometre of passive infrastructure for maglev lines less than 450 million rubles (7.4 million USD) which is comparable to the cost of one kilometre of the Project “Belkomur” [9, 10]. The overall cost of one kilometre of “RosMaglev” is estimated 1 billion rubles (17.1 million USD) which became possible with the help of cutting edge solutions in permanent magnets technologies [11].

In terms of maglev projects, it is advisable to separately consider permanent magnets technology and other technologies.

Electrodynamic (Maglev technology, Japan) and electromagnetic (Transrapid technology, China) suspensions have no application in freight transportation. Moreover, serious developments in this area have not been carried out, as enlarged calculations have shown that the energy costs for creation and maintenance of levitation will be unreasonably high. In contrast to these technologies, permanent magnets provide permanent levitation, which is compensated by the excessively high cost of infrastructure. Solution of this problem in Russian conditions allowed us to reach the estimated value of operating costs by 24 % lower than that of the conventional railway [11–13].

The cost of construction of vacuum mainline includes expenditures for maglev line construction and installation of equipment for preservation of vacuum. These are forevacuum pumps, getters or high-vacuum pumps. There is no economic assessment of creation and maintenance of vacuum. At the same time, according to experts, to lay a long tube with large diameter will be very costly.

Construction of 1 km of string transport route is estimated 800 million rubles (13.7 million USD) without considering the design work for one track in the conditions of an experimental test site. The prime cost of transportation by string transport is not defined. A reduction in operating costs by 2 times compared to traditional rail transport has been declared, but there is no information about operating costs for the freight line. Taking into account the structural features of string transport, it is more possible to forecast high costs for inspection and maintenance of the line [14].

Summing up the cost properties of application of various modes of transport for mass freight transportation, we can make the following conclusions:

- the lowest price of infrastructure is the feature of conventional railway transport;
- the lowest prime cost of transportation is ensured by maglev transport with permanent magnets “RosMaglev”;
- the lowest commercial profit can be gained from the vacuum transport.

The operational properties of railway transport are a deeply studied issue. In the USA and Canada, trains run with over 100 wagons, each one carrying 2 containers. The infrastructure and the wagons themselves are designed for speeds of 140 km/h and over. However, the daily speed of delivery of goods is still low. For example, the project «Transsib for seven days» (Transsib za sem’ sutok-in Russian) sets an ambitious goal, which consists in the passage of a distance of 1.400 km per day [15].

The Italian project of freight HSR suggests reaching a speed of 250 km/h. However, the length of the train does not exceed 16 wagons, each carrying 2 containers [5].

The operational properties of “RosMaglev” project include the length of the train with 71 wagons, which corresponds to the maximum length of the train on Russian railways. Each transport unit is capable of carrying a sea container. In this case, the rational length of the train depends on the stopping distance of the train. With the speed of 250 km/h planned for the “RosMaglev” project, this value exceeds 3 km. Technologically, the speed can be increased to 500 km/h, but the containers that exist today are not capable to withstand the impacts of the arising forces.

Vacuum transport projects, in particular Hyperloop, suggest the motion of single vehicles, which is a technologically inefficient solution. In addition, at the declared speeds (up to 1000 km/h), the above mentioned problem of container integrity arises. Operation at a speed of 250 km/h or lower does not require the creation of a vacuum space, which puts under question the feasibility of vacuum transport projects as a whole [16].

According to the operational properties, the “RosMaglev” project is at the leading position, the lowest efficiency is achieved with the use of vacuum transport.

From the environmental and safety points of view, railway transport has made significant progress in recent decades. However, the maglev and vacuum modes of transport are more environmentally friendly, which is due to the absence of emissions and other types of pollution, including noise.

In terms of safety, maglev transport is the most competitive, especially in comparison with vacuum transport. This is due to the fact that in an artificially created vacuum environment, there is an increased risk associated with a jump in the density of the medium. The slightest violation of the concentration of gas particles, a “wall” springs up before the vehicle, causing collision. With the current level of development of technology, vacuum transport becomes the most dangerous of all types of ground transport considered.

Results

Efficiency comparison of ground transport modes is given in the fig. 3.

As to the authors, for mass freight transportation by future transport the maglev transport with permanent magnets based on “RosMaglev” technologies is the future. It enables significant optimising infrastructure costs.

The second place would go to conventional railway transport. However, if the demand in transportation is low and the energy efficient traction rolling stock is implemented, the high-speed freight railway transport may be highly competitive, especially in countries with developed high-speed railway network. The vacuum transport holds firmly the third place.

As of today, vacuum transport technologies are still “raw” making it hard to forecast whether or not the Hyperloop, for example, will practically feasible. According to experts, taking into account the current level of scientific and technological progress and the dynamics of its change, to bring the transport technology to the stage of implementation requires from 30 to 50 years. Therefore, it can be said that the time for maglev transport, as the next stage in the development of railway transport, has already come. This has already been proved both technologically and economically. Whether the time for vacuum technologies will come, as the next stage in the development of maglev transport, will become clear in 20-25 years.

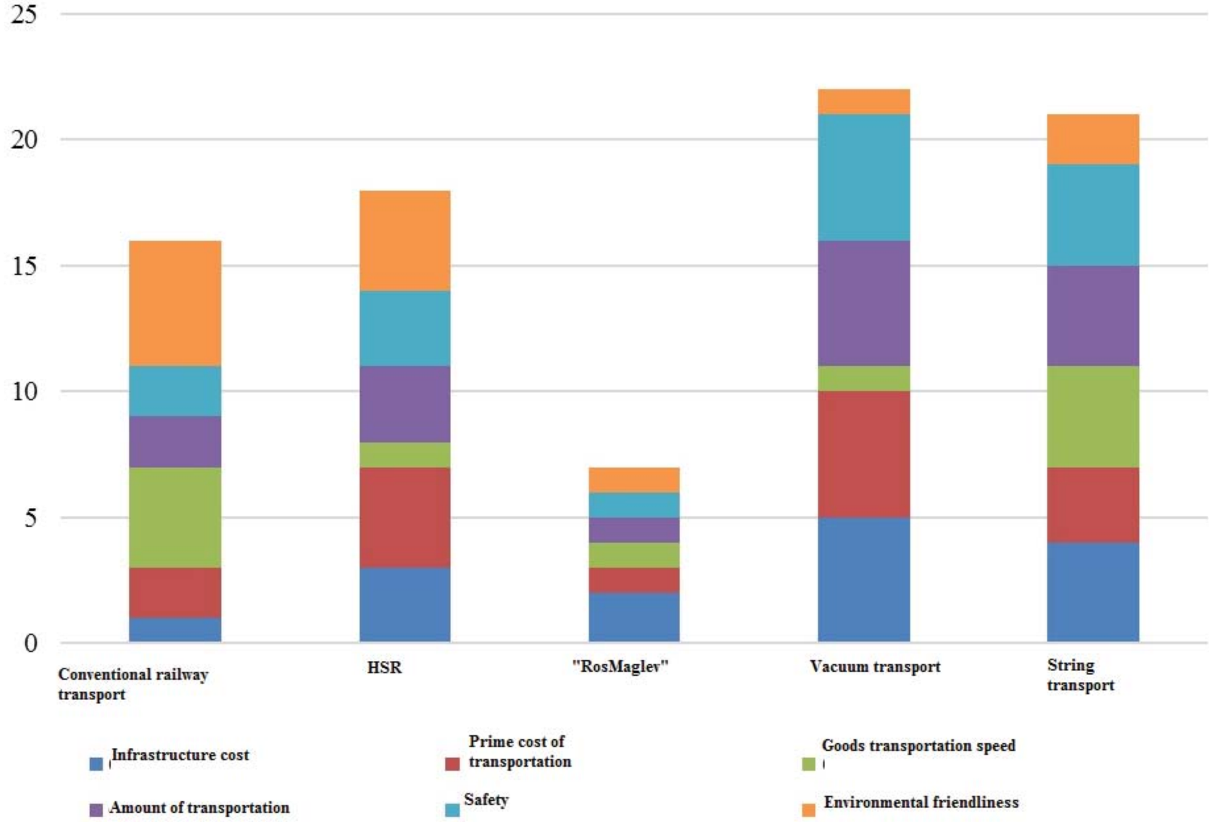

Fig. 3. Table showing efficiency of ground transport modes for mass freight transportation

Conclusion

The relevance of maglev transport implementation for mass freight transportations is obvious. The maglev technologies now in use in many countries for carrying passengers have proved profitable, safe and convenient. Technical "maturity" of these technologies allows considering all points and factors when constructing maglev freight lines which is very topical due to increasing need in searching transport routes alternative to sea routes.

Despite the today's level of vacuum and string projects related technologies, their practical feasibility is a long-term perspective requiring large investments at testing stages and thorough safety analysis.

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Information about the authors:

Sergei A. SMIRNOV, Senior Researcher.
E-mail: noc-pgups@yandex.ru
Olga Yu. SMIRNOVA, Researcher.
E-mail: noc-pgups@yandex.ru
Scientific and Educational Centre for Innovative Development of Railway Passenger Transportation