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THE OLDEST UNDERGROUND RAILWAYS IN THE WORLD AND THEIR ANNIVERSARIES

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Abstract.

The five oldest underground railways started to be operational in the 19th century. These were the metros in London, Athens, Istanbul, Budapest and Glasgow. Undoubtedly, world primacy of status in terms of age belongs to the London Underground. However, the age ranking of the others in continental Europe is more difficult to determine. Regardless of this criteria, the undergrounds of the 19th century became the basis of the world's most widespread and rational means of public transport. The further development of these named oldest undergrounds is here documented.

Keywords: Metro anniversary, metro establishment, underground railway.

1. Introduction

The nineteenth century is often characterised, somewhat figuratively but justifiably, as a century of steam. In 1825, George Stephenson, an English mechanical engineer, started the public operation of a train pulled by a steam locomotive along a track between Stockton and Darlington. His locomotive, Rocket, and newly invented hot rolled rails passed successfully into technical operation. In 1830, an indication of the future use of the underground for transportation purposes appeared on the Manchester – Liverpool rail track which was the first railway tunnel on a track using steam trains. This was the 1,066m long Edge Hill tunnel. Numerous fundamental things required for the commencement of operations in the underground (steam locomotives with the necessary power, rail-bound passenger cars, rolled rails and their fixing, design of trackwork and other technical equipment) were tried on railway tracks. Thus, the conditions for the creation of an efficient urban mass transit system – the underground railway – had been prepared.

World leadership in the development of the highest-capacity and most widely spread urban mass transport is undisputable – the first six kilometres long line of the London Underground went into service on 10th January 1863.

On continental Europe however there is a certain problem with the determination of the first metro construction project – there are three candidates. Arranged chronologically, they are the metros in Athens (1869), Istanbul (1874) and Budapest (1896). The instigation and subsequent development of metro networks in those cities exhibits noteworthy particularities and differences, making it relatively difficult to award the second place to one of them unambiguously. Nevertheless, it is a straightforward fact that celebrations of the original creation of the first metro in continental Europe are held in all of the three countries.

2. London Underground

The first Great Exhibition was held at Crystal Palace in London in 1851. The possibility of developing an underground railway was first mentioned at the exhibition. The preparatory work continued, and a company commercially registered under the name of METROPOLITAN commenced constructing the London Underground by connecting the end stations of two railway lines – the Great Western Railway and the Great Northern Railway. The basis of the London Underground was formed by developing a 6km long section between Paddington Station and the Farringdon Street railway station ([1], [2], [3]).

With respect to an operation using steam engines and the limited capacity of ventilation through chimneys, the grade lines of tunnels were designed to be at small depths (4 to 8 metres). Horseshoe-shaped profile double-track tunnel linings were constructed on wood centrings in pits dug in the space of streets and were backfilled after completion (see Fig. 1).

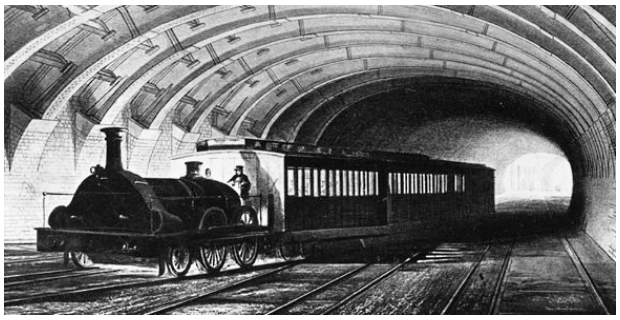

Figure 1. Historic subsurface tunnels of the London Underground [3]

The first line in the world using wooden cars pulled

by a locomotive was brought into service with great success in London at the beginning of 1863 (10th January 2018). The first day of operation was attended by 38,000 visitors, and later it was used on average by 25,000 passengers every day.

Given the extraordinary attendance rates and the interest of citizens in this new mode of transport, this subsurface variant of the London Underground using steam engines was considered for further extension. However, it was only after the introduction of electrification into the Underground in 1890 and the use of an innovated tunnelling shield with a circular profile that it became possible to successfully drive couples of single-track tunnel tubes with a diameter 3,6m through deeper parts of London.

The connection of the 1st line of the London Underground with the legendary **Thames Tunnel** is very interesting. The Thames Tunnel was constructed under the river in muddy and sandy alluvium by civil engineer Marc Isambard Brunel, who, in 1918, took out a patent for a completely new tunnelling method of excavation and supporting the excavated space by means of the world's first tunnelling shield, which became much later on the basis of tunnel excavation technologies using tunnel boring machines for all types of rock and soils. The Thames Tunnel, which was awarded the status of a technical monument, was meticulously reconstructed and, since 2010, has become part of the London Overground Railway Network, which is an extensive system of commuter railways serving a significant part of London and its regional environs.

The current **London Underground** has 11 lines with 292 stations. With its length of circa 408km it was the world's longest underground railway system until 2012. Trains corresponding to common railway transport services are operated on the subsurface lines; specially adapted trains are used on deep subsurface lines, in single-tube tunnels with the diameter of only 3.6m (see Fig. 2). Outside of central London, the Underground trains run along deep-seated lines at speeds up to 96km (60miles) per hour.

Figure 2. Cars for subsurface and deep-seated London Underground lines [3]

3. The metro in Athens

In 1969, the 100th anniversary of opening the second underground railway in Europe and also the first one in the continental part of Europe, (connecting the port of Piraeus with the Greek capital), was celebrated in Athens. The circumstances of the instigation and development of this line have often raised doubts over whether it is really a metro; nevertheless, Greeks (and many other people) consider it to be the fully-fledged germinal source of the later Athens metro system.

At about 10km long, at-grade single-track railway line was constructed during the course of two years on the basis of a contract with Edward Pickering, an English businessman ([2], [4]). It was inaugurated on 27th February 1869. It connected the railway station in Piraeus with the Thiseio railway station in Athens. During the ceremonial beginning of this service supported by the state, and attended by Queen Olga and the Prime Minister, a steam locomotive with a train set consisting of ten cars covered the distance between the two cities in 15 minutes. The line was extended to the inner city, Omonia Square, by a subsurface section in 1893, and was electrified in 1904. The at-grade portion stretch of the line still predominated. The line waited for subsequent changes until 1930 (doubling of the track – see Fig. 3), later for the extension of the track to Attiki Station in 1948; and the whole route up to the Kifisia end station was brought into service in 1957 as the first metro line. The length of this single Line 1 route amounts to 25.6km, with a 3km long section running underground. Only after a subsequent 54 years (in 2011), was Line 1 incorporated into the Athens underground railway system (the 150th anniversary of the commencement of operation will be celebrated in 2019).

Figure 3. Original Athens metro line after doubling of the track [4]

Currently **Athens Metro** (*Αττικό Μετρό*) has 3 lines (see Fig. 4) with an aggregate length of 84.5km. The work on the underground lines 2 and 3 commenced as late as 1991. The initial sections were brought into service in 2000 and were further extended; the current length of the lines amounts to 58.9km. The construction of a Line 4 is being planned. It should have a circular character. Line 1 with its historic Piraeus –

Thiseio – Omonia Square section was operated until 2011 separately from the newly developed metro system; now it is a part of it.

4. The metro in Istanbul

The only underground line was inaugurated on 23rd September 1875. It is 573m long. The 140th anniversary of bringing the second metro in continental Europe was held in Turkey in 2015 ([5], [4]). However, it raises rather legitimate doubts whether it can be considered strictly to be a metro. In this case it is obvious that it is not really the original start point of the future metro because of the fact that it has not been incorporated into the modern Istanbul metro system. Nevertheless, one primacy of status cannot be denied to this "metro" – it is the shortest one in the world.

This solitary underground line, which is currently known by the name of Tünel, was designed by Henri Gavand to be provided with a rope drive. It allowed for a more more comfortable overcoming of the sixty-metre difference in elevation with a steep rise of the surface between Karaköy and Beyoğlu, two city districts lying at the European corner of a bay on the Aegean Sea. The line has only two stations, boarding (see Fig. 4) and disembarking, both with side platforms. A double-car train set covers the distance between the stations in 1.5 minutes, running at a speed of circa 25km per hour. The single-rail track has a passing bay in the middle of the route. The car undercarriages are on rubber tyres and move along a concrete track.

Figure 4. Karaköy station of Istambul metro [3]

In 1910, the line was electrified and between 1968 and 1971 it was significantly modernised. The line has been incorporated into the Istanbul at-grade transportation system. It links to a common tramway track at the boarding station (itself linking to the Karaköy port); the disembarking station links to the historic tramway track (transfer to Line M2 of the classical metro being also possible). The line carries a daily average of 15,000 passengers.

The current **Istanbul Metro** (Istanbul Metrosu), which started operating on 3rd September 1989, had eight lines with an aggregate length of 105.8km and 82 stations in 2018. There are 6 classical metro lines marked as M1 through to M6 and two lines of the Light Rail Transit system marked as T1 and T2 also in operation. The system is undergoing substantial further extensive development – 5 additional lines with 62 stations are under construction. The metro is connected with the Taksim-Kabataş underground funicular (2006) and the trans-Bosporus Marmaray undersea railway tunnel (2013).

5. The metro in Budapest

While the Budapest Metro ([2], [6], [4]) was brought into service as late as 2nd May 1896, it must be considered that, in terms of its actual attributes, it unambiguously meets the qualification requirements for second place among the European metros, compared to the earlier operating structures in Athens and Istanbul. It was inaugurated 33 years after the London Underground. In 2016, the 120th anniversary of the metro was celebrated in Hungary.

In 1896, the volume of traffic under Andrassy Avenue, the main link of central Pest to the rapidly growing new residential development more remote from the left bank of the Danube, reached an unacceptable level. The solution was found in constructing an underground rail line which was, with respect to its character, rightly named as Kisföldalatti (ie small underground space), and with time this became abbreviated simply to Földalatti). The commencement of construction work and its rapid continuation was probably significantly affected by a more obviously political and historic aspect – the construction of the metro and the bringing of it into service was simultaneously conceived as a celebration of the thousand-year anniversary of the arrival of Hungarians to Pannonia.

The contract for the construction was awarded to the Budapest Railway Company under the condition that it would be completed before the Millenium celebrations. The railway company fulfilled the condition and the so-called Jubilee Line, 3.7km long with 11 stations, was brought into service in May 1896, only 20 months after the commencement of the construction work. Virtually the whole line, with the exception of a short at-grade section at its end, was constructed in sloped or braced pits (see Fig. 5), fast completion being therefore necessary even from the viewpoint of surface transportation. The framework structure of the reinforced concrete tunnel lining was minimised to the dimension of circa 3 × 4m, and the height of the overhead catenary was only 2.3m above the top of the rail.

The interior design of the stations was subject to quite demanding conditions set by the Budapest City Hall. The Art Nouveau style was chosen. The walls of the stations were clad with white and black tiles, while cast-iron columns along the edge of the short platform (circa 40m long) were provided with decorative heads,

Figure 5. Földalatti under Andrassy Avenue [6]

Figure 6. Kossuth Lajos Square five-vault station on Line M2 [2]

rest benches and cashier kiosks designed in the same style (see Fig. 6).

The structure of entrance staircases leading to stations was noteworthy – the treads were unusually wide, and risers were low (even entering on horseback was reportedly possible for officers). Metro cars were wooden; before their modification for the underground they were originally intended for tramway services. The first very necessary modification took place as late as the 1930s, when, in particular, the power of engines was increased, doors of the cars were reconstructed and the traction voltage was changed. However, the Belgian-produced wagons were operated until the 1960s. The Földalatti Line is newly identified as M1. It remained a sole provision in Budapest until 1970, when Line M2 of the modern metro was brought into service.

The current **Budapest Metro** (Budapest metró) has experienced an interesting evolution. The construction of Line M2 commenced in 1950; however, the work was suspended after three years and the building capacities were shifted in the direction of new residential development. Until 1963, the development of the metro was discontinued, and the finished tunnels and stations were used as stores. After the resumption of the works, Line M2 was inaugurated on 2nd

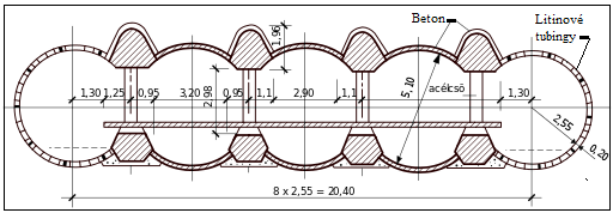

Figure 7. Kossuth Lajos Square five-vault station on Line M2 [2]

April 1970. The stations on Line M2 partially copied Soviet-type 3-vault stations. But a new concept of Budapest-type stations was also instigated (five- to six-vault stations – see Fig. 7). The Budapest metro network is currently formed by 4 lines (M1 through to M4) with an aggregate length of 40km and 52 stations; the development of a Line M5 is now under preparation.

6. The metro in Glasgow

The fourth metro, the last one brought into service in the 19th century, is the metro in Glasgow, and the second on the British Isles ([1], [4]). It went into service on 14th December 1896, in the same year as the metro in Budapest, but seven months later.

In terms of the actual system, the Glasgow metro is a certain curiosity, but there are no doubts that it belongs to the category of underground railways. It is formed by only one 10.5km long orbital line, which was never expanded during following years. Projects to expand it existed in several versions but none of them was realised, probably with respect to extensive mine galleries (in large part inundated) under the city surface.

The Glasgow orbital metro (officially named the Glasgow Subway, in guidebooks even referred to by a nickname „Clockwork Orange“, see Fig. 9) is a double-track system, with each track running through a separate tunnel tube. The diameter of the tubes is probably unique in the world – only 3.35m (11 feet); the track gauge is also atypical – 1,219 mm (4 feet).

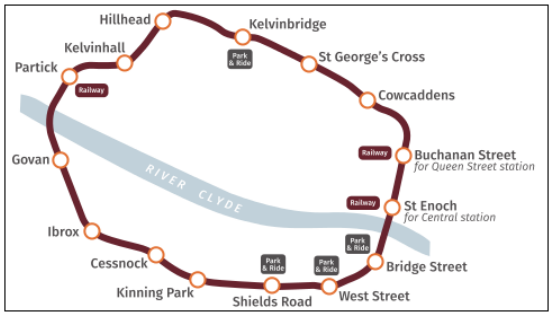

Figure 8. Glasgow orbital metro system [4]

In terms of technology, the metro was designed in a very original way. Trains were hauled by endless cables powered from a steam power plant. On the inner circle,

the car sets moved in an anti-clockwise direction; on the outer circle, they moved in the opposite direction. All 15 stations were solely equipped with intermediate platforms. For that reason the metro cars had doors only on one side. There were no cross-over tunnels with switches between the circles; no pull cable for traversing the cars to a depot was installed. The cars had to be lifted from the metro route with a crane to be carried to the depot. The cable drive was removed as late as 1935, when the metro was electrified.

Current **Glasgow Metro** (Glasgow Subway) is, in terms of the extent, the same as it was 123 years ago – a length of 10.5km and 15 stations. In 1977, it was significantly modernised, equipped with new car sets, a connection with the new depot was installed and electrification of the system was modernised. The minimum diameter of the tunnel tubes (see Fig. 10) and the reduced track gauge was preserved. A well-developed proposal for metro expansion, using the already mentioned old mine galleries under the city surface and a relic of historic coal mining, has existed since 2005.

FIGURE 9. Current Glasgow subway – Kelvinhall station [4]

In 2016, the Glasgow Transport Agency issued a report that the metro operation system would be reconstructed in the coming years to an unmanned system with the CBTC (Communication Based Train Control) system of traffic control and signalling.

7. CONCLUSION

All five structures mentioned in this paper originated in the second half of the 19th century. By their mostly successful operation, they clearly showed the path that most rational solutions to urban mass transit in large metropolises would take – underground railways. Despite the fact that the development of these oldest five metros was significantly variable, the metros have usually become bases of extensive networks of underground lines (London, Athens, Budapest) or have initiated further development of the metro (Istanbul), or exceptionally the original arrangement of the metro has remained as a final solution until the present day (Glasgow).

It is necessary for the sake of fair and complete information to mention the urban underground railway in Wien (Vienna) [4], where operation actually commenced in 1898 even though it did not have the official status of a metro. A decision was made in the 1960s that the obsolete and unsatisfactory urban railway system would be reconstructed to metro (U-Bahn) and a rapid transit system (S-Bahn). The reconstruction of this already inadequate urban railway system into a metro system then commenced in 1969.

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