



Moscow Metro's Big Expansion

The last decade has seen an unprecedented programme of metro line construction in Moscow. We asked consulting engineers Mosproekt-3 to share some of their work on this rapidly expanding network.

On 18 March 2020, a new
Guinness World Record was
achieved in Moscow for the
most TBMs ever to be operating
simultaneously on a single project:
23 TBMs were boring new metro
tunnels – and those were just
the ones that were operating that
day. Most of them were standard
6m-diameter metro machines,
but there are some 10m machines
boring double-track tunnels too.

The scale of the expansion of the Moscow Metro is staggering. It forms the largest part of the New Program of Moscow Transport Development, which started in 2011. Since then, the city has opened over 100km of lines and 50 metro stations.

Projects have included the creation of the Moscow Centre Circle, with 31 stations opened, the Moscow Central Diameters, where 58 stations have opened, and the construction of the Big Circle Line which is currently underway (teal line on map, page 11). There are also multiple extensions to existing lines, extending to the outskirts of the city and its suburbs.

The Mosproekt-3 group of companies was formed in 2014 from the merger of three design consultancies: Mosproekt-3, Mospromproekt and MNIITEP. With the huge amount of metro work promised by the city, the new group focused on strengthening its expertise in underground construction. As well as being the first company in Russia to design a metro line using BIM, Mosproekt-3's designers have worked on some of the most challenging projects on the metro, including deep stations in unstable soil and

a top-down station constructed while the line remained active. (See pages 13 and 14).

New vision

The first section of Moscow's metro opened in 1935 with 13 stations. Since then, there have been various expansion projects over the years, but none so substantial as this one – or conducted at such a fast pace.

There are several aims for the ambitious program. First to shift people's mode of travel from cars to public transport, improving their journey times and experiences and reducing congestion. This

is already happening, with Muscavites taking a reported 5m journeys on the metro in 2020. Second, the metro expansion aims to drive the regeneration of remote and depressed areas of the city with the creation of new cultural and business centres in different districts.

Moscow has said that its inspiration for the expansion program was Paris and its Grand Paris metro line, currently under construction, which will circle the city, connecting deprived neighbourhoods. But Moscow has already overtaken Grand Paris, both in ambition and in the amount of construction achieved. The Moscow Central Circle (brown on the map), running through over 20 districts of the city, opened in 2016. Linking former industrial areas, the goal of the Moscow Central Circle is to stimulate economic development in them and encourage the construction of new residential areas.

Radial metro lines were extended to remote Moscow districts: the extension of the Tagansko-Krasnopresnenskaya Line to Kotelniki station (Zhulebino district); a southern extension of the Zamoskvoretskaya Line to Alma-Atinskaya station (Brateevo district) and a northern extension to Khovriono station (Khovriono district). In 2020, the Nekrasovskaya Line was opened for passengers.

Currently three stations on the Lyublinsko-Dmitrovskaya Line are under construction, with the line being extended to Phistech station in Severny district; the Sokolnicheskaya line will be extended to Novomoskovkaya station; and the Kalininsko-Solntsevskaya Line will be extended to the Vnukovo airport, with Vnukovo becoming the first airport in Moscow with its own metro station. The Troitskaya Line is under construction, while the Birulevskaya and Rublevo-Arkhangelskaya Line are at the design phase.

The Big Circle Line certainly lives up to its name: 70km of line with 31 metro stations and three train depots. Once completed it will be the longest metro circle line in the world, pushing Bejing's Second Circle Line into second place. This is where most of the construction

Belomorskaya station: top-down construction to an active metro line



work is currently focussed.

Plans for the Big Circle Line had been on the drawing board since Soviet times. But to implement it, designers had to reconsider the alignment of the tunnel, bringing them closer to the surface to reduce the cost and the time to construct.

Moscow has drawn on international resources to help construct the circle line, with companies from the Commonwealth of Independent States getting involved. Chinese company CRCC is working on both the BCL and Troitskaya Line, and Spanish designer Bustern proposed the construction of the large-diameter, double-track tunnels.

Some of the Big Circle Line is already operational. The first section opened in 2018 and a

Pykhtino

second section in 2020. In 2022 the whole line is scheduled to be carrying passengers.

The design of each station is different, as is the tradition for Moscow metro. There have been several international design competitions, one of which was won by a consortium led by UK practice Zaha Hadid Architects which is designing the Klenovy Bulvar-2 station on the Birulevskaya Line.

The transport development

Troparyovo

program also includes surface railway lines which cross the city from one side to another providing connections, the Moscow Central Diameters. In 2019, the first two diameters, MCD-1 (Odintsovo to Lobnya) and MCD-2 (Nahabino to Podolsk) opened to passengers. The Moscow Government plans to construct a further three to improve connectivity for remote Moscow districts.



Bulvar_

Varshavskaya



Kaluzhskaya

Sevastopolskaya



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Anna Merkulova, CEO



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107031, Moscow, Kuznetskiy Most Street, 3, Russia e-mail: welcome@mosproekt3.ru

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Mospoekt's designs for Moscow Metro: some of the highlights

Okruzhnaya Station: grouting and ground freezing in unstable soils

The 6.2km extension of the northern end of the Lyublinsko-Dmitrovskaya Line from Petrovsko-Razumovskaya to Seligerskaya Station included three stations - Oruzhnaya, Verkhniye Likhobory and Seligerskaya - and a junction line to the Likhobory Metro Depot.

The extension is in a dense residential and industrial area with a huge amount of existing engineering systems and railways lines, and in very difficult geotechnical conditions. The tunnels were constructed by TBM and drill-and-blast through a composite soil consisting of sand and limestone, most of it water bearing. During the construction of the stations, main line and inclined escalator tunnels, which were located in the aqueous soil, chemical grouting and ground freezing were used.

The deepest of the three stations on the extension, at 65m, is Okruzhnaya Station, and one of the last deep stations on Moscow Metro. It has two ticket halls and underground pedestrian crossings and is equipped with elevators for people with limited mobility.

The major challenge of this project, and what makes it unique, is that it was constructed by tunnelling rather than topdown construction, with the tunnels built from shafts. Track laying and station construction



were difficult to implement because of quick soil, an aqueous soil that can liquefy in response to any mechanical impact, such as excavation.

The inclined escalator tunnel for the station was constructed under the Savyolovsky Suburban Railway Line without any disruption to train traffic. A railway track reinforcement system was installed along the inclined tunnel to protect the railway bed from deformation. Mosproekt-3 engineers proposed the construction of an ice wall to protect tunnelling from quick soil impact during the construction of the inclined escalator tunnel. As a result, the construction of this difficult

segment was conducted smoothly.

The station's South ticket hall was opened initially, while the North ticket hall will be opened later and will become a part of Okruzhnaya Transport Interchange Hub, from which it will be possible to transfer to Okruzhnaya Station on the Moscow Central Circle (MCC) and the Savyolovsky Suburban Railway Line.

The interior of the station was inspired by the Savyolovsky Suburban Railway Line, which is also located in this area. The image of railway line was reflected in decorations for the ceilings – there are five lines of suspended lights. The light falls onto the station's vault and platform. The finishes of the passenger area are grey and black granite, as well as white and colored marble with a golden tint.

After the extension was opened in March 2018, transport conditions in the North of Moscow improved, with the volume of traffic on the Dmitrovskoye Highway and Korovinskoye Highway decreasing, which had a positive impact on the environmental situation in the Beskudinovo and Zapadnoye Degunino Districts.

Troitskaya line: stations completely designed using BIM

As part of the development of the Troitskaya metro line, the Mosproekt-3 group of companies is designing the first section from the Ulitsa Novatorov station to the Mamyri station. The section of the line consists of five stations: Ulitsa Novatorov, Ulitsa Generala Tyuleneva, Universitet Druzhby Narodov, Slavyanskiy Mir, Mamyri.

Although Mosproekt-3 engineers started introducing BIM while working on the section of the Sokolnicheskaya line from Salaryevo to Kommunarka station, this 13km section of the Troitskaya line became the first metro project in Russia which was fully designed using BIM.

More than 90% of the project design documentation for Slavyansky Mir station was created using information modelling

technology. Mosproekt-3 specialists designed architectural models of the facility and all the engineering systems such as water supply, water disposal and cabling. Using BIM helps facilitate the rapid rates of construction

which are currently underway for Moscow transport schemes, says Mosproekt-3.

For example, at the design phase, engineers have new ways to link technical solutions and resolve

collisions between communications and structures, which otherwise might only be detected at the construction phase, delaying final acceptance and commissioning of the facility.

Mosproekt-3 engineers developed design solutions for the tunnels of the new section, ranging from construction technologies to the lining method. Taking

into account the

prevalence of watersaturated soils, the engineers decided to use high-precision waterproof blocks in order to prevent groundwater seepage into the structure.



Novomoskovskaya station: the first heated ground-level metro station

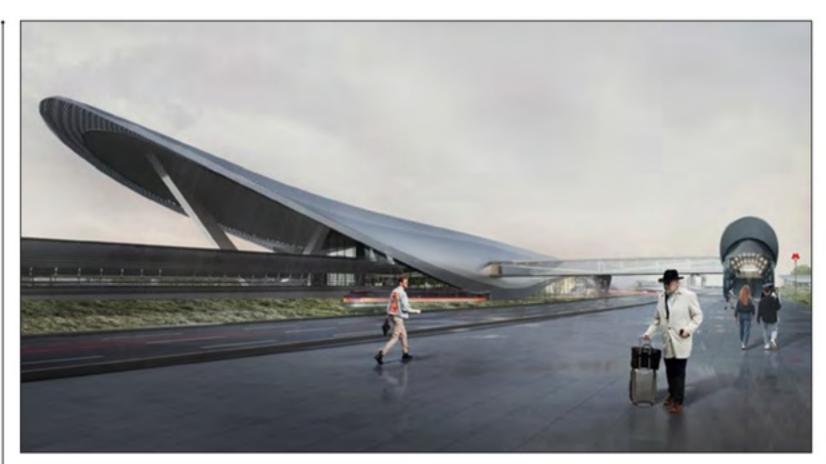
Novomoskovskaya station is located along the extension of the Sokolnicheskaya line and will be the terminal station in the near future. Construction of the station, which will be the first heated ground-level metro station, will start this year. Mosproekt-3 group engineers are currently completing project design documentation.

To install the additional equipment required to heat the four-storey station, Mosproekt-3 specialists suggested a creative and nonstandard engineering solution: installing all the equipment directly into the station envelope to maintain its architectural appearance.

Instead of ventilation chambers inside the station, the engineers located all the large equipment on the roof of the station complex. With the help of BIM technologies, they positioned the engineering services within the structure of the envelope, using information modelling to detect and resolve collisions while preserving the architectural appearance of the facility.

The name of the station, Novomoskovskaya, means New Moscow. By 2025, there will be a new urban district with 1.3 million sq km of residential and 1 million sq km of nonresidential developments.

The station's architectural design, with lines and shapes that imitate nature will be achieved



by using fibre-reinforced architectural concrete, one of the first times it has been used on Moscow Metro. Modern, durable materials will be used to decorate the exterior and interior of the station: natural stone, safety glazing, fiber concrete, and composite/ aluminum panels.

The extension of Sokolnicheskaya line to Novomoskovskaya station will significantly improve transport service of Novomoskovsky and Yuzhnoye Butovo administrative areas, where almost 70 thousand residents live and

work. Furthermore, residents of the new blocks in the Kommunarka district also will be able to use a new metro station. The new section of Sokolnicheskaya line is to open by the end of 2023.

Belomorskaya station: top-down construction to an active metro line



Belomorskaya station is located on the section of the Zamoskvoretskaya metro line between Rechnoy Vokzal and Khovrino. The station was not initially included in the construction plan, but at the request of the residents of the area, the authorities included it. The station is a columnar, sub-surface station at a depth of around 25m with an island platform which is 10m wide, 163m long and 5.1m high.

The construction of the station was carried out using a unique top-down method, due to the constrained construction site and the need to limit disruption for local residents, some of whose homes are located right next to the site. This was the first use of this method in Russia.

Top-down construction involves the installation of temporary or permanent supports inside the excavation, supporting the floors of the underground part of the facility. Excavation is carried out through special openings and concreting of the underlying floors is carried out sequentially as the soil is removed. The temporary supports for the floors are dismantled after the erection of the load-bearing walls or permanent columns.

The unique aspect of this station is that it was built on the working metro line, between the existing stations Rechnoy Vokzal and Khovrino. All work was carried out during the night windows, including finishing the walls and ceiling of the tunnel, and also connecting the new station to the existing line.

The station design references the Belomorie area near the White Sea, with shades of green, dark blue and white to symbolize the sea, night sky and snow, respectively. The columns and walls of Belomorskaya are faced with white marble from the Polotsk deposit. The floor of the station platform is covered with grey Siberian granite, and he suspended ceiling of the station is aquamarine. The LED strips on the dark blue ceiling of the lobby aim to create the effect of the Northern Lights, according to the designers.

Belomorskaya was opened on 20 December 2018, helping to alleviate transport problems in this outlying area of the northern part of Moscow.