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Redevelopment of the Moscow monorail

In the world practice of recent decades, monorail transport systems have been actively developing as an element of the mass passenger transport system. There is a monorail line in Moscow, which has exhausted its operational reserves and needs reconstruction. The article discusses the possible directions of development of the monorail in Moscow. Five possible directions of development have been identified, including the transformation of the line into other modes of transport (tram), the construction of an extension of the monorail line in various directions, the arrangement of urban public spaces and the renewal of rolling stock. Construction of an extension of the existing monorail line, rebuilding the system into a tramway, arrangement of a linear fleet — these are very costly options that require a significant amount of time to discuss projects. The most promising direction in the development of the system is the renewal of the rolling stock or its complete replacement while preserving the linear part of the monorail.

Keywords: mass passenger transport, General plan of Moscow, monorail, linear parks, tram

Currently, monorail high-speed off-street transport is actively developing in large cities and megalopolises of the world. There has been a significant increase in the length of fully automated monorail lines in China, Japan, USA, South Korea and other countries. Over the past 30 years, leading manufacturers have come a long way in improving the technical and economic parameters of their products. Monorail systems of different generations differ significantly in their efficiency and operational reliability.

The average haul length in modern monorail systems is 500...800 m with communication speeds of 30...36 km/h, with accelerations and decelerations the same as on subway cars [1–6]. For example, a monorail system built in 2015 in the city of Daegu (South Korea) with a length of 24 km (average run length 800 m) worth \$333 million (970 million rubles/km) provides a communication speed of 36 km/h (on the Moscow metro — 42 km/h). The system is characterized by high carrying capacity and is part of the Daegu subway as the 3rd subway line.

The Moscow Monorail Transport System (MMTS) is the only monorail transport line that is part of the high-speed off-street transport system in Moscow. Built in the period 2001–2004, the line runs through the territory of the North-Eastern and Northern districts of the capital from the territory of the All-Russian Exhibition Center (VDNKh) to the Timiryazevskaya station of the Serpukhovsko-Timiryazevskaya metro line. Forming a separate transport company, MMTS is part of the Moscow Metro and operates according to unified tariffs and rules of use (Fig. 1 and 2).

The development and construction of MMTS was carried out in the period from 1998 to 2004. In accordance with the decree of the Government of the city of Moscow¹. The total length of the route along which passengers are transported was 4.81 km in double-track (9.62 km in single-track) with an average run length of 960 m. The development of the Monorail as a type of urban transport was primarily

due to an attempt by the city authorities to find cheaper in terms of construction and operation alternatives to the metro. It was during that period of time that various projects of alternative systems were proposed, two of which were implemented: MMTS and the "light metro" in the Moscow region of Butovo.

For the first four years, the constructed monorail line was operated in the so-called "excursion" mode, which implied long intervals between trains and an increased cost of travel. The line switched to the mode of the passenger transport system in 2008 and worked in it until the end of 2016, after which the problem of wear and tear of rolling stock arose, and the line again switched to the "excursion" mode due to the lack of serviceable trains. The maximum volume of annual passenger traffic was reached in 2014 and amounted to 5.6 million passengers (Fig. 3).

The choice of routing the only monorail line was due to several factors: Moscow's struggle for the right to host the prestigious EXPO-2010 exhibition (which was later held in Shanghai), the presence of a finished alignment in urban development, left by the General Plan of Moscow for the development of the road network and other factors.

When the carriages are filled at the rate of 5 people/m², the capacity of a train with a length of 31.4 m is 200 passengers. The maximum carrying capacity is 6 thousand passengers per hour in one direction. While operating in the transport mode, MMTS successfully mastered, in addition to local, passenger flows in the transverse direction, between the Serpukhovsko-Timiryazevskaya and Kaluzhsko-Rizhskaya metro lines. The decrease in the role of MMTS in the transport system occurred gradually. In 2016, with the opening of the Moscow Central Ring (MCC), the task of connecting radial lines in the north of Moscow was solved with the help of a new, better transport service on the railway infrastructure, and the passenger traffic on MMTS significantly decreased. In the same year, the Fonvizinskaya metro station was opened, which also began to discuss the gravity area of the Milashenkova Ulitsa monorail station. Additionally, in 2022 it is planned to open the Savyolov-

¹ Official portal of the Mayor of Moscow. URL: <https://www.mos.ru/authority/documents/doc/15961220/>

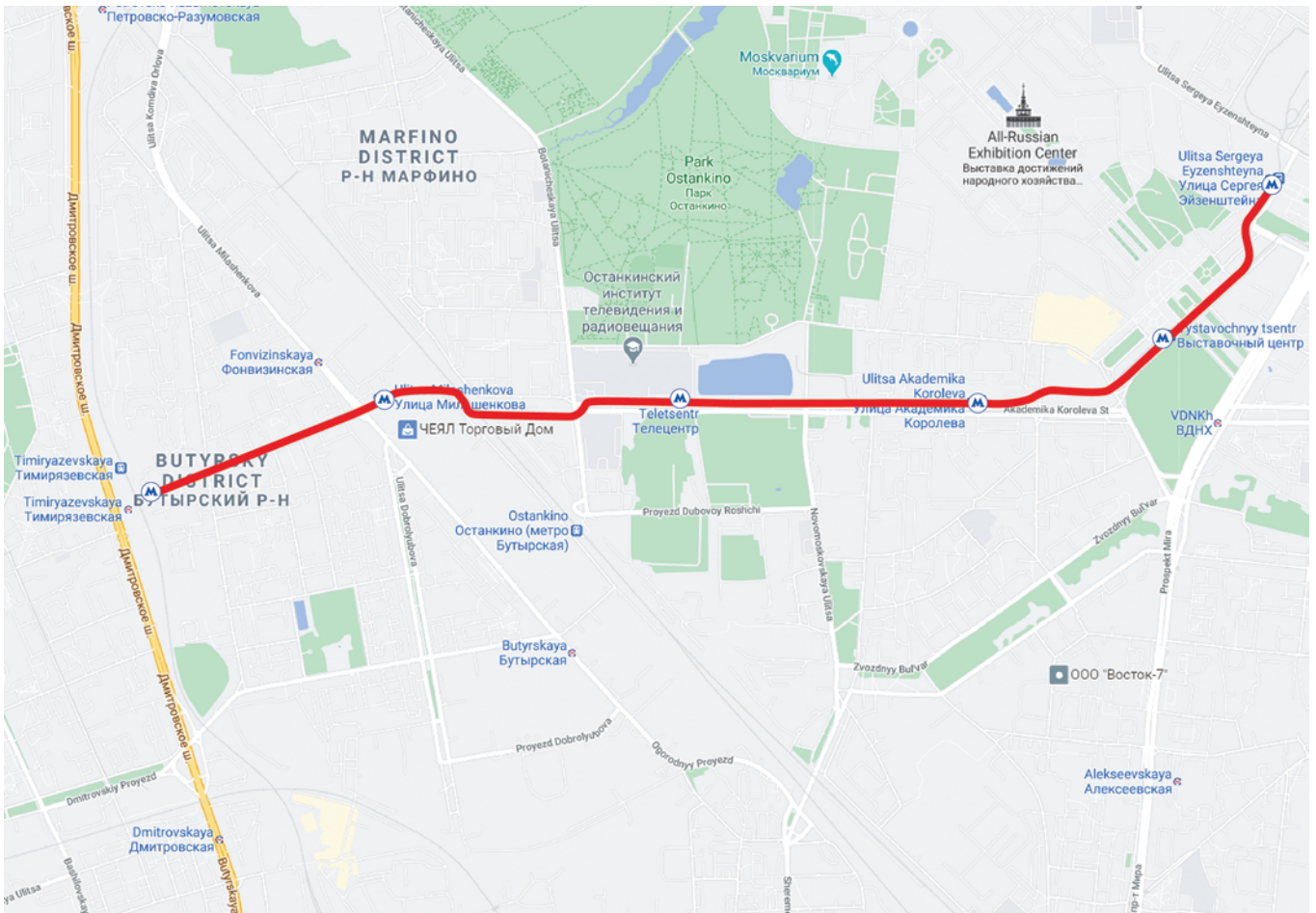


Fig. 1. Moscow monorail transport system



Fig. 2. Exterior of the rolling stock of the Moscow monorail transport system



Monorail volume of passenger traffic

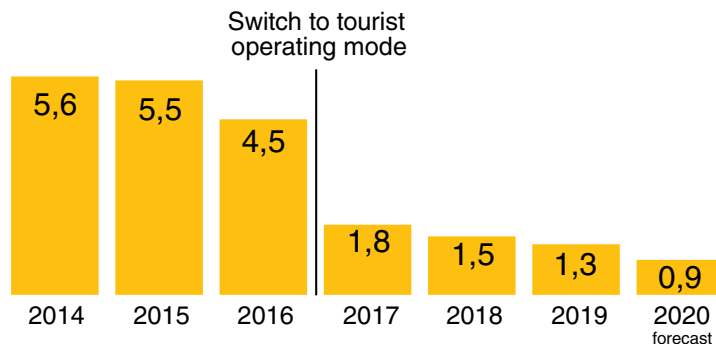


Fig. 3. Passenger traffic of the Moscow monorail transport system, million passengers/year

skaya-Rizhskaya section of the Big Circle Metro Line, which will duplicate the MMTS route from the south.

A strong blow to the passenger flow of the monorail was the gradual strengthening of tram route No. 17 in the period from 2011 to 2020. This route duplicates the monorail track by 40 % of its length. The reduction of the interval in the schedule to 2...5 minutes, the introduction of a clock schedule and the introduction of modern rolling stock led to an increase in the attractiveness of the tram and a gradual outflow of passengers from the monorail. As a result, to date, MMTS serves small local passenger traffic, which is formed mainly due to the lack of direct communication by other modes of transport through the Oktyabrskoye direction of the railway.

All of the above led to the need to develop a project for the reconstruction of the Moscow monorail system and the development of documentation for the planning of the territory of a linear transport infrastructure facility, carried out by specialists from the Institute General Plan of Moscow, RUT (MIIT) and other specialized organizations commissioned by the Moscow Committee for Architecture and Urban Planning. As part of the work, a wide range of issues were considered, including: determining the need to extend the monorail line and options for its development.

Several main directions of development of the MMTS system were considered:

- extension of the monorail line and its integration with the lines of the Moscow Central Diameters, the metro and the MCC;
- various options for the reconstruction of the monorail line with the organization of tram traffic along the route;
- elimination of train traffic and the use of line supports to create a linear park and public space;
- preservation of the monorail line with its reconstruction and the use of new rolling stock;
- use of alternative rolling stock.

Line extension

Five options for extending the monorail line from the existing section near the VDNKh metro station were considered (Fig. 4):

- along Wilhelm Pieck Street to TPU Botanical Garden;
- along Prospect Mira to TPU Rostokino;
- along Boris Galushkina Street to the Yaroslavl direction of the Moscow Railways and further along the railway: either to the Malenkovskaya platform, or to the Rostokino TPU, or further, through Losiny Island to the promising development zone near the Bogatyrsky Bridge.

The extension from TPU Timiryazevskaya was deemed not promising and was not considered.

The implementation of all options is fraught with significant difficulties: passage through densely built-up urban areas, the need to organize construction in areas with a special natural, historical and cultural status. In addition, it is necessary to take into account the dynamic development of the city's passenger transport system: the project of the Moscow Central Diameters, the construction of the metro, the development of tram traffic and the entire system of ground passenger transport, and the increase in the carrying capacity of the Moscow Central Circle. This leads to an increased cost of extending the monorail, on the other hand, reduces the demand for its services. The calculations showed that the average load of the monorail section will be from 0.5 to 2.6 thousand passengers during the "peak" hour in the maximum direction. The maximum estimated value of passenger traffic on the stretch did not exceed 5.0 thousand passengers.

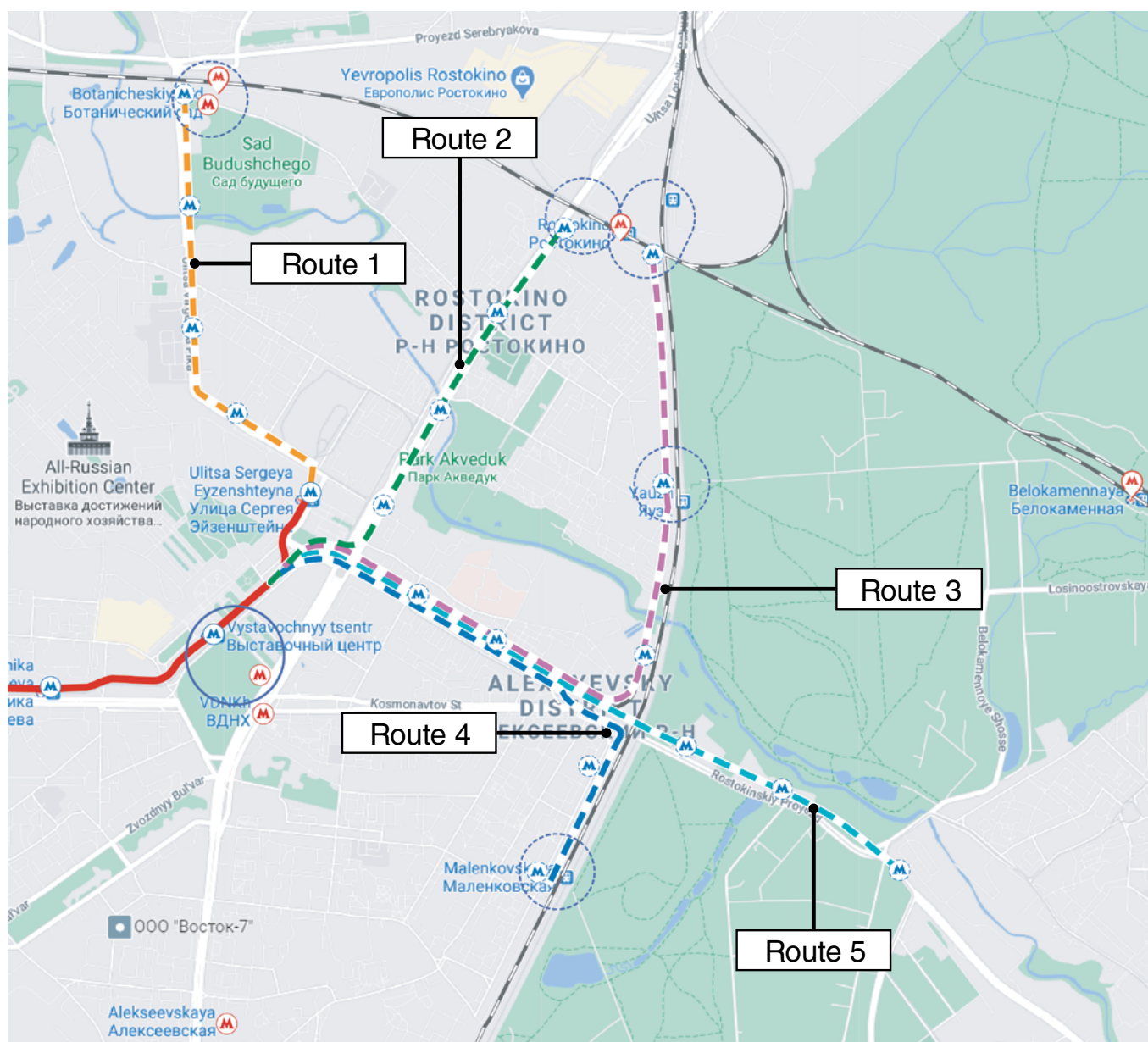
Despite the technical feasibility of the extension, the predicted value of passenger traffic and the forecast of the total amount of socio-economic effects do not allow us to say about the priority of this project. Modeling shows that with any of the options for extending the existing MMTS route, it is not possible to achieve passenger flows inherent in off-street rail transport lines. In the case of bringing MMTS to the parameters of a high-quality transport system in terms of speed and frequency of circulation, a passenger traffic of 4–6 million passengers per year can be achieved, which is equivalent to the transport mode of operation of MMTS in the period from 2008 to 2016. In the further calculation of the technical and economic parameters of the modernization of the monorail, just such target passenger flows can be used.

Organization of tram traffic

Several options were considered:

- the use of existing supports, beams and spans with the reconstruction of the track structure and the organization of tram movement along the existing route;
- dismantling of the monorail line and construction of a new tram line along its route;
- in both scenarios, the extension of the tram line through the Savelovskoe direction of the Moscow Railway and the connection with the existing tram network of the northern sector of the city was considered.

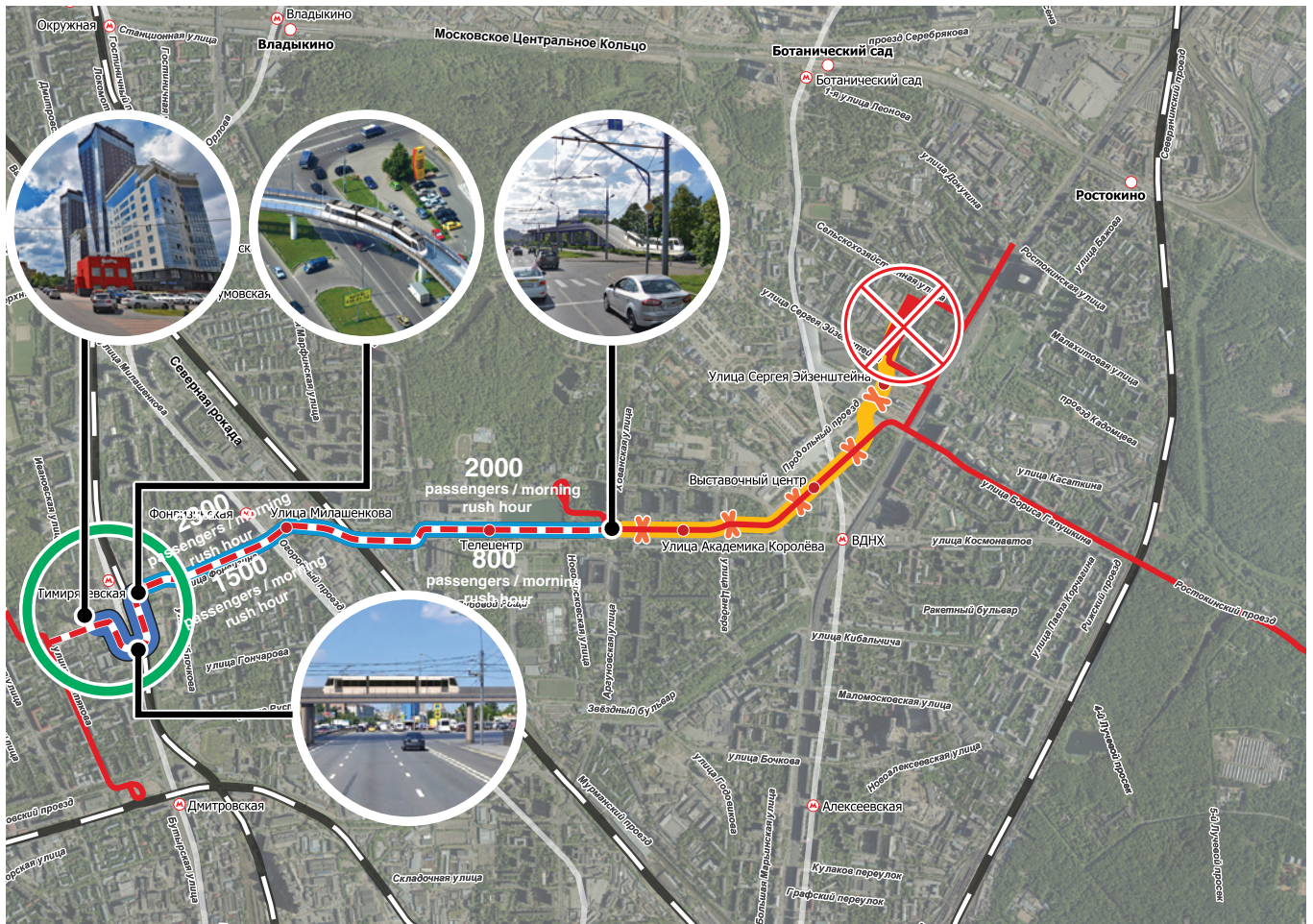
The advantage of this direction of development is the possibility of forming a single tram network in the northern sector of the city (today it is divided after the elimination of tram traffic on Prospekt



- Existing railway lines
- Existing monorail line
- Possible monorail routes
- Existing Moscow Metro station
- Existing Moscow Central Circle station
- Existing monorail station
- Planned monorail station
- Existing change
- Planned change

Fig. 4. Options for extending the Moscow monorail transport system





- Existing tram lines
- - - New tram line
- X Monorail line dismantle zone
- Zone of overpass tram line
- Construction zone for overhead road and tram line

Fig. 5. Schematic diagram of the tram network connection in the northern sector of Moscow

Mira). A schematic diagram of the tram network connection is shown in Fig. 5.

The calculations showed that the geometric parameters of the route and the bearing capacity of the existing route will not be able to ensure the movement of the tram, i.e. in fact, it is necessary to demolish most of the monorail structures and rebuild, taking into account the static and dynamic loads from the tram rolling stock. In addition, a complete reorganization of the energy sector, the system of maintenance and operation of the monorail is required. The option with an extension is associated with significant costs for the construction of new transport facilities and the reconstruction of engineering networks. In general, the cost of constructing a tram line along the monorail route is estimated at 14–16 billion rubles.

Creation of a linear park and public space

The creation of linear parks on the site of former transport structures is becoming a fashionable trend in the mid-end of the twentieth century. The territory for the creation of linear parks was the former railway structures. The relocation of production from city centers in Europe and the United States made them unnecessary for freight traffic. Some of them were used to develop passenger traffic, some were eliminated, and some were used to organize linear parks — public spaces [7].

One of the first such projects was implemented in Paris, and the most famous one in New York, High-Land-Park. (Fig. 6). The project is a public green space, organized in the structures of a former railway overpass, which provides transportation of goods to enterprises located in the Manhattan area.

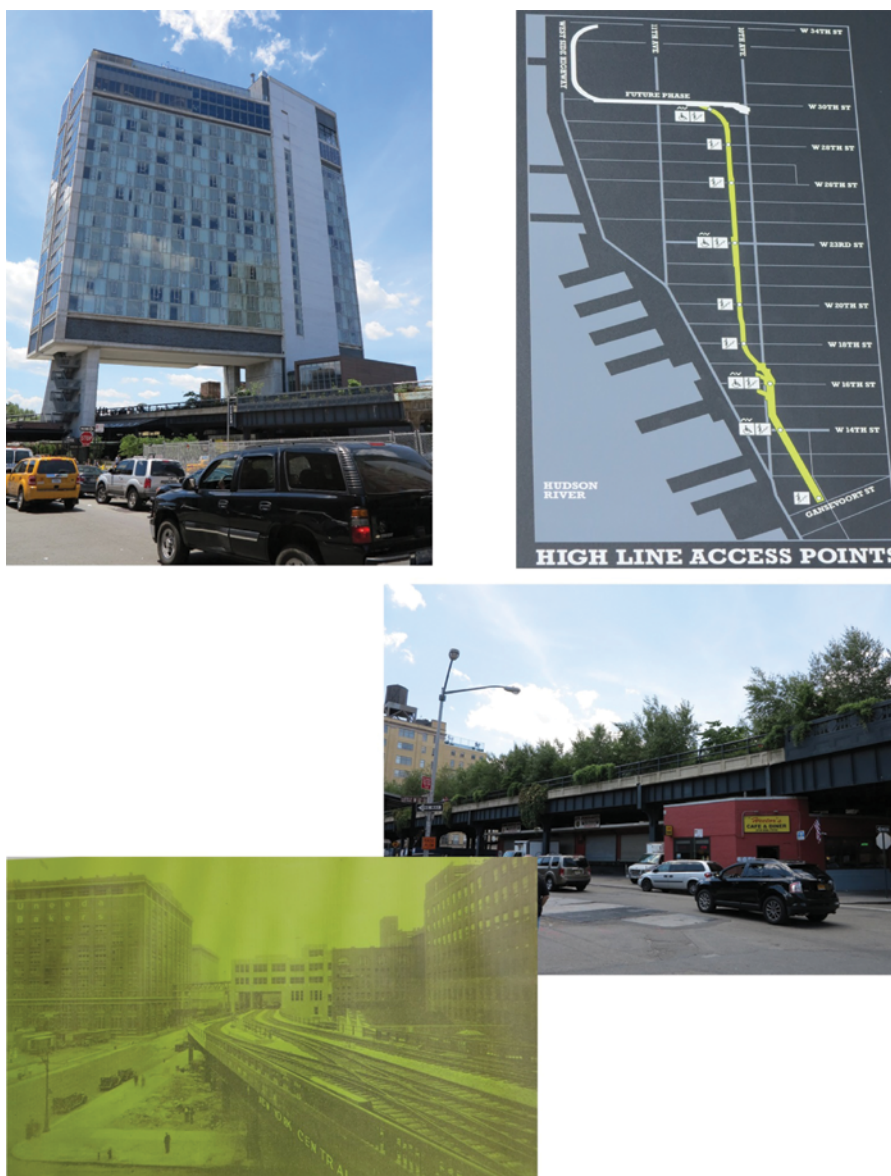


Fig. 6. Schematic diagram and appearance of High-Land-Park in New York

To date, a significant number of similar projects have been implemented in world practice, related not only to the transformation of the railway, but also to the reconstruction of the street and road network of cities:

- the Big Dig project in Boston [8], where a federal transit highway that passed through the city center on an overpass was rebuilt and removed into a tunnel that passes under the city center, meeting the Boston subway line and the Atlantic Ocean;
- the project for the restoration of the Cheonggyecheon River, when in the 60s of the last century the river was removed into a pipe, and a highway was built above it, and at the beginning of the 21st century the highway was liquidated, the channel was opened and a single public space was created.

The characteristic features of such projects are their high cost, significant implementation periods (most often in separate stages lasting for several years). An important aspect is a long-term public discussion of various options for transforming space. Given the

need to make a prompt decision on the future fate of the monorail, this option does not seem appropriate.

Preservation of the monorail line with its reconstruction and the use of new rolling stock

The monorail system is based on the developments of Intamin, a Swiss engineering company. During the construction of the MMTS system, the following were redesigned: the drive, the central locking system that ensures traffic safety and the traffic control system.

To obtain significant results that allow assessing the safety of work and the technical condition of MMTS, the specialists of TOMAK LTD carried out tests and tests of starting, braking and energy modes of train operation on all existing tracks. To increase the reliability of the measurement results, at the suggestion of the monorail depot specialists, traction and energy tests were carried out on different trains.

Curves of movement were processed in accordance with an innovative method of processing test results, verified during state acceptance tests of subway trains of the “NeVa” project. It takes

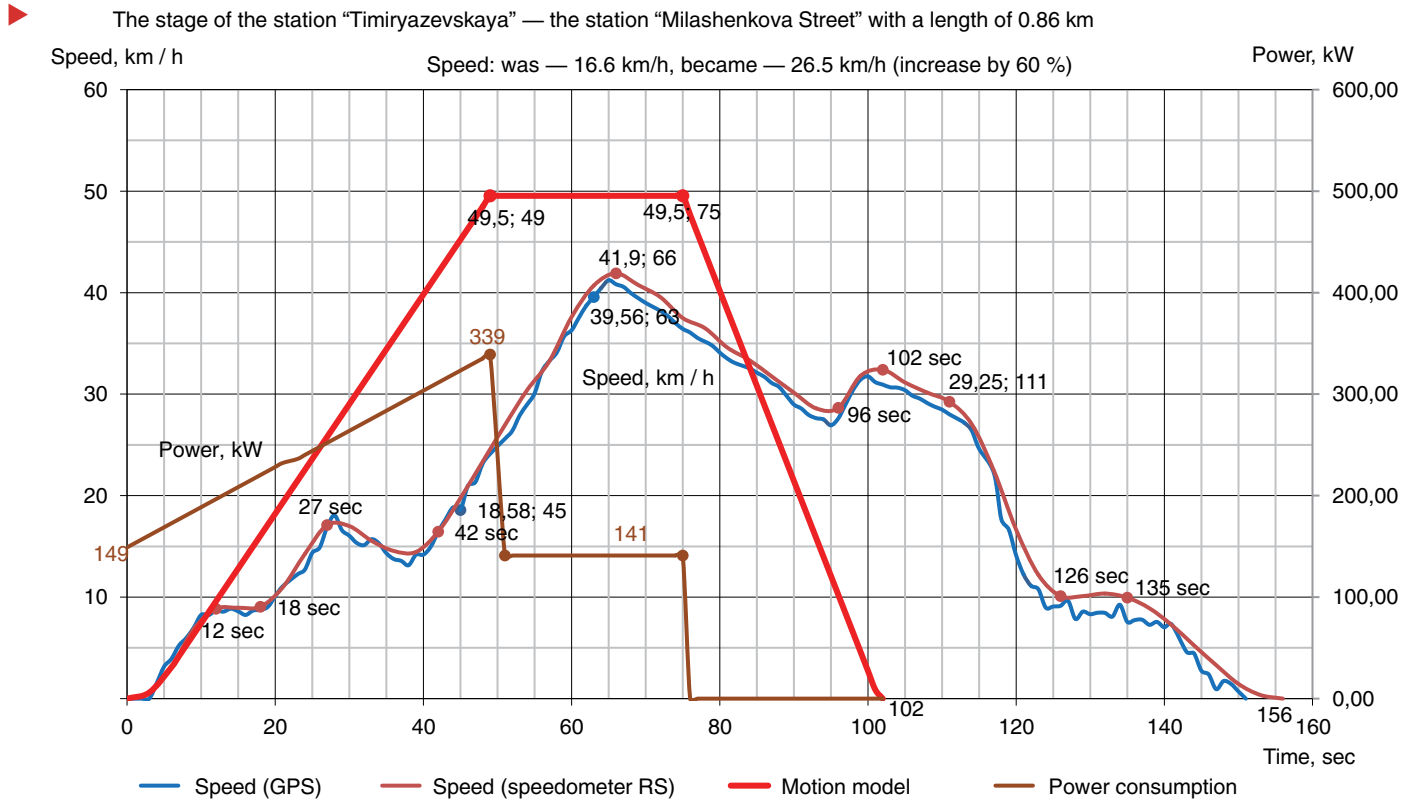


Fig. 7. Curves of thrust, energy and movement of a monorail train

into account not only the very energy of the movement of electric rolling stock, but also the influence of the track profile on it, which is very significant in the case of a sharply variable profile of the monorail track. Traction-energy calculations of motion were carried out according to it and proposals were developed to improve their traction, energy and braking characteristics [9–13].

It was found that in the operational mode of movement the speed of trains on the line is significantly underestimated. This is due to the various restrictions imposed on their movement by the complex track profile and the presence of small-radius curves on the track. In this regard, tests were carried out with increased (from 0.3 to 0.8 m/s²) accelerations and decelerations. This made it possible to find out how an increase in the acceleration and deceleration of mono-trains affects the energy indicators of traction and the speed of communication. It was found that in the speed range of 30..60 km/h, the growth of acceleration is impeded by the characteristics of linear asynchronous traction motors, which do not have a field weakening mode, which allows maintaining a constant traction power.

Fig. 7 shows the results of experimental measurements and calculations of traction, braking and energy modes of train operation. The modernized train operating mode with a traffic speed of 26.5 km/h is applied to the normal operating mode with a communication speed of 16.6 km/h. The communication speed in the modernized mode has increased by 60 %, and the power consumption by 35 %.

As a result of the tests carried out, it was found that with the existing technique and technology of monorail traction, based on the use of linear asynchronous traction motors, the route speed of monorail trains can be increased by no more than 1.5 times (from 16 to 24 km/h). These results indicate the presence of an unused reserve for improving the quality of MMTS operation in the current conditions.

Use of alternative rolling stock

If a decision is made to change the type of rolling stock, the following requirements must be taken into account:

- maximum preservation of the existing linear infrastructure and depot;
- taking into account the bearing capacity of the main elements of the linear infrastructure;
- the possibility of increasing the length of the rolling stock (taking into account the available length reserve of platform sections);
- changing the layout of the rolling stock in accordance with modern requirements (through passage through the train, limited number of seats);
- the ability to fully automate the transportation process;
- improvement of the linear motor and, as an option, the introduction of a partial magnetic suspension system;
- etc.

As part of the work on the development of the project, the layouts of the monorail were carried out with possible suppliers of the new rolling stock for the monorail. Suppliers are ready to supply modern electric rolling stock for the modernization of MMTS, each with different traction technologies and various automation and control systems for train traffic safety.

In the future, it is necessary to estimate the costs of [14, 15] for the implementation of projects and holding open tenders with the participation of leading domestic and foreign manufacturers with the formation of legally binding commercial proposals.

Main conclusions:

- the construction of the Moscow monorail was completed in 2004. The system has been integrated into the Moscow passenger transport system, however, for the last 4 years the system has been operating at extended intervals due to wear and tear of the rolling stock and a number of other factors.
- five main options for the development of the monorail system are considered. The extension of the line was considered not promising due to the insignificant demand for monorail services in the considered sector of the city. The option of constructing a tram along the monorail route has a number of town planning advantages, but it has a high cost of implementation. The project of creating a linear park requires a long discussion with the public of the city and large costs;
- the most promising areas for the development of the system are: renewal of rolling stock or the use of alternative rolling stock.

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Реконструкция Московского монорельса

В мировой практике последних десятилетий активно развиваются системы монорельсового транспорта как элемент системы массового пассажирского транспорта. В Москве существует линия монорельса, которая исчерпала резервы эксплуатации и нуждается в реконструкции. В статье рассмотрены возможные направления развития монорельса в Москве. Определены пять возможных направлений развития, включая трансформацию линии в другие виды транспорта (трамвай), продление линий монорельса в различных направлениях, устройство городских общественных пространств и обновление подвижного состава. Строительство продлеваемой существующей линии монорельса, перестройка системы в трамвайный транспорт, устройство линейного парка являются очень затратными вариантами, требующими значительного времени для обсуждения проектов. Наиболее перспективным направлением развития системы является обновление подвижного состава или его полная замена с сохранением линейной части монорельса.

Ключевые слова: городской пассажирский транспорт, Генеральный план города Москвы, монорельс, линейные парки, трамвай

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