UDC [УДК] 629.439.016.56
DOI 10.17816/transsyst20184326-35

**© B. M. Lapidus**
Joint Scientific Council of JSC Russian Railways,
UIC (International Union of Railways)
(Moscow, Russia)

# MAGNETIC LEVITATION AS THE FUNDAMENTAL BASIS FOR SUPERFAST VACUUM LEVITATION TRANSPORT TECHNOLOGIES

***Abstract.*** The article reviews the strategic trends of transport development that meet the modern requirements of the economy and society. It was revealed that the key trend is to increase the speed of traffic. To achieve breakthrough results in this direction, it is proposed to use magnetic levitation in combination with the use of a vacuum environment - the creation of vacuum-levitation transport systems. It is noted that the Joint Scientific Council of JSC Russian Railways formed the requirements for the creation of such systems and focused attention on the problem of the socio-economic efficiency of its creation. It was concluded that railway transport, in the interests of its strategic competitiveness, should be the initiator and active participant in the creation of vacuum-levitation transport systems, which, in turn, can become an important incentive for integrating the efforts of the world scientific community.

***Keywords:*** social and economic trends, strategic trends in transport development, convergence of transport systems, magnetic levitation, vacuum-levitation transport systems, scientific priorities of speed increase, intermodal transportation, business cooperation of transport systems.

**© Б. М. ЛАПИДУС**
Объединенный ученый совет ОАО «РЖД»,
Международный Союз железных дорог
(Москва, Россия)

# МАГНИТНАЯ ЛЕВИТАЦИЯ – ФУНДАМЕНТАЛЬНАЯ ОСНОВА ДЛЯ СВЕРХСКОРОСТНЫХ ВАКУУМНО-ЛЕВИТАЦИОННЫХ ТРАНСПОРТНЫХ ТЕХНОЛОГИЙ

***Аннотация.*** В статье проанализированы стратегические тренды развития транспорта, отвечающие современным требованиям экономики и общества. Выявлено, что ключевой тренд – повышение скорости движения. Для достижения прорывных результатов в этом

**Received: 01.08.2018. Revised: 01.08.2018. Accepted: 01.10.2018.**
**Transportation Systems and Technology. 2018;4(3):26-35**

**doi: 10.17816/transsyst20184326-35**

направлении весьма перспективно применение магнитной левитации в сочетании с использованием вакуумной среды – создание вакуумно-левитационных транспортных систем. Отмечено, что Объединенным ученым советом ОАО «РЖД» сформированы требования к созданию таких систем, сфокусировано внимание на проблеме социально-экономической эффективности их создания. Сделано заключение, что железнодорожный транспорт в интересах своей стратегической конкурентоспособности должен быть инициатором и активным участником создания вакуумно-левитационных транспортных систем, что, в свою очередь, может стать важным стимулом для интеграции усилий мирового научного сообщества.

***Ключевые слова:*** социально-экономические тенденции, стратегические тренды развития транспорта, конвергенция транспортных систем, магнитная левитация, вакуумно-левитационные транспортные системы, научные приоритеты повышения скорости движения, интермодальные перевозки, бизнес-кооперация транспортных систем.

The global and economic tendencies which formed themselves at the end of XX and beginning of XXI century, demand drastic acceleration of transport communication. The establishment of new transport systems is a crucial task, successful solution of which will broadly determine increase of life quality and trade and economic efficiency of the regions, cities, and countries. When choosing a direction of research, one needs assess risks and possibilities associated therewith, and develop certain relative actions.

## STRATEGIC TENDENCIES IN TRANSPORT DEVELOPMENT

Macro-and microeconomic requirements for a transport system are characterised by factors which produce decisive influence on evolution of transport [1]. Among them, five factors are distinguished:

- increase of life quality of population;
- increase of human capital cost;
- deepening of interregional demographic disproportions;
- increase of demographic and industrial impact on environment;
- decrease of resource intensity of economy, perfection of raw materials processing techniques, increase of final products share in the transportation structure.

With these factors in mind, the global requirements for future transport systems are becoming speed acceleration, safety, namely environmental safety, energy efficiency, passenger services flexibility, and integration into multimodal transport systems.

Received: 01.08.2018. Revised: 01.08.2018. Accepted: 01.10.2018.
Transportation Systems and Technology. 2018;4(3):26-35

doi: 10.17816/transsyst20184326-35

Figure 1 shows today's modes of transport which hold leading positions or are aspirant to take leading positions at the transportation market. In terms of safety, namely environmental safety, the first position is held by railway transport, whereas remainder of positions is held by car, pipeline, aircraft, and maritime transports. The strategic benchmarks for railway transport are increase of service flexibility, provision of intermodality, and speed acceleration. Altogether, these strategic trends are most rapidly developing in car transport, which demonstrates aspiration to leadership in the growing segment of society's requirements for transport services.

Due to population growth, increase of human capital cost [2], and value of time, the demand and requirements for high-speed passenger transportation development are also on the rise. These tendencies are verified by boosting growth of high-speed railways (HSR) construction over the last decade [3]. In China alone, over 22 thousand kilometres of HSR were built, that is more than elsewhere in the world. According to UIC forecast, this dramatic development of HSR global network will continue in the future.

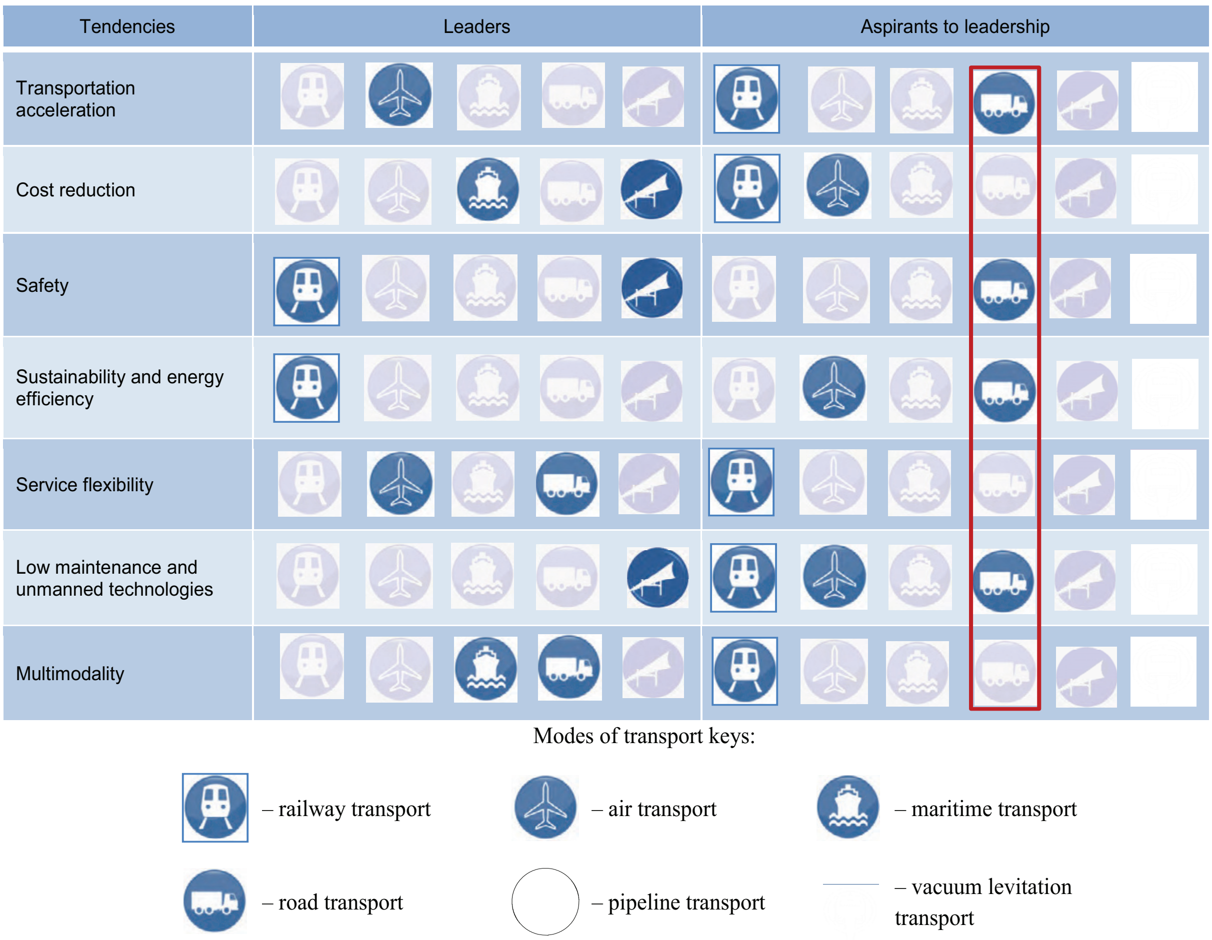


Fig. 1. Strategic tendencies in transport system development

Received: 01.08.2018. Revised: 01.08.2018. Accepted: 01.10.2018.
Transportation Systems and Technology. 2018;4(3):26-35

doi: 10.17816/transsyst20184326-35

As a modern tendency, the "borrowing" of one transport mode's advantages by another for its subsequent development is considered. For instance, train speed is approaching that of aircraft, and load and passenger capacity of the latter are striving for that of railway counterparts. It was not by coincidence that the term "transport systems convergence" was introduced. And the technological borrowing of transport systems' elements is called "synergetic evolution of transport systems". There are projects that have been developed and implemented, where technological solutions of a train, car transport and even aircraft converge. Quite promising is the railway channel that unites maritime and railway transports (carrying of ships by rail), which enables covering hundreds of kilometres without the need to construct water channels. The air-and-railway projects, suggested by Tomsk (a city in Russia) scientist Boris Weinberg represent interest as well [6]. Today, the idea of "floating trains" is crystallised in such projects as magnetic levitation and vacuum levitation trains. In this regard, it is required that the projects of ET3 [7] and actively realised Hyperloop as well as the concept of "plain trains" should be emphasised [4].

At the same time, the tendency of XXI century is to achieve high speed together with the use of alternative energy sources, traction transmission mode, and artificial environment for traffic in transport systems.

## PROSPECTS OF MAGNETIC LEVITATION IN COMBINATION WITH VACUUM ENVIRONMENT

The application of magnetic levitation combined with vacuum seems promising for transport systems [8, 9]. These solutions foster overcoming the most energy-intensive hindrances to transport systems traffic – wheel-rail contact [12, 13], and air resistance [12, 13]. The application of evacuated environment with 100 times and more reduced pressure on transport, provides opportunity to double speed performance of the magnetic levitation system "train-infrastructure". Whereas, the application of a deeper near-vacuum environment will enable achieving the speeds of five or six times higher than the maximum one [14].

The scientific basis for solving technical and technological, and economic issues is being actively developed in Russia at present. Basing on the findings of the studies conducted by JSC "Russian Railways" Joint Scientific Council, the technical requirements for development and vacuum levitation transport system (VLTS) have been designed, which are summarised in the monograph [5]. The viability of VLTS, namely in Russian conditions, has been proven, in

Received: 01.08.2018. Revised: 01.08.2018. Accepted: 01.10.2018.

Transportation Systems and Technology. 2018;4(3):26-35
doi: 10.17816/transsyst20184326-35

terms of potential competitiveness at medium distance (500–1000 km) and long distance transportation (over 1000 km), provided that there is logistics and digital cooperation of new transport system with conventional railway network.

As a result of the activity of JSC "Russian Railways" Joint Scientific Council [15 – 17], it was made possible to identify future technical requirements for VLTS construction. These must cover basic parameters of VLTS infrastructure and rolling stock, methods of air resistance reduction in vacuum, achieving movement using magnetic levitation, and creating of safety and risks assessment systems.

## SCIENTIFIC PRIORITIES FOR CONSTRUCTION OF VACUUM LEVITATION TRANSPORT

In the process of working out the concept, the following priorities were determined to achieve speeds of 1 000–12 000 km/h with 100 times reduction of resistance.

1. Determination of major infrastructure parameters:
- proportion of sizes and dimensions;
- terra-efficiency;
- stations and passing loops;
- minimal curvatures.

2. Ensuring traffic based on magnetic levitation: constructive solutions for propulsion, acceleration, and braking.

3. Provision of safety systems:
- physiological hindrances;
- incidents;
- technological and man-induced risks.

4. Determination of major vehicle parameters:
- geometric parameters;
- aerodynamic form;
- equipment;
- materials.

5. Achieving resistance reduction:
- near vacuum;
- rarefied medium;
- alternative physical principles of movement.

6. Reproduction of life supporting systems:
- life supporting for passengers;

Received: 01.08.2018. Revised: 01.08.2018. Accepted: 01.10.2018.

Transportation Systems and Technology. 2018;4(3):26-35
doi: 10.17816/transsyst20184326-35

- heat profile;
- sources and accumulators of energy.

7. Choosing principles, methods, and equipment to construct the near-vacuum infrastructure or to reduce resistance;

8. Assessment of contingency and relevance of replacement of the near vacuum in the infrastructure of the transport system with light gas medium corresponding to relative resistance reduction objectives;

9. Assessment of contingency of application of alternative physical principles and constructive solutions for additional reduction of resistance to the maglev system pod.

10. Assessment of energy optimality in power supply systems relying on existing energy sources, and possibility to accumulate heat and kinetic energy during the train movement;

11. Assessment calculations-based forecast of heat profile of vehicles and infrastructure for various movement modes within the speed range of 0–1 200 km/h;

12. Constructive solutions for passengers' onboard life supporting systems.

## IDENTIFICATION OF A NICHE IN THE MARKET FOR INNOVATIVE TRANSPORT SYSTEMS

One of the crucial economic issues is to identify a commercial niche in the transport services market so as to make the projects profitable and promising. The main technology related prerequisite for mass operation of VLTS consists in promptest solving the fundamental task of achieving superconductivity.

However, in our time the efficiency of any transport system, e.g. HSR [18], is achieved not only through their commercial operation. A more weighty contribution is made by creation of social and economic effects and associated businesses for investors [19].

Let us consider systematised requirements for development of energy sources, routes, increase of travel distance, and speed in each segment of the market (Fig. 2). In segments from 150 to 500 km it is promising to develop competitiveness between conventional railway and maglev transport, whereas in segments with over 500 km – VLTS; after finalising physical principles of creating levitation and reducing cost of maglev transport system elements, the latter will be used on a broader scale. These risks are significant for railway operator companies, therefore railway science and railway management should be interested in introduction of maglev systems and VLTS. The formation of these systems must be perceived

Received: 01.08.2018. Revised: 01.08.2018. Accepted: 01.10.2018.
Transportation Systems and Technology. 2018;4(3):26-35

doi: 10.17816/transsyst20184326-35

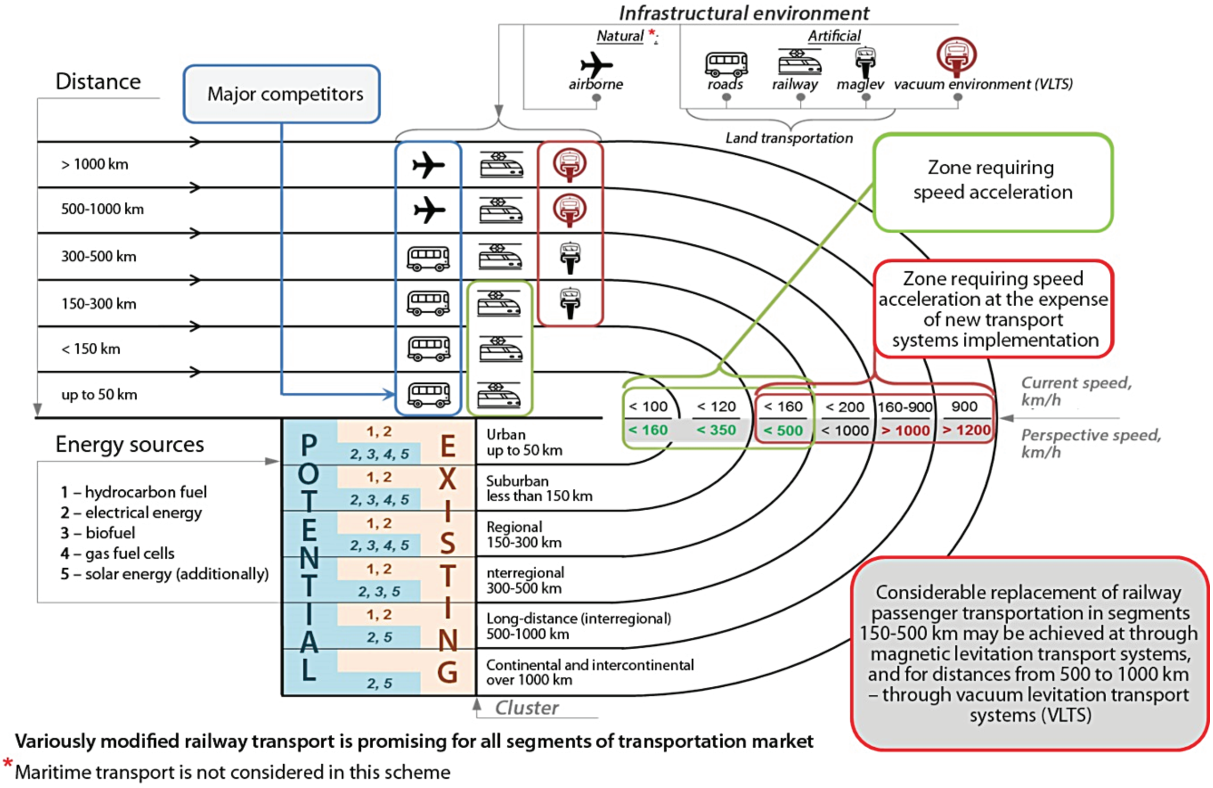


Fig. 2. Scheme of passenger transportation perspective development

as another stage of railway transport development. Other ways of thinking will inevitably result in drastic redistribution of business against the latter.

Thus, a key tendency in transport development, which addresses the social and economic challenges of today, is transportation speed increase. A revolutionary increase of transportation speed may be achieved using maglev in combination with vacuum environment, i.e. VLTS. The fundamental requirements for those are identified by JSC “RZD” Joint Scientific Council.

It is necessary to achieve convergence of VLTS and conventional railways, which will make implementation of maglev efficient and will serve for the benefit of railway business development. Firstly, construction of VLTS lines can be done above existing railway lines, i.e. the infrastructure cooperation is achievable. Secondly, realisation of intermodal transportation using VLTS lines and railway lines can provide an expanded logistics network and an immense transport services coverage. Thirdly, business cooperation: creation of VLTS may become a good business type and strategic investments into transport systems development.

The work over the promising maglev transport development projects must stimulate integration of the world society so as to accelerate in choosing the best constructive and technological solutions for XXI century transport.

Received: 01.08.2018. Revised: 01.08.2018. Accepted: 01.10.2018.
Transportation Systems and Technology. 2018;4(3):26-35

doi: 10.17816/transsyst20184326-35

## Библиографический список / References

1. Лапидус Б.М., Мачерет Д.А. Методология оценки и обеспечения эффективности инновационных транспортных систем // Экономика железных дорог. – 2016. – № 7. – С. 16–25. [Lapidus BM, Macheret DA. Metodologiya ocenki i obespecheniya ehffektivnosti innovacionnyh transportnyh system. *Ehkonomika zheleznyh dorog*. 2016;7:16-25. (In Russ.)].
2. Капелюшников Р.И. Сколько стоит человеческий капитал России? Часть I // Вопросы экономики. – 2013. – №1. – С. 27–47. [Kapelyushnikov RI. Russia's Human Capital: What Is It Worth? Part I. *Voprosy Ekonomiki.* 2013;1:27-47. (In Russ.)].
3. High Speed Rail: Fast Track to Sustainable Mobility. UIC Brochure, June 2015.
4. Лапидус Б.М., Лапидус Л.В. Железнодорожный транспорт: философия будущего. – М.: Прометей, 2015. – 232 с. [Lapidus BM, Lapisus LV. Zheleznodorozhnyi transport: filosofiya budushchego. Moscow: Prometey; 2015. 232 p. (In Russ.)].
5. Galen J. Suppes, A Perspective on Maglev Transit and Introduction of the PRT Maglev. *Transportation Research Record.*1995;1496:103-111.
6. Вейнберг Б.П. Движение без трения. Доступно по: http://veinberg.o7.ru/pdf/no_friction_motion.pdf/. Ссылка активна на 09.08.2018. [Veinberg BP. Dvizhenie bez treniya. Available from: http://veinberg.o7.ru/pdf/no_friction_motion.pdf/. Accessed August 09, 2018. (In Russ.)].
7. Patent №USOO5950543A/ 14.09.1999. Daryl Oster. Available from: https://patents.google.com/patent/US5950543A/en.
8. Зайцев А.А., Юдкин В.Ф. Транспортная система для межстрановых и межконтинентальных перевозок на основе магнитной левитации // Русский инженер. – 2016. – № 4 (51). – С. 36–40. [Zaitsev AA, Yudkin VF. Transportnaya sistema dlya mezhstranovykh i mezhkontinental'nykh perevozok na osnove magnitnoi levitatsii. *Russkii inzhener*. 2016;4:36-40. (In Russ.)].
9. Зайцев А.А., Антонов Ю.Ф. Магнитолевитационная транспортная технология. – М.: ФИЗМАТЛИТ, 2014. – 476 с. [Zaitsev AA, Antonov YuF. Magnitolevitatsionnaya transportnaya tekhnologiya. Moscow: FIZMATLIT; 2014. 476 p. (In Russ.)].
10. Камчатный В.Г. Особенности динамики взаимодействия высокоскоростных объектов с рельсовой направляющей. // Испытания материалов и конструкций. – Нижний Новгород: Интелсервис. – 200 с. [Kamchatny VG. Osobennosti dinamiki vzaimodeistviya vysokoskorostnykh ob»ektov s rel'sovoi napravlyayushchei. *Ispytaniya materialov i konstruktsii.* Nizhny Novgorod: Intelservis. 200 p. (In Russ.)].
11. Камчатный В.Г., Бутова С.В. Опыт реализации в РФЯЦ-ВНИИЭФ высокоскоростного движения объектов по рельсовым направляющим. Научно-технические проблемы // Бюллетень Объединенного ученого совета ОАО «РЖД». 2013. №2. С. 38–44. [Kamchatny VG, Butova SV. Experience of realization of high-speed objects transportation on guide rails in RFNC – VNIIEF. Scientific-technical issues. *Bulletin of Joint Scientific Council of JSC Russian Railways.* 2013;2:38-44. (In Russ.)].
12. Кирякин В.Ю., Лежава В.Ш., Новгородцева А.В., и др. Об оценке оптимальной скорости вакуумных поездов и выборе глубины вакуума // Бюллетень Объединенного ученого совета ОАО «РЖД». 2016. №5. С. 26–38. [Kiryakin VYu, Lezhava VSh, Novgorodtseva AV, et all. An estimate of the vacuum trains optimum speed and the choice of vacuum level. *Bulletin of Joint Scientific Council of JSC Russian Railways*. 2016;5:26-38. (In Russ.)].

Received: 01.08.2018. Revised: 01.08.2018. Accepted: 01.10.2018.


doi: 10.17816/transsyst20184326-35

13. Воробьев И.А., Кондратенко Р.О., Нестеров С.Б., Белоконев А.Н. Оценка характеристик вакуумной среды и энергетических параметров инфраструктуры для вакуумно-левитационного транспорта // Бюллетень Объединенного ученого совета ОАО «РЖД». – 2016. – № 4. – С. 18–25. [Vorob'ev IA, Kondratenko RO, Nesterov SB, Belokonev AN. Evaluation of the vacuum environment characteristics and energy infrastructure parameters for vacuum levitation transport. *Bulletin of Joint Scientific Council of JSC Russian Railways*. 2016;4:18-25. (In Russ.)].
14. Вакуумно-левитационные транспортные системы: научная основа, технологии и перспективы для железнодорожного транспорта: коллективная монография членов и научных партнеров Объединенного ученого совета ОАО «РЖД» / Под ред. Лапидуса Б.М., Нестерова С.Б. – М.: ООО «РАС», 2017. – 192 с. [Lapidus BM, Nesterov SB, editors. Vakuumno-levitatsionnye transportnye sistemy: nauchnaya osnova, tekhnologii i perspektivy dlya zheleznodorozhnogo transporta: kollektivnaya monografiya chlenov i nauchnykh partnerov Ob»edinennogo uchenogo soveta OAO “RZhD”. Moscow: OOO RAS; 2017. (In Russ.)].
15. Кирякин В.Ю., Лежава В.Ш., Новгородцева А.В. Применение вакуумной среды для создания скоростных транспортных систем. Математическое моделирование обтекания объектов (метод дискретных вихрей) // Бюллетень Объединенного ученого совета ОАО «РЖД». – 2015. – № 6. – С. 28–36. [Kiryakin VYu, Lezhava VSh, Novgorodtseva AV. The use of a vacuum environment for creating highspeed transport systems. Mathematical modelling of flow around objects (the method of discrete vortices). *Bulletin of Joint Scientific Council of JSC Russian Railways*. 2015;6:28-36. (In Russ.)].
16. Зайцев А.А. Отечественная транспортная система на основе магнитной левитации // Бюллетень Объединенного ученого совета ОАО «РЖД». – 2015. – № 6. – С. 22–27. [Zaitsev AA. The domestic transport system based on magnetic levitation. *Bulletin of Joint Scientific Council of JSC Russian Railways*. 2015;6:22-27. (In Russ.)].
17. Воробьев И.А. и др. О возможностях, специфике, научных задачах по созданию вакуумной среды для транспортных систем // Бюллетень Объединенного ученого совета ОАО «РЖД». – 2016. – № 1–2. – С. 28–38. [Vorob’ev IA et al. The possibilities, specifics and scientific tasks of creating a vacuum environment for transport systems. *Bulletin of Joint Scientific Council of JSC Russian Railways*. 2016;1-2:28-38. (In Russ.)].
18. Лапидус Л.В. Социально-экономические эффекты высокоскоростного железнодорожного сообщения // Экономика железных дорог. – 2013. – № 12. – С. 58–63. [Lapidus LV. Sotsial'no-ekonomicheskie effekty vysokoskorostnogo zheleznodorozhnogo soobshcheniya. *Ekonomika zheleznykh dorog*. 2013;12:58-63. (In Russ.)].
19. Мишарин А.С. ВСМ – новый импульс развития экономики // Пульт управления. – 2015. – № 4. – С. 6–9. [Misharin AS. VSM – novyi impul's razvitiya ekonomiki. *Pul't upravleniya*. 2015;4:6-9. (In Russ.)].

**Information about the author:**
**Boris M. Lapidus**, Doctor of Economics, professor;
eLibrary SPIN: 6429-2736; ORCID: 0000-0002-4887-4255;
E-mail: lapidusbm@mail.ru

Received: 01.08.2018. Revised: 01.08.2018. Accepted: 01.10.2018.


doi: 10.17816/transsyst20184326-35

**Сведения об авторе:**
**Лапидус Борис Моисеевич**, д.э.н., профессор;
eLibrary SPIN: 6429-2736; ORCID: 0000-0002-4887-4255;
E-mail: lapidusbm@mail.ru

**To cite this article:**
Lapidus BM. Magnetic Levitation as the Fundamental Basis for Superfast Vacuum Levitation Transport Technologies. *Transportation Systems and Technology.* 2018;4(3):26-35. doi: 10.17816/transsyst20184326-35

**Цитировать:**
Лапидус Б.М. Магнитная левитация – фундаментальная основа для сверхскоростных вакуумно-левитационных транспортных технологий // Транспортные системы и технологии. – 2018. – Т. 4. – № 3. – С. 26-35. doi: 10.17816/transsyst20184326-35