Rubric 4. TRANSPORT ECONOMICS

DOI 10.17816/transsyst202394108-116

© L.F. Kazanskaya, N.V. Batalova
Emperor Alexander I Petersburg State Transport University
(St. Petersburg, Russia)

INNOVATIVE TECHNOLOGIES IN THE DEVELOPMENT OF HIGH-SPEED GROUND TRANSPORT

Aim: is a comparative analysis of the technical and economic characteristics of various types of land rail transport.

Methods: comparative analysis, structuring of high-speed traffic processes, logical analysis of the cause-and-effect organization of the high-speed highways, made it possible to formalize the technical advantages of maglev transport technology in comparison with the construction of high-speed highways.

Results: A key trend has been identified to increase traffic speeds, requiring the convergence of various transport systems. The main criteria for innovative high-speed ground transport systems are classified. It is substantiated that increasing the level of technical characteristics of innovative technologies in the development of high-speed ground transport will allow maglev transport to become a key link in multimodal transport corridors. A comparison of the technical and economic characteristics of various types of land railway transport confirms that the introduction of MLTT into the transport complex will be able to significantly influence the matrix of the transport industry and accumulate both the passenger flow of air and rail traffic, as well as part of the containerized cargo, and become a key link in the multimodal transport corridors of the Russian Federation.

Conclusion: The conclusions are based on a representative sample of data on the innovative, technological and economic parameters of two high-speed rail construction technologies: wheel-rail and magnetic levitation.

Key words: high-speed highways, magnetic levitation, convergence.

Рубрика 4. ЭКОНОМИКА ТРАНСПОРТА

УДК [UDC] 338.47

© Л.Ф. Казанская, Н.В. Баталова
Петербургский государственный университет путей сообщения Императора Александра I
(Санкт-Петербург, Россия)

ИННОВАЦИОННЫЕ ТЕХНОЛОГИИ В РАЗВИТИИ ВЫСОКОСКОРОСТНОГО НАЗЕМНОГО ТРАНСПОРТА

Цель: сравнительный анализ технико-экономических характеристик различных видов наземного рельсового транспорта.

Received: 24.11.2023 **Revised: 28.11.2023** **Accepted: 30.12.2023**
Поступил: 24.11.2023 **Одобрена: 28.11.2023** **Принята: 30.12.2023**

Методы: сравнительный анализ, структурирование процессов высокоскоростного движения, логический анализ причинно-следственной организации высокоскоростных магистралей, позволили формализовать технические преимущества технологии маглев-транспорта по сравнению со строительством высокоскоростных магистралей.

Результаты: выявлена ключевая тенденция увеличения скоростей движения, требующая конвергенции различных транспортных систем. Классифицированы основные критерии инновационных систем высокоскоростного наземного транспорта. Обосновано, что повышение уровня технических характеристик инновационных технологий при развитии высокоскоростного наземного транспорта позволит маглев-транспорту стать ключевым звеном в мультимодальных транспортных коридорах. Сравнение технико-экономических характеристик различных видов наземного железнодорожного транспорта подтверждает, что внедрение МЛТТ в транспортный комплекс сможет существенно повлиять на матрицу транспортной отрасли и аккумулировать как пассажиропоток воздушного и железнодорожного сообщения, так и часть контейнерных грузов, и стать ключевым звеном мультимодальных транспортных коридоров Российской Федерации.

Заключение: сделано на основе репрезентативной выборки данных об инновационных, технологических и экономических параметрах двух технологий строительства высокоскоростных железных дорог: колесно-рельсовой и магнитно-левитационной.

Ключевые слова: высокоскоростные магистрали, магнитная левитация, конвергенция.

INTRODUCTION

The 21st century for the Russian Federation is the time of realizing the country’s territorial potential through the commissioning of transport infrastructure, the peak capacity of which has today reached its maximum with existing production capacities. A further increase in route speeds will depend on the design features of the processes dictated by the design features of railway transport. This trend applies to both the freight and passenger transportation sectors. To solve this problem, new transport technologies are required. And in the first place in these technologies there should be convergence, that is, the unification of railway, road, aviation and other transport systems on one basis, “borrowing” the advantages of one type of transport into the development of technologies and technical solutions of others. Scientists and practitioners of the transport industries in many countries around the world have come to the conclusion that the concept of transport of the future is generally based on the idea of convergence of several modes of transport.

MATERIALS AND METHODS

The construction of high-speed transport lines is the main driver in the develop-ment of high-speed ground transport trends. At the same time, the key

Received: 24.11.2023 **Revised: 28.11.2023** **Accepted: 30.12.2023**
Поступил: 24.11.2023 **Одобрена: 28.11.2023** **Принята: 30.12.2023**

fact in the field of construction of extended transport networks is that the profit received by the carrier from the direct provision of transport services is significantly less than the income received by the state due to the growth of the tax base and business activity of the population in these regions [1-3]. A striking example of this is the doubling of real estate and land prices in regions of France integrated by high-speed highway corridors (HSR) into a single transport system.

However, the creation of a comprehensive integrated transport network in Russia is a task that cannot be solved only by already tested and implemented technologies, primarily based on the “wheel-rail” principle.

Traditional rail transport has exhausted its development potential at 350 km/h, mainly for the following reasons:

• losses due to the action of dissipative friction forces caused by the “wheel-rail” joint;

• technical features of current collector. Current collectors are subject to exponential wear at speeds above 400 km/h;

• increased wear and tear of the infrastructure, which necessitates the use of damping mats and frequent repairs;

• increased wear of overpasses, in which, due to the large distance between the wheel pairs, a large value of the dynamic coefficient is observed, calculated according to Eurocode methods [4] (a hypothetical increase in speeds to 500 km/h will lead to the appearance of resonant peaks that are multiples of the resonant frequency, requiring a significant increase in strength and material consumption of structures).

This work uses such research methods as comparative analysis, structuring of high-speed traffic processes, logical analysis of the cause-and-effect organization of high-speed lines, which made it possible to formalize the technical advantages of maglev transport technology in comparison with the construction of high-speed highways.

RESULTS

Russia has a much larger territory than Japan, South Korea, Germany, and France, where the integration of high-speed lines into the transport complex has successfully completed its tasks. In Russia, the average distance between key socio-economic centers is 190 km in the European part and 320 km beyond the Urals. In the above countries, the same is usually the length of the entire HSR line, on the basis of which we can conclude that the speeds that the HSR can provide (350 km/h) will have a significantly smaller consolidating effect in the conditions of socio-economic centers dispersed throughout Russia. This fact is confirmed by the experience of the People's Republic of China, where the high-speed railway can with great difficulty provide a comfortable trip duration (2.5-4

Received: 24.11.2023 Revised: 28.11.2023 Accepted: 30.12.2023
Поступил: 24.11.2023 Одобрена: 28.11.2023 Принята: 30.12.2023

hours) between the main economic centers Beijing - Shanghai (1318 km - trip duration 4.48 hours)[5].

It is generally accepted that high-speed railway lines cannot ensure the transportation of goods. Therefore, the decision to build a high-speed highway is made solely on the basis of the parameters of existing and projected passenger flows in this direction. Today, the estimate of the profitable HSR passenger flow is from 7 to 14 million passengers per year [6]. This leads to the a priori impossibility of constructing HSR lines in all directions in Russia, except Moscow-St. Petersburg. The main disad-vantages of high-speed rail construction in Russia are presented in Fig. 1.

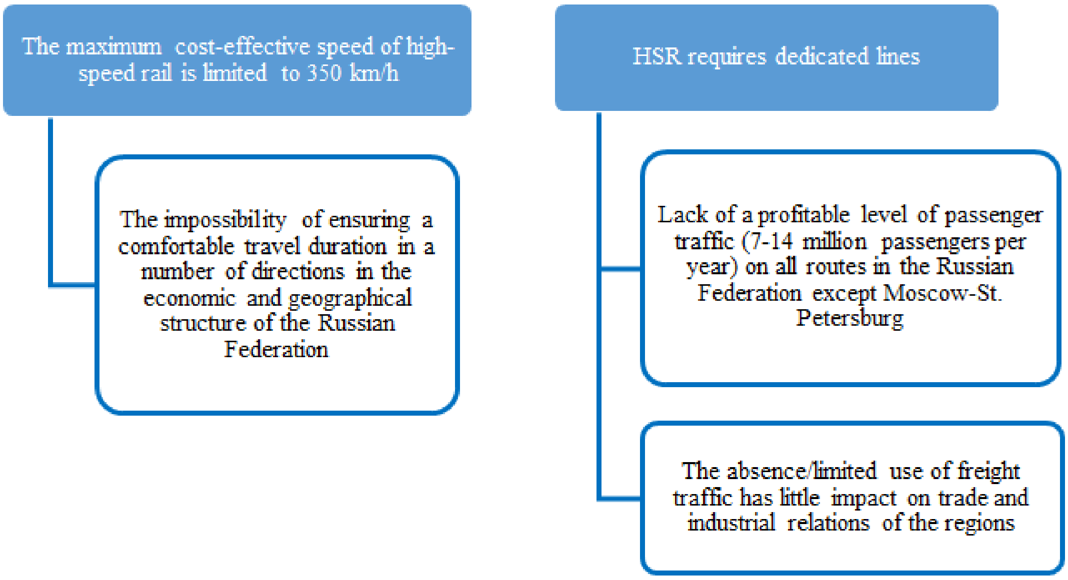

Fig. 1. The main disadvantages of high-speed rail construction in the conditions of the Russian Federation

The line designs of most high-speed lines provide for the possibility of moving freight trains with a C8 load at normal speed, which will entail corresponding logistical difficulties in coordinating schedules.

It is obvious that the search for solutions to improve transport accessibility and carrying capacity in Russia lies in the field of innovative solutions. Our colleagues have defined the concept of innovative high-speed ground transport systems (HSGTS) as systems that meet the following criteria [7]:

1. Cost-effective transportation speed is 600 km/h, which makes it possible to compete with air transport in almost all directions of the continental part of Russia (transportation lengths up to 5000 km).

2. A significant change in the current matrix of the transport industry with the introduction of HSGTS into the transport complex due to the dragging of passenger traffic and cargo traffic.

To date, there are various HSGTS concepts (magnetic levitation transport;

Received: 24.11.2023 Revised: 28.11.2023 Accepted: 30.12.2023
Поступил: 24.11.2023 Одобрена: 28.11.2023 Принята: 30.12.2023

vacu-um train; hovercraft trains; trains using screen effect), the unifying parameters of which are the absence of direct contact between the train and the guide track, as well as significant potential over traditional technology based on contact "wheel-rail", which provides the following advantages:

- reduced wear and tear of infrastructure;
- increasing the cost-effective speed range;
- great potential for reducing energy consumption.

The most proven technology, with functioning prototypes and commercial lines, is maglev transport technology (MLTT), which has objectively historically surpassed other subtypes according to a number of criteria [8]:

- testing;
- possibility of precise control;
- line scalability;
- prospects due to the emergence of high-temperature superconductors.

At the same time, the experience of constructing pilot routes has shown that, de-spite the innovativeness of maglev equipment, the main cost item is the construction of transport infrastructure (spans and overpasses), which amounts to 60-80 % of the total project budget [9]. Research conducted by employees of the “Bridges” department of the Emperor Alexander I St. Petersburg State Transport University revealed the key features of the interaction of maglev transport together with overpass structures [10].

Calculations verified in two software packages Midas Civil and Sofistik showed significant differences in the load transfer of maglev transport from the traditional wheel-rail technology. The nature of the differences is as follows: due to the significantly smaller characteristic distance between individual suspension magnets in MLTT than between pairs of wheels in wheel-rail systems (0.258 m and 16-22 m, respectively), a smoother response of the span is achieved when the train moves along it resonant speeds. A clear example of this is the comparative graphs of the movement of the middle of the span when a maglev train and a Thalus high-speed train pass through it (Fig. 2, 3).

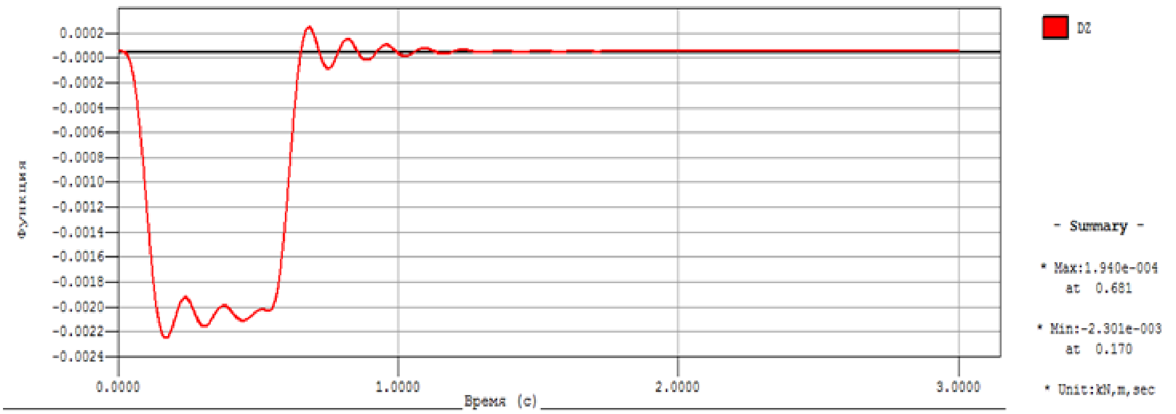

Fig. 2. Movements of the center of the superstructure during the passage of the Transrapid maglev train at a speed of 500 km/h [10]

Received: 24.11.2023 Revised: 28.11.2023 Accepted: 30.12.2023
Поступил: 24.11.2023 Одобрена: 28.11.2023 Принята: 30.12.2023

Due to these differences, beam span structures for maglev transport can combine the following advantages:

• less weight;
• the ability to handle heavier loads, including freight trains;
• high efficiency of material use;
• reduction of operating costs.

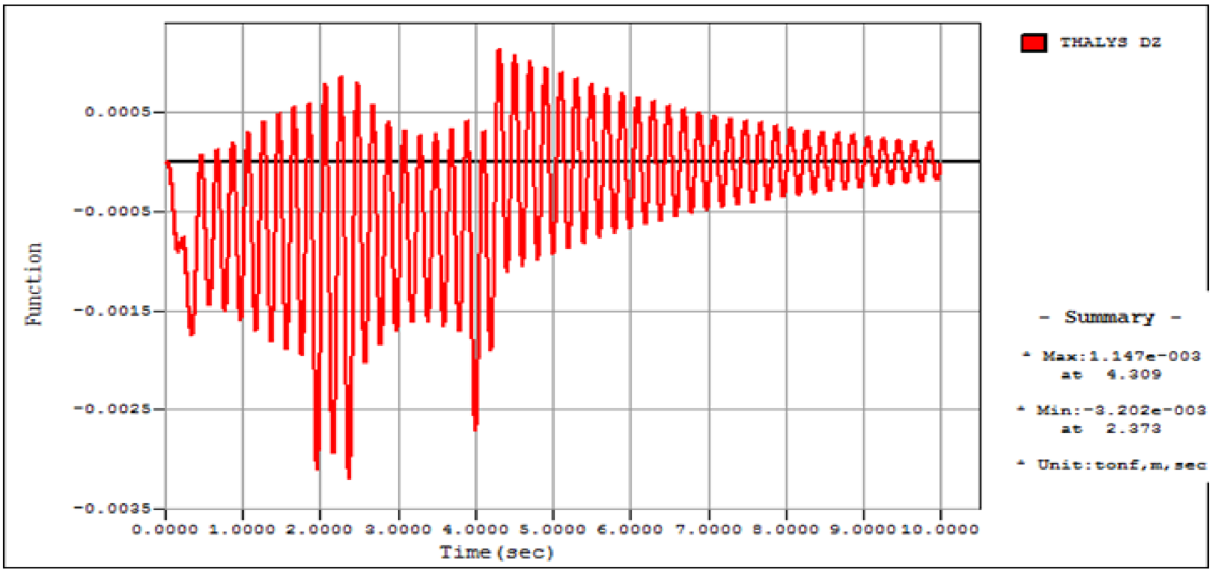

Fig. 3. Movements of the center of the superstructure during the passage of a Thalus train at a speed of 350 km/h [10]

In the context of the construction of large-scale developed high-speed transport networks, the use of MLTT will have a positive multiplier effect by reducing costs at all stages of construction. In addition, the introduction of MLTT into the transport complex will be able to significantly influence the matrix of the transport industry and accumulate both the passenger flow of air and rail traffic, as well as part of the containerized cargo, and become a key link in the multimodal transport corridors of the Russian Federation.

A comparative analysis of the main time parameters of a trip on the Moscow-St. Petersburg direction between the high-speed modes of transport existing today and the maglev line is presented in Fig. 4. Due to a higher level of speeds, carrying capaci-ty and, as a result, a unique trade offer, the maglev line between St. Petersburg and Moscow can capture the entire total passenger flow, which is currently accumulated by aviation and railway traffic (9.3 million people).

Received: 24.11.2023 Revised: 28.11.2023 Accepted: 30.12.2023
Поступил: 24.11.2023 Одобрена: 28.11.2023 Принята: 30.12.2023

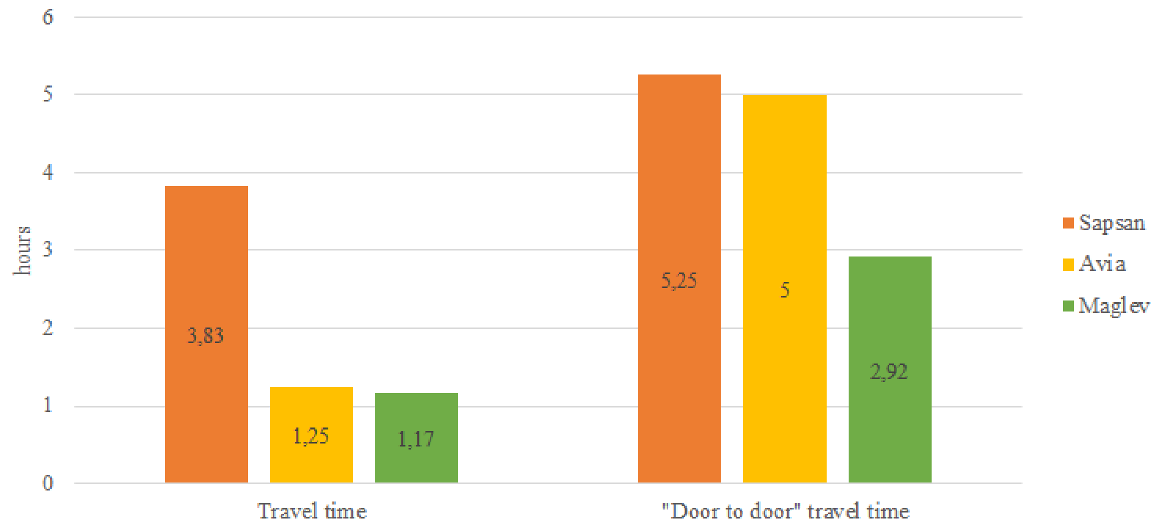

Fig. 4. Comparison of the main time parameters of a trip
on the Moscow - St. Petersburg direction by high-speed modes of transport

A comparative analysis of technical characteristics between HSR and HSGTS is shown in Table.

Table. Specifications of HSR and HSGTS

Specifications	HSR	HSGTS
Representatives	TVG, ICE, KTX etc.	Vacuum Maglev
Maximum cost-effective speeds, km/h	350	600/1000*
Effective range, km	1400	5000 and more
Possibility of cargo transportation	No freight/limited traffic at speeds up to 140 km/h	Possibility of cargo transportation without speed limits

**in the traditional version on a trestle/in a pipe with low pressure (technical vacuum)*

It is worth noting that the economic description of such projects can be viewed from different angles, since transport systems, unlike other sectors of the economy, are not capable of quickly responding to changes, for example, a change in techno-logical structure [11, 12].

CONCLUSION

Changes in the scientific and technical sphere of recent decades have significantly influenced new trends in the development of the transport sector. MLLT is a product of the convergence of various transport systems, which is actively involved in the transformation of the world economy, and the creation of systems that meet the criteria of HSGTS will contribute to a significant improvement in transport accessibility of the regions of the Russian Federation

Received: 24.11.2023 Revised: 28.11.2023 Accepted: 30.12.2023
Поступил: 24.11.2023 Одобрена: 28.11.2023 Принята: 30.12.2023

and eliminate the shortcomings of traditional high-speed rail "wheel-rail" systems within the framework of the economic and geographical location of Russian Federation [13, 14].

References

1. Integrated transport system. Center for Strategic Development. Available on: https://www.csr.ru/upload/iblock/9f5/9f59e8789c4af88f7a67ce69c17d288e.pdf [cited 2023 Sep 20]. (In Russ).
2. Kazanskaya L. Development of high-speed rail transport as a factor in increasing the competitiveness of the country's national economy. *Economics and management in the 21st century: current issues, achievements and innovations*. Penza; 2017. pp. 55-63. (In Russ.). The link is active on: 28.09.2023. Available from: https://elibrary.ru/item.asp?edn=ylsfgz
3. Misharin A. Aspects of creating an integrated network of high-speed and high-speed communication in the Russian Federation. *Transport of the Russian Federation*. 2014;2(51):9-13. (In Russ). The link is active on: 28.09.2023. Available from: https://e-library.gumrf.ru/cgi
4. Special technical conditions. Artificial structures on the site Moscow-Kazan high-speed railway Moscow-Kazan-Yekaterinburg. Technical standards and requirements for design and construction. (In Russ.). [cited 2023 Sep 20] Available from: https://www.rzd.ru/api/media/resources/c/1/121/72402?action=download
5. China in the fast lane: bullet train and maglev. [Internet]. [cited 2023 Sep 20]. Available on: https://asiatimes.com/2018/08/china-in-the-fast-lane-bullet-trains-and-maglev-lines/
6. Igolkin G. Prospects for the use of control automation systems in magnetic levitation transport technology. *Technologies for constructing cognitive transport systems*. Materials of the All-Russian Scientific and Practical Conference. May 30-31, 2018. St. Petersburg: IPT RAS, 2018, 278 p. (In Russ.). The link is active on: 28.09.2023. Available from: https://www.iptran.ru/images/pdf/Cognitive_transport_systems_2018.pdf?ysclid=lpujn8xgxa276168836
7. Igolkin G, Pegin P. Formation of the concept of innovation systems high-speed ground transport. *Bulletin of Civil Engineers*. 2018;4(69):181-189. (In Russ.). doi: 10.23968/1999-5571-2018-15-4-181-188
8. Lapidus B. Magnetic levitation is the fundamental basis for super high-speed vacuum-levitation technologies. *Transportation Systems and Technology*. 2018;4(3):26-35. doi: 10.17816/transsyst29184326-35
9. Walraven JC, Romeijn A, Hoogenboom CJ. Dynamic Simulation of the Maglev Guideway Design. *Delft University of Technology*. 2008:145. The link is active on: 28.09.2023. Available from: https://www.researchgate.net/publication/245281868
10. Igolkin G, Dyachenko L, Smirnov V, Pegin P. Peculiarities dynamic interaction of magnetic levitation high-speed transport and bridge structures. *Bulletin of scientific research results.* 2018;1:111-118. (In Russ.). The link is active on: 28.09.2023. Available from: http://brni.info/archive/2018/1.html
11. Zhuravleva N. Conceptual framework for assessing development effects projects of high-speed transport systems based on magnetic levitation. *Transportation Systems and Technology*. (In Russ.). 2019;5(1):89-102. doi:10.17816/transsyst20195189-102

Received: 24.11.2023 **Revised: 28.11.2023** **Accepted: 30.12.2023**
Поступил: 24.11.2023 **Одобрена: 28.11.2023** **Принята: 30.12.2023**

12. Smirnov SA, Smirnova OY. Features of the assessment of socio-economic effects arising from the construction of lines of freight maglev transport. *Modern Transportation Systems and Technologies*. 2022;8(3):142-156 (In Russ.). doi: 10.17816/transsyst202283142-156

13. Smirnov SA, Smirnova OYu. Prospects of maglev transport in the unified integrated transport system Eurasian economic union. *Modern Transportation Systems and Technologies*. (In Russ.). 2023;9(2):110-120. doi: 10.17816/transsyst202392110-120

14. Zaitsev A, Klühspies J, Kircher R, et al. Maglev 2018. Abstracts of the 24th International Conference. St. Petersburg, Russian Federation. The link is active on: 28.09.2023. Available from: http://mtstpgups.ru/pictures/mtst18-maglev2018/Theses-correction-30072018.pdf

Сведения об авторах:
Казанская Лилия Фаатовна, доктор технических наук, профессор;
eLibrary SPIN: 6073-9446; ORCID: 0000-0002-8734-1064; Scopus ID: 57205125533;
E-mail: yalifa@inbox.ru
Баталова Наталья Владимировна, старший преподаватель;
eLibrary SPIN: 4027-4771, ORCID: 0000-0002-5948-7226;
E-mail: natalyabatalova@yandex.ru

Information about the authors:
Lilia F. Kazanskaya, Doctor of technical sciences, Professor;
eLibrary SPIN: 6073-9446; ORCID: 0000-0002-8734-1064; Scopus ID: 57205125533,
E-mail: yalifa@inbox.ru
Natalia N. Batalova, Senior Lecturer;
eLibrary SPIN: 4027-4771, ORCID: 0000-0002-5948-7226;
E-mail: natalyabatalova@yandex.ru

Цитировать:
Казанская Л.Ф., Баталова Н.В. Инновационные технологии в развитии высокоскоростного наземного транспорта // Инновационные транспортные системы и технологии. – 2023. – Т. 9. – № 4. – С. 108–116. doi: 10.17816/transsyst202394108-116

To cite this article:
Kazanskaya LF, Batalova NV. Innovative technologies in the development of high-speed ground transport. *Modern Transportation Systems and Technologies.* 2023;9(4):108-116. doi: 10.17816/transsyst202394108-116

Received: 24.11.2023 **Revised: 28.11.2023** **Accepted: 30.12.2023**
Поступил: 24.11.2023 **Одобрена: 28.11.2023** **Принята: 30.12.2023**