«ECOLOGICAL IMPERATIVE» AND INNOVATIVE DEVELOPMENT OF TRANSPORT

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ABSTRACT

The article considers one of the key characteristics of the new industrial revolution which is the increase in environmental friendliness of production or the «ecological imperative». Areas for improving environmental friendliness in the transport sector have been identified, and a number of inventions (innovative proposals) have been analyzed that contribute to the implementation of the ecological imperative. On the basis of the analysis, a matrix classification of innovations is presented, representing innovations significant for transport, primarily railway. Conclusions are drawn regarding the long-term development of rail transport in order to improve its environmental friendliness, an adequate response to the global challenges of the future.

Keywords: railway transport, ecological imperative, innovative development, economic growth, energy efficiency, bionics.

Background. *The appearance of railways became one of the results of the industrial revolution of the beginning of the 19th century, which opened a new era in the economic history of mankind – the era of modern economic growth. All the further, almost two-centuries long, development of the railway industry occurred in close relationship with subsequent industrial revolutions, which are differently classified by different researchers, but under any classification it is obvious that they had impact on the development of railways and that this development, in turn, contributed to the deployment of each subsequent industrial revolution and the formation of prerequisites for a new one [1].*

Therefore, while forecasting the prospects of the railway industry and transport in general, trying now to prepare possible answers to probable future challenges, it is necessary to very carefully monitor new trends in economic development in order not to miss the start of another industrial revolution that will certainly generate both new requirements and new opportunities for transport.

Objective. *The objective of the authors is to consider «ecological imperative» and innovative development of transport.*

Methods. *The authors use general scientific methods, comparative analysis, evaluation approach, statistical analysis.*

Results. *According to Peter Marsh, a well-known British specialist, the new, fifth according to his classification, industrial revolution is unfolding now. It «began around 2005 and will last until about 2040, but it is possible that its full effect will only be manifested at the end of the century» [2, p. 363].*

One of the key characteristics of the new industrial revolution, on which it is necessary to focus attention, is the increase in the ecological compatibility of production, or, in the terminology of Marsh, the «ecological imperative». The need should be noted for a balanced and careful attitude to the ecological aspect of development. Regardless of the obvious importance of environmental problems, many economists are skeptical about the «apocalyptic» conclusions of a number of environmental experts about the consequences of industrial production on the environment [3, p. 526–556] or even give negative assessments to some actions in favour of protection of the environment [4, p. 286].

From the economic point of view the approach of Dipak Lala is the most balanced. It is reinforced by the position of a number of prominent specialists, according to which the «ecological economy» in its correct interpretation boils down to the application of cost-benefit analysis based on the principles of the welfare economy [5, p. 381].

P. Marsh, while considering the environmental aspects of the new industrial revolution, although he does not declare such theoretical approaches, also links environmental compatibility and economy. And, accordingly, he does not oppose the preservation of the environment to economic growth, but shows the possibilities of realizing both. In his view, the new industrial revolution will be characterized by «economical management of resources and minimization of the impact on the environment… This will be a world in which the growth of the economy will continue, but production for the first time in history will reduce the impact on the environment instead of increasing this impact» [2, p. 211].

Achievement of such goals is seen at the expense of a combination of different thematic areas:

– reduction of energy consumption and water consumption, primarily – by improving the design of consuming devices;

– reducing the environmental load through the use of high-strength wear-resistant materials;

–elimination of unnecessary production stages and associated harmful emissions and other types of environmental impact;

–recycling of secondary raw materials, which solves two problems at once: eliminates waste dumps and reduces the use of primary resources (minerals).

The latter direction can be most fully realized within the framework of the «closed cycle economy», which presupposes a «continuous cycle of processing materials that connects old and new products» [2, p. 224–225]. Thanks to this, a combination of environmental friendliness and profitability of production is possible. «If <…> the effective operation of such a closed circulation of materials has been achieved, then the source materials in such a system, by definition, are extracted easily and very cheaply. Due to low costs, companies working on this principle can set themselves the task of achieving higher profit rates than their competitors …» [2, p. 225]. Thus, speaking of the «ecological imperative», Marsh does not resort to the general thesis «there are more important things than profits and competition», and shows, including a number of examples, how the ecological compatibility of the products increases the efficiency and competitiveness of the producer.

The influence of the «ecological imperative» on rail transport can be viewed in different aspects.

Firstly, the reduction in the consumption of fossil sources of raw materials for the production of energy and materials will reduce (at least, relative to the volume of industrial production and GDP, and, possibly, absolutely) extraction and, consequently, transportation of fossil resources. Given that these goods dominate in the structure of rail transportation, this will have a significant negative impact on their volumes. Increased transportation of recyclables, most likely, does not compensate for the decline in transportation of fossil resources. But even providing growth of transportation of secondary raw materials, railway men must take special measures. As unlike transportation of coal and ore, this sector of the market will be more competitive. Obviously, both new types of cars and new logistics of cargo delivery will be needed.

To an even greater extent than the total traffic volumes, their distribution by routes will change. Cargo flows from places of extraction of minerals to places of their processing or ports will be partially replaced by cargo flows from places of concentration of recyclables

Table 1

Classification of inventions (innovation proposals), corresponding to the «ecological» imperative and significant for transport

	Innovations implemented in railway transport, as well as on other modes of transport, allowing to ensure synergy with the development of railways	Innovations implemented in other modes of transport that can give them a competitive advantage in the transportation market	Innovations in other, non-transport industries, the absorption of which by rail and other modes of transport opens up new opportunities to improve the efficiency of transport companies
Reduction of energy consumption and water consumption	**A unique wireless technology for engines** is a sensor capable of wirelessly transmitting information about engine temperature, which allows to save vehicles from wires and reduce power consumption.	**The project of high-speed energy efficient magnetoplanes** is a prototype of a pipe for magnetic trains, inside of which the air resistance is 10 times lower than the atmospheric pressure at sea level, which allows the magnetoplanes to move almost silently, thus spending an order of magnitude less energy.	**Almost no energy consuming magnetic chip** – a magnetic chip that consumes the minimum possible amount of energy for computing, almost equal to the Landauer limit, which is a million times smaller than the similar energy costs in modern processors.
			Energy-efficient temperature control in buildings – substitution of air conditioners with mirrors, redirecting excess heat to space.
Reducing CO_2 emissions, development of renewable energy	**Passenger express Solar Bullet** is a special project of a high-speed passenger train with power supply from efficient solar batteries.	**Electric cars using graphene batteries** – electric vehicles using the finest material – graphene, which makes it possible to make lightweight, durable batteries with huge capacity, capable of charging from renewable energy sources.	**Transparent solar battery** is a solar battery capable of absorbing ultraviolet radiation and is applicable in a variety of designs, obtained by energy from which it will be possible to charge cell phones, temperature sensors and other devices.
	The railway power plant is a pilot project for generating and storing energy using an iron mini-road, which is considered the best option for solving the energy supply problem.	**Stella is a solar-powered car** – the world's first solar-powered car, due to its low weight providing a long distance of mileage.	**Solar batteries that produce electricity during the rain** are solar panels that can generate electricity in both sunny and rainy weather.
	Hyperloop transport system project – passenger aluminum alloy capsules moving at a speed of up to 1200 km / h on a special low pressure pipeline lifted above the ground on supports, without CO_2 emissions and with low energy costs.		**A spray that converts any surface into a battery** is a method to convert a traditional battery into a liquid, which can then be applied to any surface like paint from a can to create a power source.
	SkyTran – innovative urban transport – small capsules built of composite materials, with a capacity of up to 2 people, held on a monorail at a height of six meters with the help of magnetic levitation. The main idea of the project: the replacement of cars with environmentally friendly transport, which in the future can be equipped with solar batteries.		**Remote acquisition of energy from bacteria** is based on the ability of bacteria to release electrical charge from within the cell.
	A fully electric aircraft is an airplane with a single centralized power supply system that would ensure all its energy needs.		**Perovskite solar batteries** – batteries made from a new material – perovskite, giving the opportunity to receive energy at a price of $2.7 per watt compared to $3.9 per watt for modern solar batteries.
	MagLev systems – based on the use of magnetic suspension, MagLev (Magnetic Levitation) system will raise the level of public transport above the level of land lines and make the movement of transport cabins independent of traffic jams, accidents and other twists and turns of land transport without CO_2 emissions.		**Hybrid crystal** is a black crystal on a perovskite matrix, with very low power consumption.
			An air vehicle is a car with a pneumatic engine, for which compressed air is used.
	Technology Super-MagLev – technology, allowing to avoid air resistance, which in theory will allow trains on a magnetic cushion to accelerate to speeds of 3 thousand kilometers per hour.		**The triboelectric generator** is a device that generates electricity as a result of friction between two surfaces.
			A traction motor using the energy of microwaves is an engine that does not need fuel because it uses the energy of microwaves.
			The technology that allows to convert water and carbon dioxide in liquid fuel is a pilot plant that allows to convert water (H_2O) and carbon dioxide ($CO_{2)}$ into liquid hydrocarbons, synthetic gasoline, kerosene and diesel fuel.
The use of high-strength wear-resistant effective materials	There is no data in the sample used.	**Freight cars on graphene supercapacitors** – a new model of a tilt-covered van with a pre-installed hybrid engine system, saving about 25% of fuel, and also reducing harmful emissions.	**Super-strong steel to save fuel** – a new super-strong steel of the third generation, which reduces fuel consumption by reducing the weight of the vehicle.
		Innovative tire repair technology uses a sealant for self-restoring tires.	**Electric concrete, self-cleansing itself of snow and ice** – concrete capable of heating itself and melting the accumulated snow and ice, while the coating is absolutely safe for a human and any technique.
			Accumulators on carbon batteries – accumulators, on new, graphene batteries, withstanding up to three thousand cycles of recharging without loss of capacity, against several hundred in modern lithium-ion batteries.

			High-strength aluminum is as light as aluminum metal, but twenty-five times stronger.
			Vanadium batteries – batteries that can work almost forever.
			Wood glass is a sturdy, cheap, renewable and very pliable innovative wood-based material that has found its application in the manufacture of windows and solar panels as a cheaper alternative to traditional silicon glass.
Elimination of unnecessary production stages	**Car-washing complex with the use of the detergent «O-BIS»** is an ecologically safe, resource-saving technology for washing railway tank boilers, the feature of which is simultaneous degassing from the residual gas and washing the internal surface of the boiler.	**Airplanes with printed 3D details** are a new method for producing metal parts of aircraft using 3D printing that will save fuel, materials and other resources.	There is no data in the sample used.
		StreetScooter C16 is an electric car made on a 3D printer – a prototype of a small electric car, almost the whole body of which and most of the other parts were manufactured using an industrial three-dimensional printer capable of printing with several different materials.	
Bionics	**Trains-invisible: the know-how of the Japanese railway** – a new design-chameleon of high-speed trains that will merge with the surrounding terrain, providing harmony of transport and the natural environment.	There is no data in the sample used. 2.1.	**Unbreakable glass** – a new technology for glass processing, thanks to which it was possible to significantly increase its strength, prompted by the properties of shellfish shells.
	The technology of creating «live» cars is the technology of creating cars from biological materials that can change and adapt to the environment.		

to places of its processing. This redistribution will have to be taken into account when planning the development of infrastructure and traction of transportation. In addition, the cargo flows of recyclables will probably be more difficult to route than cargo flows of fossil resources, especially for sender routing. Accordingly, it will be more difficult to ensure the high weights of trains, thereby reducing the cost of transportation.

Of course, all these changes are a matter of perspective, and probably not very close – while the «closed cycle economy» is at an early stage and its impact on the volumes and structure of rail transportation will not be manifested very soon. Nevertheless, we must start preparing for these changes, even conceptually, today. We cannot be like «bad economists» (in the words of H. Hazlitt), lightly neglecting the prospect [6, p. 19].

Secondly, increase in environmental requirements of global value chains can facilitate the transition of some freight flows from less environmentally friendly road and water transport to railways. So, the European program «Shift2Rail», setting this goal, is largely based precisely on environmental motivation. And, for example, in Japan, a decisive argument in favor of partial replacement of sea traffic by rail transportation on one of the routes was the reduction of harmful emissions.

However, one must take into account that ecological advantages alone, without an effective combination of price and quality of transportation, cannot ensure the competitiveness of railways. Yes, and other modes of transport are actively working to improve the environment in the concept of «green» transport and the development of technologies of «green» logistics, the relevance and demand of which is shown in [7].

The concept of «green» transport must be linked with the general «ecological imperative» of the new industrial revolution in such a way as to combine high environmental friendliness and efficiency.

Currently, in the framework of growing environmental friendliness of the railway transport, the emphasis is on reducing harmful emissions, noise and specific energy consumption. The latter («energy efficiency») is fully combined with the task of increasing economic efficiency.

Reuse or recycling of materials on railways has also traditionally been used (and has always been considered as a cost-saving measure, not from a position of reducing the environmental load), but the implementation of the concept of a closed-cycle economy in the industry is a matter of the future. As examples from other industries show, this may require a reduction in the number of types of materials used for the manufacture of railway equipment and structures (to simplify their processing).

It should be mentioned that the concept of an economy of a «closed cycle» also provides for «the need to repair and resell things that have ceased to meet the requirements of the original owners» [2, p. 225].

From this point of view, the above concept (even without any resale) fits in well with the overhaul of technical equipment with the extension of their service life, in which a large amount of experience has been accumulated in railway transport. (Of course, its implementation should not contradict the requirements of efficiency and safety of transportation).

Enhancement of environmental friendliness of the railway transport also requires the use of environmentally friendly materials and materials with increased strength and durability. Fulfillment of this condition allows to reduce costs of the life cycle of the corresponding technical means or devices.

To assess the prospects and directions for the implementation of the «ecological imperative» in the transport sector, an analysis of a number of inventions (innovation proposals) has been carried out according to sources [8–43]. They are classified in the following areas:

– reduction of energy consumption and water consumption;

– reduction of CO_2 emissions, including through the development of renewable energy (use of wind, solar, various types of hydropower, etc.);

– application of high-strength wear-resistant effective materials;

– liquidation of unnecessary production stages;

– bionics (applied science on the application of the principles of organization, properties, functions and structures of living nature in technical devices and systems).

In addition, in the future, increased attention should be paid to innovations that ensure the recycling of secondary raw materials and to implementation of the principles of a non-waste economy of a «closed cycle» for transport.

In terms of applying these innovations to transport (with a focus on railways) or of their impact on transport, they are classified into three categories:

– innovations implemented in railway transport, as well as in other modes of transport, allowing to ensure synergy with the development of railways;

– innovations implemented in other modes of transport that can give them a competitive advantage in the transportation market;

– innovations in other, non-transport, industries, the absorption of which by rail and other modes of transport opens up new opportunities to improve the efficiency of transport companies.

(Such a grouping is a modification of the classification of innovations that are significant for rail transport, proposed in [44]).

The resulting matrix classification of innovations corresponding to the «ecological imperative» and significant for transport, especially the railway, is shown in Table 1.

Conclusion. *Based on the analysis of inventions (innovation proposals) formed within the framework of the ecological paradigm and significant for the long-term development of transport, a number of significant conclusions can be drawn.Of five identified areas of implementation of the ecological paradigm, the most actively developing direction is associated with the reduction of CO_2 emissions and the use of renewable energy. In this case, most of the inventions and innovations both in this area and in general are carried out in non-transport industries (which is quite natural). To improve the environmental friendliness of railway and other modes of transport, target absorption is required, and then diffusion of such innovations.*

Regaring modes of transport (air and road) competing with the railways one can take note of a number of promising inventions that can give them a competitive advantage in terms of environmental friendliness. This requires the railway men to react adequately.

Most innovations directly affecting rail transport are associated with innovative transport systems that have the potential for synergy with the development of railways. To realize this potential, a purposeful scientific, technical and economic policy is needed.

It is necessary to radically intensify developments in the field of new high-strength wear-resistant effective materials for a railway transport (as well as diffusion of developments available in other industries) and in the development of new technologies that reduce the number of production stages.

We should pay attention to the lack of activity in the sphere of radical innovations, which reduce energy consumption and water consumption in railway transport. In the industry, the diffusion of previously created innovations (such as the Elbrus system in Russia) takes place, but new inventions are needed that would allow dynamic increase in energy efficiency of railways in a strategic perspective.

Innovations require great efforts and support in the framework of currently unusual field of of «bionics», which can concern not only the use of properties of specific objects of wildlife, but also the mechanisms of interaction between them, such as symbiosis, which can serve as a basis for harmonizing the interaction of various transport systems and technologies.

REFERENCES

1. Macheret, D. A., Izmaikova, A. V. Innovative development of railway transport in the context of the industrial revolutions [*Innovacionnoe razvitie zheleznodorozhnogo transporta v kontekste promyshlennyh revoljucij*]. *Vektor transporta*, 2015, Iss. 4, pp. 60–63.

2. Marsh, P. New industrial revolution. Consumers, globalization and the end of mass production [*Novaja promyshlennaja revoljucija. Potrebiteli, globalizacija i konec massovogo proizvodstva*]. Moscow, Publishing House of Gaidar Institute, 2015, 420 p.

3. Maddison, E. Contours of the world economy in the years 1–2030. Essays on macroeconomic history [*Kontury mirovoj ekonomiki v 1–2030 gg. Ocherki po makroekonomicheskoj istorii*]. Moscow, Publishing house of Gaidar Institute, 2012, 584 p.

4. Landsburg, S. Economist on the couch: economic science and everyday life [*Ekonomist na divane: ekonomicheskaja nauka i povsednevnaja zhizn'*]. Moscow, Publishing house of Gaidar Institute, 2012, 304 p.

5. Lal, D. Return of the «invisible hand»: The relevance of classical liberalism in XXI century [*Vozvrashhenie «nevidimoj ruki»: Aktual'nost' klassicheskogo liberalizma v XXI veke*]. Moscow, Novoe izdatel'stvo publ., 2009, 426 p.

6. Hazlitt, H. Economics in one lesson [*Ekonomika za odin urok*]. Moscow, William publ., 2007, 256 p.

7. Mukhina, I. V., Smirnova, A. V. «Green» Logistics. *World of Transport and Transportation*, Vol.14, 2016, Iss.1, pp. 186–190.

8. The Russian «know-how»: a unique wireless technology for engines was created in St. Petersburg Polytechnic University [*Russkoe «nou-hau»*: v *peterburgskom Politehe sozdana unikal'naja besprovodnaja tehnologija dlja dvigatelej*]. [Electronic resource]: https://ruposters.ru/news/13–11–2014/russkoe-nou-xau-v-peterburgskom-politexe-sozdana-unikalnaya-беспроводная-texnologiya-dlya-dvigatelej. Last accessed 01.06.2016.

9. Physicists have created almost no power magnetic chip [*Fiziki sozdali pochti ne potrebljajushhij energii magnitnyj chip*]. [Electronic resource]: http://news.ifresh.ws/40702-fiziki-sozdali-pochti-ne-potreblyayuschiy-energii-magnitnyiy-chip.html. Last accessed 01.06.2016.

10. A first transparent solar cell in the world was developed [*Razrabotana pervaja v mire prozrachnaja solnechnaja batareja*]. [Electronic resource]: http://www.innovanews.ru/info/news/energy/15769/. Last accessed 01.06.2016.

11. «Magnetic» train will transport from Paris to Moscow in an hour [«*Magnitnyj» poezd dostavit iz Parizha v Moskvu za chas*]. [Electronic resource]: http://hitech.vesti.ru/news/view/id/4747. Last accessed 01.06.2016.

12. Solar panels were created, capable of generating electricity even in the rain [*Sozdany solnechnye paneli, sposobnye generirovat' elektrichestvo dazhe v dozhd'*]. [Electronic resource]: https://hi-news.ru/technology/sozdany-solnechnye-paneli-sposobnye-generirovat-elektrichestvo-dazhe-v-dozhd.html. Last accessed 01.06.2016.

13. Spray that turns any surface into a battery [*Sprej, prevrashhajushhij ljubuju poverhnost' v batareju*]. [Electronic resource]: https://r-ht.ru/interesting/novosti/sprej_prevrashhajushhij_ljubuju_poverkhnost_v_batareju/1–1–0–525. Last accessed 01.06.2016.

14. Stella – a solar-powered car for the whole family [*Stella – avtomobil' na solnechnyh batarejah dlja vsej sem'i*]. [Electronic resource]: http://24gadget.ru/1161054356-stella-avtomobil-na-solnechnyh-batareyah-dlya-vsey-semi.html. Last accessed 01.06.2016.

15. Possibility of remote obtaining energy from bacteriais achieved [*Dostignuta vozmozhnost' distancionnogo poluchenija energii iz bakterij*]. [Electronic resource]: http://www.innovanews.ru/info/news/energy/15176/. Last accessed 01.06.2016.

16. The combination of different materials gives high conversion efficiency [*Sochetanie raznyh materialov daet vysokuju konversionnuju effektivnost'*]. [Electronic resource]: http://www.innovanews.ru/info/news/energy/15817/. Last accessed 01.06.2016.

17. The hybrid crystal pushes the boundaries of efficiency LED lamps [*Gibridnyj kristall razdvigaet granicy effektivnosti svetodiodnyh lamp*]. [Electronic resource]: http://www.innovanews.ru/info/news/energy/15808/. Last accessed 01.06.2016.

18. Air vehicle (pneumatic vehicle) [*Vozduhomobil (pnevmomobil)*]. [Electronic resource]: http://greenevolution.ru/

enc/wiki/vozduxomobil-pnevmomobil/. Last accessed 01.06.2016.

19. Solar Bullet – project of speed passenger express train with energy supply from solar panels [*Solar Bullet – proekt skorostnogo passazhirskogo ekspressa s energosnabzheniem ot solnechnyh batarej*]. [Electronic resource]: http://www.dailytechinfo.org/energy/191-solar-bullet-proekt-skorostnogo-passazhirskogo.html. Last accessed 01.06.2016.

20. A new high-efficiency technology is developed, which allows to turn water and gas into liquid fuels [*Razrabotana novaja vysokoeffektivnaja tehnologija, pozvoljajushhaja prevrashhat' vodu i uglekislyj gaz v zhidkoe toplivo*].[Electronic resource]: http://www.dailytechinfo.org/eco/6493-razrabotana-novaya-vysokoeffektivnaya-technologyiya-pozvolyayuschaya-prrevraschat-vodu-i – carbon-gas-to-liquid-toplivo.html. Last accessed 01.06.2016.

21. In Russia an all-electric aircraft is being created [*V Rossii sozdaetsja polnost'ju elektricheskij samolet*]. [Electronic resource]: http://www.popmech.ru/technologies/15737-v-rossii-sozdaetsya-polnostyu-elektricheskiy-samolet/. Last accessed 01.06.2016.

22. Urban public transport of the future – a system on magnetic suspension MagLev [*Gorodskoj obshhestvennyj transport budushhego – sistema na magnitnoj podveske MagLev*]. [Electronic resource]: http://www.dailytechinfo.org/auto/1248-gorodskoj-obshhestvennyj-transport-budushhego-sistema-na-magnitnoj-podveske-maglev.html. Last accessed 01.06.2016.

23. Super-Maglev technology allows magnetic levitation trains to reach speeds of up to 3000 kilometers per hour [*Tehnologija Super-Maglev pozvolit poezdam na magnitnoj podushke razvivat' skorost' do 3000 kilometrov v chas*]. [Electronic resource]: http://www.dailytechinfo.org/auto/5893-tehnologiya-super-maglev-pozvolit-poezdam-na-magnitnoy-podushke-razvivat-skorost-do-3000-kilometrov-v-chas.html. Last accessed 01.06.2016.

24. Graphene supercapacitors improve the efficiency of road freight transportation by 25 per cent [*Grafenovye superkondensatory podnimajut effektivnost' gruzovyh avtoperevozok na 25 procentov*]. [Electronic resource]: http://www.dailytechinfo.org/auto/8085-grafenovye-superkondensatory-podnimayut-effektivnost-gruzovyh-avtoperevozok-na-25-procentov.html. Last accessed 01.06.2016.

25. The future, represented by of Skytran transport system arrives in Tel Aviv [*Budushhee, v lice transportnoj sistemy Skytran, pribyvaet v Tel'-Aviv*]. [Electronic resource]: http://www.dailytechinfo.org/auto/5040-buduschee-v-lice-transportnoy-sistemy-skytran-pribyvaet-v-tel-aviv.html. Last accessed 01.06.2016.

26. New thinnest material for batteries with a huge capacity [*Novyj tonchajshij material dlja akkumuljatorov s ogromnoj emkost'ju*]. [Electronic resource]: http://telegraf.com.ua/tehnologii/1303588-novyiy-tonchayshiy-material-dlya-akkumulyatorov-s-ogromnoy-emkostyu.html. Last accessed 01.06.2016.

27. Triboelectric Revolution? [*Triboelektricheskaja revoljucija?*]. [Electronic resource]: http://www.nanonewsnet.ru/news/2014/triboelektricheskaya-revolyutsiya. Last accessed 01.06.2016.

28. Load electricity with cars! [*Gruzite elektrichestvo vagonami!*]. [Electronic resource]: http://www.nanonewsnet.ru/news/2014/gruzite-elektrichestvo-vagonami. Last accessed 01.06.2016.

29. NASA tested an engine that operates without fuel and refutes the laws of physics [*V NASA protestirovali dvigatel', rabotajushhij bez topliva i oprovergajushhij zakony fiziki*]. [Electronic resource]: http://www.newsru.com/world/04aug2014/emdrive.html. Last accessed 01.06.2016.

30. First look at the new generation transport system from Hyperloop [*Pervyj vzgljad na transportnuju sistemu novogo pokolenija ot kompanii Hyperloop*]. [Electronic resource]: https://hi-news.ru/technology/pervyj-vzglyad-na-transportnuyu-sistemu-novogo-pokoleniya-ot-kompanii-hyperloop-one.html. Last accessed 01.06.2016.

31. Super-strong steel for fuel saving [*Sverhprochnaja stal' dlja ekonomii topliva*]. [Electronic resource]: http://evonews.org/news/interesnie-novosti/5126-sverhprochnaya-stal-dlya-ekonomii-topliva.html. Last accessed 01.06.2016.

32. The new concrete will save the roads from icing, and corporations – from industrial espionage [*Novyj beton spasjot dorogi ot obledenenija, a korporacii – ot promyshlennogo shpionazha*]. [Electronic resource]: http://www.vesti.ru/doc.html?id=2712198&cid=2161. Last accessed 01.06.2016.

33. Technology of tire restoration [*Tehnologija vosstanovlenija shin*]. [Electronic resource]: https://ig-store.ru/news/transport/13961-tehnologiya-vosstanovleniya-shin. Last accessed 01.06.2016.

34. New Japanese batteries will make electric cars cheaper and safer [*Novye japonskie batarei sdelajut elektromobili deshevle i bezopasnee*]. [Electronic resource]: https://hi-news.ru/technology/novye-yaponskie-batarei-sdelayut-elektromobili-deshevle-i-bezopasnee.html. Last accessed 01.06.2016.

35. Russian scientists turn aluminum into steel [*Rossijskie uchenye prevrashhajut aljuminij v stal'*]. [Electronic resource]: https://rusevik.ru/interesnoe/165750-rossiyskie-uchenye-prevraschayut-alyuminiy-v-stal.html. Last accessed 01.06.2016.

36. A high-capacity flow-through battery has been created [*Sozdana protochnaja batareja vysokoj jomkosti*]. [Electronic resource]: http://www.nanonewsnet.ru/news/2015/sozdana-protochnaya-batareya-vysokoi-emkosti. Access 01.06.2016.

37. Scientists from Sweden created a «wooden glass» [*Uchenye iz Shvecii sozdali «derevjannoe steklo»*]. [Electronic resource]: http://www.nanonewsnet.ru/news/2016/uchenye-iz-shvetsii-sozdali-derevyannoe-steklo. Last accessed 01.06.2016.

38. Car-washing complex with the use of «O-BIS» detergent [*Vagonomoechnyj kompleks s primeneniem mojushhego sredstva «O-BIS»*]. [Electronic resource]: http://www.saveplanet.su/tehno_305.html. Last accessed 01.06.2016.

39. 3D printing allows to reduce the weight of aircraft parts and simplify their production [*3D-pechat' pozvoljaet dobit'sja umen'shenija vesa detalej samoletov i uprostit' ih proizvodstvo*]. [Electronic resource]: http://nnm.me/blogs/sepet716/3d-pechat-pozvolyaet-dobitsya-umensheniya-vesa-detaley-samoletov-i-uprostit-ih-proizvodstvo/. Last accessed 01.06.2016.

40. StreetScooter C16 is a prototype of an electric car manufactured using a three-dimensional printer [*StreetScooter C16 – prototip elektricheskogo avtomobilja, izgotovlennogo pri pomoshhi trehmernogo printera*]. [Electronic resource]: https://oko-planet.su/science/sciencenews/262138-streetscooter-c16-prototip-elektricheskogo-avtomobilya-izgotovlennogo-pri-pomoschi-trehmernogo-printera.html. Last accessed 01.06.2016.

41. The invisible train merges with the environment [*Poezd-nevidimka slivaetsja s okruzhajushhej sredoj*]. [Electronic resource]: http://www.popmech.ru/technologies/236988-poezd-nevidimka-slivaetsya-s-okruzhayushchey-sredoy/. Last accessed 01.06.2016.

42. In the future, cars will learn to repair themselves [*V budushhem avtomobili nauchatsja sami sebja remontirovat'*]. [Electronic resource]: http://hronika.info/tehnologii/32520-v-buduschem-avtomobili-nauchatsya-sami-sebya-remontirovat.html. Last accessed 01.06.2016.

43. Scientists came up with a safety glass based on the structure of shellfish shell [*Uchenye pridumali neb'jushheesja steklo na osnove struktury pancirja molljuskov*]. [Electronic resource]: https://hi-news.ru/technology/uchenye-pridumali-nebyushheesya-steklo-na-osnove-struktury-pancirya-mollyuskov.html. Last accessed 01.06.2016.

44. Izmaikova, A. V. Innovations, significant for railway transport [*Innovacii, znachimye dlja zheleznodorozhnogo transporta*]. *Bulletin of Joint Scientific Council of JSC Russian Railways*, 2014, Iss. 3, pp. 53–69.

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