REVIEW ARTICLE
DOI: https://doi.org/10.30932/1992-3252-2022-20-1-5

World of Transport and Transportation, 2022,
Vol. 20, Iss. 1 (98), pp. 171–183

An Innovative Approach to Creation of New Types of Urban Passenger Transport

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ABSTRACT

Currently, the population is increasingly concentrated in large cities and metropolitan areas, urban outskirts are being actively built up. According to sociologists, more than 80 % of the population will live in cities by 2025. Megacities are characterised by social tension associated with the transport and environmental situation, which is aggravated due to population growth, an increase in its density and an increase in the number of cars per capita.

The «city–transport» system has feedback features. When the city will exhaust the capacity of the created transport system regarding rapid and convenient movement of passengers, it will be necessary to change the characteristics of urban transport vehicles up to creation of fundamentally new ones based on modern energy sources.

Transport is a service industry and must meet the requirements of those who use it. For urban passenger transportation, the core thing is the quality of service.

At all times, people had a desire to move around, using a variety of animals for this depending on the region of residence. Wealthy people had special carts, carriages, and animals in their property. Ordinary people travelled on foot, but with the growth of settlements and cities, they began to experience great difficulties in moving over long distances. The idea of creating public transport, i.e., available for use by any inhabitant for a moderate fee was formulated by the famous natural philosopher, mathematician, physicist, writer Blaise Pascal in 1661.

This idea saw serious development later due to the intensive growth of cities and due to developments of scientists in the field of exact sciences.

This review article has used research method which is the analysis of the history of emergence and development of each mode of transport in world and domestic practices, that has made it possible to trace evolution of urban transport up to the present day. The objective of this article is to present further evolution of the city's transport service, which requires an innovative approach to creation of new modes of transport.

The author's research has been reflected in the relevant articles, as well as in the chapters on «Urban transport» of several textbooks.

The article discusses an innovative approach to modernisation of existing urban vehicles and creation of new ones that will ensure environmental friendliness, accident-free operation, reduce the occupancy of the city, create comfortable conditions for transportation of passengers, etc. This provides for the widespread use of digital technologies, as well as of non-traditional transport systems.

The prospective introduction of fundamentally new vehicles is considered and analysed using the examples of the experience of cities and megacities in Russia and abroad.

Keywords: public urban transport, innovation, hybrid transport; ecology, interchangeable types of energy, occupancy of the city territory, use of underground space.

For citation: Troitskaya, N. A. An Innovative Approach to Creation of New Types of Urban Passenger Transport. World of Transport and Transportation, 2022, Vol. 20, Iss. 1 (98), pp. 171–183. DOI: https://doi.org/10.30932/1992-3252-2022-1-5.

The text of the article originally written in Russian is published in the first part of the issue.
Текст статьи на русском языке публикуется в первой части данного выпуска.

BACKGROUND

The analysis of the history of emergence and development of each mode of transport on a global scale made it possible to divide the entire history of urban transport into several periods:

1) From the end of the 17th century to the last quarter of the 18th century, the cities were dominated by pedestrians, it was also possible to travel on horseback or in horse teams. This kind of transportation dictated the density and size of buildings to get an acceptable time and effort to move. The «passenger transportation for hire» service, which can be conditionally considered as the beginning of public transport and of the modern taxi, originated in Great Britain in 1639, when a license to transport was established. It is difficult to name the exact date of birth of the Russian private cab. Until 1898 there was a period of cabbies, each of whom had its own badge with a number. Then taximeters appeared and in 1904 a taxi society was organised [1].

2) In the last quarter of the 18th – mid-19th centuries, a horse-drawn cart appeared (speed up to 10 km) intended for small cities, experiments began with steam vehicles, a prototype car appeared which was the self-propelled cart of Nicolas-Joseph Cugnot in 1769 (France); the first two-wheeled metal bicycle was designed in 1801 by E. Artamonov.

3) In the second half of the 19th century, with a sharp increase in industrial production and the growth of cities, rails were laid for horse traction («horse car or tram»). In London, a steam-powered underground was opened in 1863, steam traction was replaced with electric traction in 1890; the first subway line in New York City opened in 1868 as a cable-hauled surface railway line on metal overpasses. Cables were replaced by steam in 1871 and by electric traction in 1890.

4) The end of the 19th – the first quarter of 20th century is characterised by development of rail electric transport: the tram (1874, Russia; 1881, Germany), the subway spread to many cities of the world (in Russia in 1935), the first monorail was built in Wuppertal (Germany) in 1901; the connection of the cities with the suburban areas with the help of rail transport has expanded. An individual car appeared. Some backlog in Russia from emergence of certain types of transport was due to unwillingness of the owners of horse-drawn tram lines (Russian public urban passenger transport) to lose its capital costs and income.

5) From the first quarter of the 20th century to the present, modes of electric transport (with some disadvantages) and vehicles with internal combustion engines (environmentally unfriendly) prevail in all cities of the world. In this connection, there is an intensive development of various types of urban transport using various types of energy to eliminate the shortcomings that exist today regarding each type of urban transport.

The *objective* of this article is to analyse the results of research on improvement of vehicles for urban conditions. The newly adopted vehicles can improve technical performance, reduce air pollution, improve traffic safety, etc.

RESULTS

The transport of the future faces new challenges that require an innovative approach. For passenger urban transportation, it is important, first, to reduce time and comfort of the trip. Designers traditionally offer high-speed railway trains to save passengers' time, but this applies primarily to intercity traffic. Almost all advanced countries are working on technologies in this area. The speeds that are currently used in intercity passenger traffic are practically impossible to implement in a city where there are certain regulatory requirements for the location of public transport stops.

Alternative options for urban transportation of passengers, it should be noted, comprise, first, fundamentally new types of urban transport, approved and being now introduced, as well as already known types that have switched to renewable energy sources.

Singapore with 5,8 million people is deemed to be the smartest city in the world today thanks to the use of existing innovations in transport. In a relatively short period of time, it was possible there to introduce all modern achievements related to transport, eliminating traffic jams on the streets, thanks particularly to special equipment for tracking and distributing flows, supplying the population with mobile devices, the use of unmanned buses and other technical means.

In Singapore, an unmanned hybrid electric bus for 80 passengers with a length of 12 m was successfully tested in 2019. Its range is 25 km, the electrical plant is fully charged in six minutes while parking or at bus stops. The bus is equipped with GPS system and with sensors that allow receiving and processing information about remote objects, and with special cameras that broadcast a three-dimensional image of the surroundings, considering local traffic and

Pic. 1. Model X is a full-size, all-wheel drive electric car. [Electronic resource]: https://tesla-online.ru/model_x. Last accessed 12.01.2022.

climate. An unmanned taxi was launched within the territory of the Singapore business centre, subsequently the system was extended to the entire city[1].

In California (USA), a smart city infrastructure is being developed with smart roads, free Wi-Fi, LED streetlights, air pollution sensors and solar panels, and driverless buses will also be used here. The first «green» railway will appear, i.e., a railroad that reduces the environmental impact by using energy from renewable sources. California will switch to «green» buses by 2040[2].

Significant number of the world cities set development of infrastructure for cycling as of ecologically friendly urban transport as priority. There are several rankings that assess namely the comfort of city infrastructure for cyclists. For example, a 2019 ranking comprised as top 10 cities Copenhagen, Amsterdam, Utrecht, Antwerp, Strasbourg, Bordeaux, Oslo, Paris, Vienna, Helsinki, Bremen, Bogotá, Barcelona, Ljubljana, Berlin, Tokyo, Taipei, Montréal, Vancouver, Hamburg[3].

It should be noted that a bicycle as a form of urban transport is very common in Asian countries (China, Vietnam, etc.) and in many European countries (Holland, Germany, etc.). Moscow can serve as an example at the present time, on the streets of which bicycle paths have been created (with no access for pedestrians) and special parking lots for bicycle rental are provided.

In recent years, an increasing number of cities in the world (Dubai, New York, Paris, etc.) have begun to offer a system for exchanging mechanical bicycles for electric ones.

The development and phased introduction of electric vehicles in cities is underway. In 2012, the Model X prototype was presented in Los Angeles – a full-size, all-wheel drive luxury SUV-electric car with automatically folding Falcon Wing rear doors («falcon wing»), providing access to the second and third row of seats (Pic. 1)[4].

There are now electric cars capable of traveling 975,6 km on a single charge[5].

This was made possible by changing the usual shape of the car to an aerodynamic one, using powerful batteries and solar panels for additional recharging.

There are already electric bikes that can travel 350–400 km on a single charge[6].

The Segway electric scooter, appeared in 2002, is a personal mobility vehicle (PMV) with

[1] The future of sustainable mobility in Singapore. [Electronic resource]: https://www.webuildvalue.com/en/megatrends/singapore-smart-city.html. Доступ 12.01.2022.

[2] California will switch to «green» buses by 2040 [*California pereydyot na «zelyonye avtobusy k 2040 godu*] (in Russian). [Electronic resource]: https://nplus1.ru'news/2018/12/17/zero-emission-california. Last accessed 12.01.2022.

[3] The 2019 Copenhagenize Index of bicycle-friendly cities [Electronic resource]: https://copenhagenizeindex.eu/about/the-index. Last accessed 12.01.2022.

[4] New Tesla Model X – the world's fastest electric crossover (in Russian). [Electronic resource]: https://tesla-online.ru'model_x. Last accessed 12.01.2022.

[5] 1000 km on a single charge? Tesla is already preparing such electric vehicles (in Russian). [Electronic resource]: https://www.ixbt.com/news/2020/11/25/1000-km-na-odnoj-zarjadke-tesla-uzhe-gotovit-takie-jelektromobili.html. Last accessed 12.01.2022.

[6] How long can an e-bike travel on a single charge? (in Russian) [Electronic resource]: https://eveloprosto.com'how-long-can-e-bike-go-on-one-… Last accessed 12.01.2022.

Pic. 2. Electric scooter Segway (https://www.segway.com).

an unusual balancing system to keep a person in balance (Pic. 2)[7]. PMV – means for movement of a person through the use of an electric motor or muscle energy (roller skates, scooters, monowheels, etc., except for bicycles and wheelchairs).

The emergence of electric vehicles marked a new problem associated with construction of charging stations.

The geography of Supercharger electric charging stations in the USA allows the owners of such cars to cross the entire territory of the USA in any direction[8].

In EU, about 287,000 public charging stations had been built by the end of 2020[9], the battery charging time for them is about six minutes. According to some estimates, their number could attain more than 350,000 in 2021, and the need for them by 2050 could be estimated as more than 3 mln.

In Russia, there is an intensive testing of electric city buses. It has been established that replacing one diesel bus with an electric bus reduces CO_2 emissions by 60,5 tons per year. In Moscow, more than 700 environmentally friendly electric buses were operated daily in August 2021[10].

According to the agreement with the plant, KamAZ will not only produce part of those new vehicles but will also ensure their full maintenance for 15 years[11].

The problem of road accidents is relevant all over the world: according to WHO, one person dies in road accidents in the world every 24 seconds, and there are 1,25 million victims per year [2]. This problem has led to the need to create urban unmanned vehicles, i.e., driverless, with fully automatic control. Russia joined the UN global campaign «Streets for Life» to draw attention to the vulnerable road users [2].

The city of Innopolis in the Republic of Tatarstan has been conducting since 2018 an experiment to introduce an unmanned taxi car. Such a car evaluates the traffic situation in a 360-degree zone and within a distance of 100–200 m using a set of sensors (six radars and cameras) 50 times per second[12].

In 2019, the Yandex company launched an unmanned taxi service on the territory of the Skolkovo innovation centre near Moscow[13].

There are many examples of testing and introduction of driverless subway trains in many countries. For example, testing of the first fully automated subway line «Yanshan–Fangshan» has begun in Beijing. The new Beijing trains do not have driver's cabs, and the operation and maintenance of the line is handled by a «smart» system[14].

The project of the Canadian division of Bell Helicopter received official support from the public authorities to develop unmanned versions of helicopters and urban air taxis. US cities are

[7] Segway store Website. [Electronic resource]: https://store.segway.com/about-us. Last accessed 12.01.2022.

[8] The network of charging stations Tesla Supercharger. [Electronic resource]: https://www.tesla.com/supercharger. Last accessed 12.01.2022.

[9] Werwitzke, C. EAFO study: charging infrastructure in the EU. [Electronic resource]: https://www.electrive.com/2021/03/05/eafo-study-charging-infrastructure-in-the-eu/. Last accessed 12.01.2022.

[10] Sergey Sobyanin spoke about development of electric transport in Moscow (in Russian). [Electronic resource]: https://www.mos.ru/mayor/themes/2299/7574050/. Last accessed 12.01.2022.

[11] Soon every fifth Moscow bus will be that form KAMAZ conveyors (in Russian). [Electronic resource]: https://realnoevremya.ru/articles/163962-kamaz-peredast-mosgortransu-elektrobusy-na-40-milliardov. Last accessed 12.01.2022.

[12] Unmanned taxis will appear in Moscow, Sochi and Tatarstan (in Russian). [Electronic resource]: https://rg.ru'2021…reg…taksi-poiaviatsia-v…tatarstane.html. Last accessed 12.01.2022.

[13] Drone on the roads of Skolkovo (in Russian). [Electronic resource]: https://taxi.yandex.ru/blog/bespilotnik-v-skolkovo/. Last accessed 12.01.2022.

[14] Beijing launched a fully automated subway line without a driver. It is reported by «The Rambler» (in Russian). [Electronic resource]: https://news.rambler.ru/moscow_city/43385177/?utm_content=news_media&utm_medium=read_more&utm_source=copylink. Last accessed 12.01.2022.

a)

b)

Pic. 3. Unmanned vehicle designed by MADI (Moscow Automobile and Road Construction State Technical University) (a), and an Estonian unmanned shuttle bus operating in designated areas of the cities (b) [5].

becoming «proving grounds» for introduction of unmanned flying taxis[15]. Similar projects are being developed in several European countries (Pic. 3).

In Russia, it is necessary, first, to make laws to consolidate the use of unmanned vehicles with a high degree of automation for driving on public roads based on the passport of the national project «Safe high-quality roads». It is assumed that movement of unmanned vehicles will be provided on 55 sections of the country's roads by the end of 2024.

In the city of the future within the Neom «THE LINE» project in Saudi Arabia, a highway for unmanned vehicles is to be designed. The city should be built by 2025 [3].

Experimental operation of hydrogen-fuelled vehicles has expanded. In the UK in 2005, a silent motorbike was revealed which runs on a hydrogen-powered fuel cell and was called Emission Neutral Vehicle[16].

An unmanned city bus powered by hydrogen fuel is operating in the city of Tartu (Estonia) [5].

In Russia, the KamAZ automobile plant is developing buses, and the GAZ plant is developing hydrogen-fuelled trucks. The domestic electric car 5G «Kama-1» running on a hydrogen-powered fuel was the winner of the «Technological breakthrough» award in 2020[17].

To implement the idea of overtaking cars moving at different speeds on the road, to be able to bypass traffic jams, China is developing an Airbus, bus moving over cars (Pic. 4). It will move around the city at speeds up to 60 km/h, carry up to 1400 people, which can replace 40 conventional buses, save 800 tons of fuel, and reduce carbon dioxide emissions by 2480 tons per year[18].

Videos and photos of this unusual bus have been published by the world's leading media. A single unit was built, which passed testing successfully, but there is no information on its further development.

[15] Air taxi station to be built in the US (in Russian). [Electronic resource]: https://www.gazeta.ru/tech/2020/11/12/13358161/aerotaxi.shtml. Last accessed 12.01.2022.

[16] Single track car BAC Mono will get a hydrogen version. The experimental car is not inferior in emotions to the usual Mono with a gasoline internal combustion engine (in Russian). [Electronic resource]: https://motor.ru'news/odnomestnyi-trek-kar-bac-mono…na…270…; Fuel cell motorbike unveiled, but too quiet? [Electronic resource]: https://www.nbcnews.com/id/wbna7206396. Last accessed 12.01.2022.

[17] The first hydrogen electric bus from KamAZ (in Russian). [Electronic resource]: https://kamaz.ru'press/releases/pervyy_vodorobus…kamaza/) (https://motor.ru'news/kamaz-hydrogen-bus-07–09–2021.htm. Last accessed 12.01.2022.

[18] China launched a bus tunnel that travels along the road above cars and is not afraid of traffic jams (in Russian). [Electronic resource]: https://novate.ru/blogs/290716/37401/. Last accessed 24.01.2022.

Pic. 4. A bus moving in the general flow over passenger cars (in Russian). [Electronic resource]: https://www.kommersant.ru/gallery/3054311#id1307215. Last accessed 12.01.2022.

Japanese designers to solve a similar problem in the design of the car propose to provide for a variable height of front and rear axles, able to rise the vehicle above the car in front.

A further increase in the number of roads in cities and of multi-level intersections on them leads to a decrease in the area of land used for other needs of the city. This problem has urgently required the emergence of new types of transport technologies that need but limited support on the ground or tunnels.

The first underground, as mentioned earlier, was launched in London (England) in 1863. Then the subway became the main mode of transport in metropolitan areas. Today, it constitutes the basis for development of urban transport systems such as Moscow Central Circle (MCC) which are being built for communication, primarily, with metro stations, airports and train stations, i.e., create a single urban transport system.

Transport systems with a support built into the ground are off-street monorail transport. The first urban monorail was built in 1901 in Germany (Wuppertal). It has been still in operation with a high degree of traffic safety: only one accident has been registered during the entire period of operation. Maximum speed is 60 km/h, distance between stations is of 780 m (Pics. 5a and 5b).

In Newark, near New York, USA, a 4,8 km long monorail links the airport, bus and train stations, and parking lots.

In Moscow in 2004, a 4,7 km long monorail transport system with six stations was built as a flyover. However, the choice of a district as a host site for this system showed its economic inefficiency due to insufficient passenger traffic, which led to a partial replacement with tram traffic[19].

Until 1950, the monorail had not been widely used, but in recent years it has become widely used in Asian countries due to the lack of extra territory in old densely built-up cities. So, in Chóngqìng (China), a 13,5 km long monorail has been operating since 2005, the line of which passes through a residential building (Pic. 6)[20].

In Japan, the total length of monorails in eight cities is of 102 km. Osaka has the longest road of 23,8 km. In 2003, an 8,6 km long monorail was opened in Kuala Lumpur (Malaysia). The length of monorail in Jakarta (Indonesia) is 27 km.

The main disadvantage of the monorail is its noise. In 1979, at the international exhibition in Hamburg (Germany), a monorail was demonstrated, operating on the principle of electromagnetic suspension with a linear electric drive[21], which worked almost silently.

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[19] Tram lines will partially replace Moscow monorail (in Russian). [Electronic resource]: https://stroi.mos.ru/news/tramvainyie-puti-chastichno-zamieniat-moskovskii-monoriel-s?from=cl. Last accessed 21.01.2022.

[20] In the Chinese metropolis, the railway was laid right through a residential building (in Russian). [Electronic resource]: https://novate.ru/blogs/210317/40563/. Last accessed 21.01.2022.

[21] Transrapid design history. [Electronic resource]: https://www.maglev.net/transrapid-design-history. Last accessed 21.01.2022.

a)

b)

Pics. 5a, 5b. Monorail in Wuppertal (Germany). [Electronic resource]: https://schwebebahn.de/en/mediathek. Last accessed 12.01.2022.

Pic.6. Monorail in Chóngqìng (China). [Electronic resource]: https://novate.ru/blogs/210317/40563/. Last accessed 12.01.2022.

Pic. 7. System Transrapid: Pudong airport – Longyang metro station in Shanghai (China). [Electronic resource]: https://transport.mos.ru/mostrans/all_news/21786 with reference to photo source: media.thyssenkrupp.com. Last accessed 12.01.2022.

In Transrapid's ultra-high-speed maglev system, vehicles hover over a frictionless rail guide using an attractive magnetic force. For 14 hours of operation, the system transported 7500 people, the railway, with a maximum train capacity, could transport 440 persons[22].

Transrapid primarily competed with InterCityExpress (ICE), i.e., high speed rail system. The problem was that in Germany and some other European countries by that time there was a developed unified network of high-speed railways.

The Transrapid system is used today in China. Currently, the fastest electromagnetic road in the world is the route between Pudong Airport and Longyang Metro Station in Shanghai (PRC). The length of the line is about 30 kilometers, which the train passes in 7,5 minutes at a speed of about 430 km/h (Pic. 7)[23].

Studies have found that a magnetic suspension system allows reaching the speed of urban public transport that is 2,5–4 times higher than the speed of a tram or trolleybus and 2–2,5 times than that of the subway. At the same time, the volume of energy consumed per kilometre is 20–25 % lower as compared to ground electric transport, and three times less as compared to metro.

Companies from several countries are engaged in development of such systems, in particular the Swiss company SwissRapide AG, and others.

It is worth reminding previous, though sometimes unsuccessful, experience of developing monorail systems using air cushion technology. French engineers implemented it within the framework of AéroTrain project. As a rail, they decided to use a reinforced concrete beam of inversed T-shape, mounted on supports. Air was injected under the bottom of the car, which rests on the beam, creating thus a kind of «air lubrication» that ensures easy movement of the car. The car of different models were equipped with different propulsion and traction systems (gas turbines, aircraft turbojet systems, linear electric motors). The train once attained the maximum speed of 430,4 km/h[24] [7].

HSST technology based on linear motor has been developed in Japan since 1972, since 2005 the only magnetic levitation commercial transit system has been connecting Fujigaoka station of subway line and Yakusa station of Aichi Loop Line, the length of the line is 8,9 km[25].

The construction and expansion of metro and high-speed urban rail systems require significant material costs, so there is now renewed interest in proposals for new environmentally friendly transport systems.

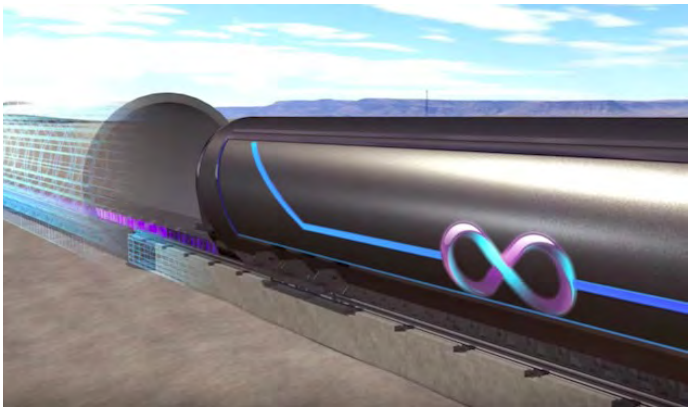
New modes of transport comprise Hyperloop trains, developed in the US by Elon Musk (Pic. 8). The idea of a train moving in a tube with near-vacuum environment is not new and arose

[22] «Transrapid 05», the first «flying» above the rails (in Russian). [Electronic resource]: https://zen.yandex.ru/media/incrediblmech/transrapid-05-pervyi-letiasciinad-relsami-5c1272477c9de200aac7a62a. Last accessed 21.01.2022.

[23] Transrapid Maglev Shanghai. [Electronic resource]: https://www.maglevboard.net/en/facts/26-transrapid-maglev-shanghai. . Last accessed 21.01.2022.

[24] E.g..: Transport that never was. [Electronic resource]: https://fabricofparis.com/2020/02/18/transport-that-never-was-aerotrain.html; Vereycken, K. Aérotrain, high speed rail and nuclear technology: the lessons of Jean Bertin. [Electronic resource]: https://solidariteetprogres.fr/IMG/pdf/karelvereycken.fr-aerotrain_high_speed_rail_and_nuclear_technology_the_lessons_of_jean_bertin.pdf. Last accessed 21.01.2022.

[25] Websites of Chubu HSST Development Corporation and Linimo. [Electronic resources]: http://hsst.jp/linimo_e.htm; https://www.linimo.jp/language/en/. Last accessed 21.01.2022.



a) tube and passenger capsule (section). [Electronic resource]: https://hi-news.ru/technology/kak-rabotaet-hyperloop.html. Last accessed 12.01.2022.

b) transparent tube for the city. [Electronic resource]: https://telecomdaily.ru/news/2019/08/19/vse-chto-nuzhno-znat-o-hyperloop. Last accessed 12.01.2022.

Pic. 8. Passenger capsule in the tube.

at the beginning of 20th century. These are technologies for lifting a capsule using a magnetic field, i.e., magnetic levitation or magnetic suspension (maglev).

In 2013, the Hyperloop system was introduced in the USA as the transport of the future. Driverless capsules (a prototype of a wagon) are placed in a transport tunnel with air pumped out of there to be accelerated to the highest possible speed. The new vehicle, as declared, particularly by mass media, will be twice as fast and ten times safer as an airplane, and more resource saving in operation than analogic modes of transport[26].

[26] See, e.g.: Hyperloop Alpha [Electronic resource]: https://www.tesla.com/sites/default/files/blog_images/hyperloop-alpha.pdf; Hyperloop versus airplanes: What's safer? [Electronic resource]: https://www.cnbc.com/2017/05/02/hyperloop-versus-airplanes-whats-safer.html; Hyperloop: Faster than a plane, cheaper than a train and completely green! [Electronic resource]: https://www.indiatoday.in/world/story/hyperlopp-elon-musk-tesla-motors-pay-pal-founder-new-transport-system-173603–2013–08–11. Last accessed 21.01.2022.

The hyperloop transport network project is based on the same principle as pneumatic mail. Through pipes made of a special material that can withstand low pressure and minimise turbulence with increasing speed, the capsule with passengers is «pushed» into the tube with great acceleration, where it continues to move due to air flows and special magnets that guide the capsule.

The inventors of the system proposed not to strive for a high vacuum in the pipe, but to limit themselves to the so-called fore vacuum, which can be created using relatively inexpensive pumps, and the air remaining in the tube can be used to create an air cushion under the moving capsule.

The capsule is driven by a linear electric motor, the stator is a 15 m long rail on the bottom of the tube. The rotor is in each capsule. Since the stator performs not only acceleration, but also braking, in the latter case, the kinetic energy is converted into electrical energy, which gives an overall energy saving.

Pic. 9. The first passengers of Hyperloop Virgin were CTO Josh Giegel and head of passenger services Sarah Lucian. [Electronic resource]: https://www.virgin.com/about-virgin/latest/passengers-travel-safely-on-a-hyperloop-for-the-first-time. Last accessed 12.01.2022.

In 2020, Virgin Hyperloop tested its train with passengers for the first time at the DevLoop site near Las Vegas at speeds up to 160 km/h. The 500-meter distance was covered in 15 seconds (Pic. 9). The maximum speed that, according to the calculations of the developers, the hyperloop will develop in the future is 1223 km/h.

This type of transport is offered to several countries. Tel Aviv–Eilat route (distance 350 km) is considered among other possible routes. The project can be implemented by 2025. According to some calculations, the construction of this route will be three times cheaper than the construction of a conventional high-speed railway. Several intermediate stations are planned for the Hyperloop One line. Travel time will be reduced from 4–6 hours to 20 minutes[27].

Another fundamentally new system of public passenger transport on magnetic levitation is being developed, namely skyTran, intended among other objectives, to combat urban traffic jams. The system runs on electricity, is environmentally friendly, cheap, silent, fast, and comfortable. In the future, it is possible to use solar energy. The new system has been developed by the skyTran Inc., a NASA Space Act Company (Pic. 10)[28].

This system is the implementation of the concept within the more general approach to Personal Rapid Transit, first proposed by aerospace engineer Douglas Malewicki in 1990. SkyTran capsules travel at a height of six meters above ground and can accelerate to 240 km/h.

According to the company's statement, the company signed a contract with Israel Aerospace Industries to build a test track with an elevated loop 400–500 meters long. A commercial skyTran network will be built in a number of cities in Israel, as well as an elevated rail system to serve Ramon Airport[29].

The Dubai government has unveiled a futuristic SkyPod transportation system that will reduce energy costs and require less infrastructure. In 2019, skyTran and the Dubai's Roads and Transport Authority (UAE) began developing the SkyPod transit system[30].

The Memorandum of Understanding was also signed with Mirel (UAE) to study and implement a personal rapid transit system project on Yas Island[31].

More generally, the desire to have a personal comfortable space during trips leads to the search for new public transport options that provide services to a specific person. The search continues around the world for better Personal Rapid

[27] From Tel Aviv to Eilat in 20 minutes soon it will become a reality (in Russian). [Electronic resource]: https://isralove.org/load/16–1–0–1525. Last accessed 21.01.2022.

[28] NASA and skyTran websites. [Electronic resource]: https://www.nasa.gov/centers/ames/researchpark/partners/industry/skytran; https://skytran.com/. Last accessed 21.01.2022.

[29] In Israel individual maglev-transport SkyTran will be launched (in Russian). [Electronic resource]: http://gsmavto.com/v-izraile-zapustyat-individualnyj-maglev-transport-skytran/. Last accessed 21.01.2022.

[30] Dubai's RTA and SkyTran sign MoU to introduce driverless sky pods. [Electronic resource]: https://www.roadtraffic-technology.com/news/sky-pods-dubais-rta-skytran/. Last accessed 21.01.2022.

[31] Yas Island to use skyTran transportation technology. [Electronic resource]: https://businesschief.eu/technology/yas-island-use-skytran-transportation-technology. Last accessed 21.01.2022.

Pic. 10. SkyTran system.

Transit (PRT) systems, which is a form of public transport that uses small, automated vehicles that operate on a network of purpose-built tracks. PRT is a type of automated travel along guides. PRT vehicles are designed for individual trips or trips in small groups of no more than three to six passengers. The guides are located within a networked urban topography, with all stations located on sidings and routes have frequent merging/divergence points. This allows you to make non-stop trips from point to point, bypassing intermediate stations. The point-to-point service is compared to a taxi.

Many PRT systems have been proposed, but most have not yet been implemented. Examples of successful PRT projects include currently operating systems in West Virginia University in Morgantown (USA, since 1975), in Masdar Institute of Khalifa University in Masdar City (Abu Dhabi, UAE, since 2010), a ten-vehicle system has been operating in Masdar City, UAE; at London Heathrow Airport (Ultra Global PRT, since 2011)[32].

The design of a high-speed string transport system on supports for urban passenger, freight and intercity transport was proposed in Belarus, promoted by A. E. Yunitskiy [8–10]. This is SkyWay string transport system.

In the SkyWay system, driverless mounted or suspended high-speed electric vehicles-modules of various passenger capacity with steel wheels with a diameter of 50–70 cm should move along a continuous pre-tensioned string-rail overpass (Pic. 11).

The system is planned to consist of supports and two current-carrying string-rails, separated from each other, along which the cars move. Anchor supports are designed to be installed at intervals of 500–2000 m, and intermediate ones – at intervals of 20 to 100 m. Supports are installed on any terrain, and their height is determined by the terrain and the height of the objects over which the loop route passes.

Jointless rail-string, according to the intention of the authors, is a rigid thread formed by a hollow rail with steel ropes stretched with a force of 2500 kN inside. The sagging of the rail thread in spans up to 100 m long is no more than 10 cm. The speed of movement is up to 300 km/h and higher with automatic traffic control. Passenger stations for embarking and disembarking of passengers are arranged along the ring [9–10].

Moving of transport arteries underground is currently associated with the problem of urban land being occupied by engineering structures and an increased level of motorisation. Transport systems can occupy up to 30 % of the territory in cities, and up to 70 % in their central parts.

Transferring traffic to tunnels gives good results. The Big Dig project in Boston (USA) is a milestone. It is a network of engineering structures, including long motor transport tunnels [5; 11]. The project consisted mainly of replacing the elevated highway with a tunnel. After the construction was completed, the elevated highway was demolished, and more than 45 parks and city squares were created in its place. Due to this project, the environmental situation was improved: the citywide level of carbon monoxide emissions decreased by 12 %.

[32] West Virginia University PRT. [Electronic resource]: https://prt.wvu.edu/home; Masdar. Mubadala Investment Company website. Mobility. [Electronic resource]: https://masdar.ae/Masdar-City/the-city/Mobility; Ultra Gloval PRT website. [Electronic resource]: https://www.ultraglobalprt.com/wheres-it-used/heathrow-t5/. Last accessed 21.01.2022.

Pic. 11. Passenger car of A. E. Yunitskiy's system SkyWay [Unicar vehicle U4-431. Operation manual. Minsk, Strunnye technology LLC., 2018, P. 220].

This idea is currently also of interest to Elon Musk, who is promoting innovative types of urban transport to be located in underground multi-tiered tunnels in the future.

E. Musk's urban transportation project develops high-speed technologies for moving cars underground at a speed of about 200 km/h. Cars are installed on special platforms and lowered underground with electrical equipment. A network of such tunnels, according to the authors of the project, can save the city from traffic jams.

The project of a linear city («the Line») where residents will not use cars on the surface, and in which «all the infrastructure will be hidden underground, where they will make a transport level for high-speed transport controlled by artificial intelligence (AI)», is being developed in Saudi Arabia [33, 34, 35].

Construction of a high-speed underground road from O'Hare International Airport (79,81 million passengers per year) to Chicago (USA) with a length of 27 km was discussed [Chicago Express Loop]. Unmanned single wagons for 16 people were suggested to be used at a speed of 160 km/h and departing every half minute. Travel time on the route might be 12 minutes [36].

ABB Daimler Benz Transportation, at the initiative of Moscow city government, developed a project for construction of a high-speed passenger transport system Transrapid to connect terminals of Sheremetyevo international airport and the Moscow City Business Centre [37].

Original ideas are presupposed by another project: the Dahir Insaat gyrotrain [gyroscope-stabilised trains], moving over urban traffic with the help of a gyroscope [38].

Dahir Insaat's gyrocars could be equipped with gyroscopes that maintain balance due to a flywheel and slide along the rail, being above ordinary cars and pedestrians at a height of several metres. Such a rail should be placed on the dividing strip between the rows of cars. The height of the rail from the level of the road is only two centimetres, and it does not interfere

[33] Saudi Arabia will have a linear city without cars (in Russian). [Electronic resource]: https://rg.ru/2021/01/14/v-saudovskoj-aravii-poiavitsia-linejnyj-gorod-bez-mashin.html. Last accessed 03.02.2022.

[34] Saudi Arabia bets on the city of the future (in Russian). [Electronic resource]: https://www.kommersant.ru/doc/4652223. Last accessed 03.02.2022.

[35] In Saudi Arabia, a million-plus city without cars will be built. Up to $ 200 billion will be spent on construction of the «city of the future» (in Russian). [Electronic resource]: https://motor.ru/news/saudiarabia-theline-11–01–2021.html. Last accessed 03.02.2022.

[36] High-speed underground railway will be built to Chicago airport (in Russian). [Electronic resource]: https://tourism.interfax.ru/ru/news/articles/49931. Last accessed 21.01.2022.

[37] Decree of June 2, 1998 N 439-PP On the concept of building a high-speed transport system between the Moscow International Business Center «Moscow City» and the airport complex «Sheremetyevo». [Electronic resource]: https://mos.ru/authority/documents/doc/27166220/. Last accessed 21.01.2022.

[38] A gyroscope (from other Greek γῦρος «circle» + σκοπέω «I look») – a device capable of responding to changes in the orientation angles of the body on which it is installed relative to the inertial of frame reference. The term was first introduced by J. Foucault in 1852.

with vehicular traffic. As a result, busy megacities can get a large vehicle capable of moving over city roads using only the median strip between the lane[39].

There has been a completely new approach to creating vehicles for transportation of passengers focused on hybrid vehicles. Currently, there are attempts in many countries to create an «ideal hybrid», in which the advantages of each mode of transport should replace its shortcomings.

Overall, many of the general futuristic trends refer to transport in one way or another[40].

CONCLUSION

Based on the study and analytical review of domestic and world experience in the field of improving existing and creating innovative vehicles for transporting passengers in the city, it is possible to identify the main trends in the area under consideration.

They include, first, the transition to renewable energy sources that improve the environment; development of high-speed systems to reduce travel time for passengers; construction of tunnels that reduce the occupancy of city areas; introduction of drones that reduce the number of accidents; widespread popularity of bicycles as an opportunity to reduce physical inactivity of urban residents, and a number of other trends.

Further development of the transport infrastructure, especially in large cities and megacities around the world, should consider the available scientific and research developments and the cumulated experience of their application to solve urban problems and best practices.

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Article received 12.01.2022, revised and updated 03.02.2022, approved 15.02.2022, accepted 25.02.2022.