The TBM used for Line 1 of the Belgrade Metro

TBM, short for Tunnel Boring Machine, is special-purpose equipment exclusively designed for underground tunnel excavation, with a long application history spanning over a century.

The TBM deployed for Line 1 of the Belgrade Metro features an excavation diameter of 9.7 meters, an overall length of approximately 110 meters, and a total weight of around 1,500 tons. Although a TBM looks extremely bulky, it is assembled from hundreds of individual components. It needs to be fully assembled on-site before excavation work commences. Once the tunneling task is completed, the machine will be disassembled into separate units for transportation off the construction site.

As one of the safest tunnel excavation technologies available today, the TBM construction method realizes continuous integrated tunneling, rock cutting, muck removal and lining installation. Compared with traditional blasting and drilling excavation, it effectively minimizes ground deformation, surface settlement and risks of collapse, while delivering higher construction efficiency and better working safety in underground projects.

The Development History of Tunnel Boring Machine (TBM)

The evolution of TBM stretches back more than 200 years, divided into four key phases: the origin of tunnelling shields, early mechanical tunnelling attempts, breakthrough of modern rock TBMs, and diversified intelligent TBM technology today.

1. Origin of Tunnelling Shields (1820s–1850s)

The theoretical prototype of mechanized tunnelling emerged in 1825, when French-British engineer Marc Isambard Brunel invented the world's first tunnelling shield to build the Thames Tunnel under London's River Thames. Inspired by wood-boring marine worms, the iron frame shield supported unstable soft soil to prevent collapse, while workers dug manually inside. Though it lacked automatic cutting functions, this shield laid the core logic of modern TBM's front supporting structure.

In 1864, engineers Barlow and Greathead upgraded the design into a circular shield equipped with hydraulic jacks for forward propulsion, which became the direct ancestor of today's soft-ground shield TBM.

2. Failed Early Hard Rock TBM Trials (1850s–1940s)

As early as 1856, the U.S. Hoosac Tunnel project tested the first full-face rotary rock excavator with cutters, grippers and muck conveyors, yet poor metallurgy and structural flaws limited its advance to merely several meters. Over the next century, dozens of rock-cutting machines were patented across Europe and North America, but drag picks wore out rapidly against hard rock, leading to low efficiency and frequent breakdowns. For nearly 100 years, drill-and-blasting remained the mainstream rock tunnelling method, and mechanized rock boring made little practical progress.

3. Birth & Popularization of Modern TBM (1950s–1990s)

A landmark breakthrough arrived in 1956, when James Robbins replaced drag picks with rolling disc cutters. This design crushes rock via concentrated pressure instead of scraping, drastically boosting cutting efficiency on soft and medium-hard rock at a Toronto sewer project, proving TBM's economic value for the first time. This machine marked the official launch of the modern hard-rock TBM industry.

- 1960s–1970s: European and Japanese manufacturers developed two major soft-ground systems: Slurry Shield and Earth Pressure Balance (EPB) Shield, suitable for water-rich sand, silt and urban soil layers.
- 1970s–1990s: Double-shield hard-rock TBMs were invented to adapt to fractured, mixed ground. Equipment diameters expanded, and complete assembly/disassembly modular designs took shape—giant machines could be split into hundreds of components for transportation and reassembled underground, matching the logistics mode of the Belgrade Metro Line 1 TBM. Major brands including Herrenknecht, Robbins and Mitsubishi formed a mature global supply chain.

4. Diversified & Intelligent Era (2000s–Present)

Since the 21st century, TBM technology has developed rapidly worldwide, especially with large-scale applications in China, Europe and Southeast Europe.

- Full-geology adaptability: Composite TBMs can switch between rock and soft soil without machine replacement, coping with complex strata in metro, railway and hydropower tunnels.
- Ultra-large & ultra-long specifications: Tunnel boring diameters now reach nearly 18 meters, while single TBM weights exceed 1,500 tons, identical to the 9.7m-diameter machine used for Belgrade Metro Line 1.
- Intelligent upgrading: Built-in monitoring sensors, AI predictive maintenance and automatic lining installation systems reduce manual intervention, further lifting safety and construction speed.
- Global infrastructure application: TBMs have become the preferred solution for urban metro tunnels due to minimal ground settlement, low noise and high safety, replacing traditional excavation in densely built cities like Belgrade.

Today, after over 170 years of technological iteration, TBM has evolved from a clumsy experimental device into an integrated underground mobile factory, recognized as one of the safest and most efficient tunnel construction methods globally.