IEEE Milestone dedication ceremony
20th of October 2022

Metro line No.1 in Budapest

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IEEE

Draft

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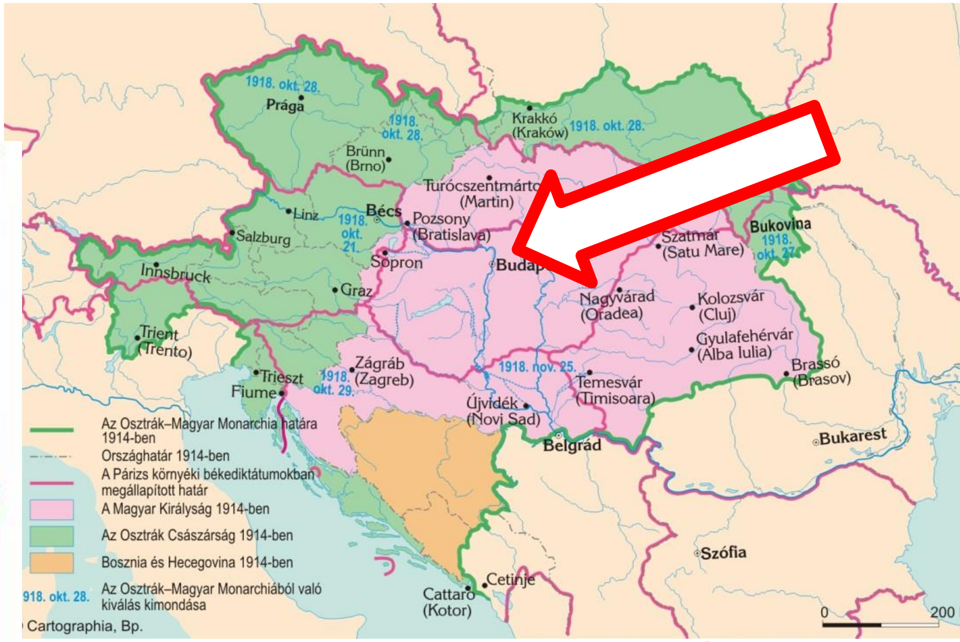
8. Power supply
9. Renewals

Innovations:

1. Unified locomotive + passenger carriage, no external locomotive
2. Goose neck chassie
3. Bi-directional operation
4. Upper current collector
5. Bogie
6. Lighting
7. Signalisation
8. Cut-and-cover
9. Pattern for Berlin, Paris and Buenos Aires

Budapest, Hungary in Central Europe, 1896

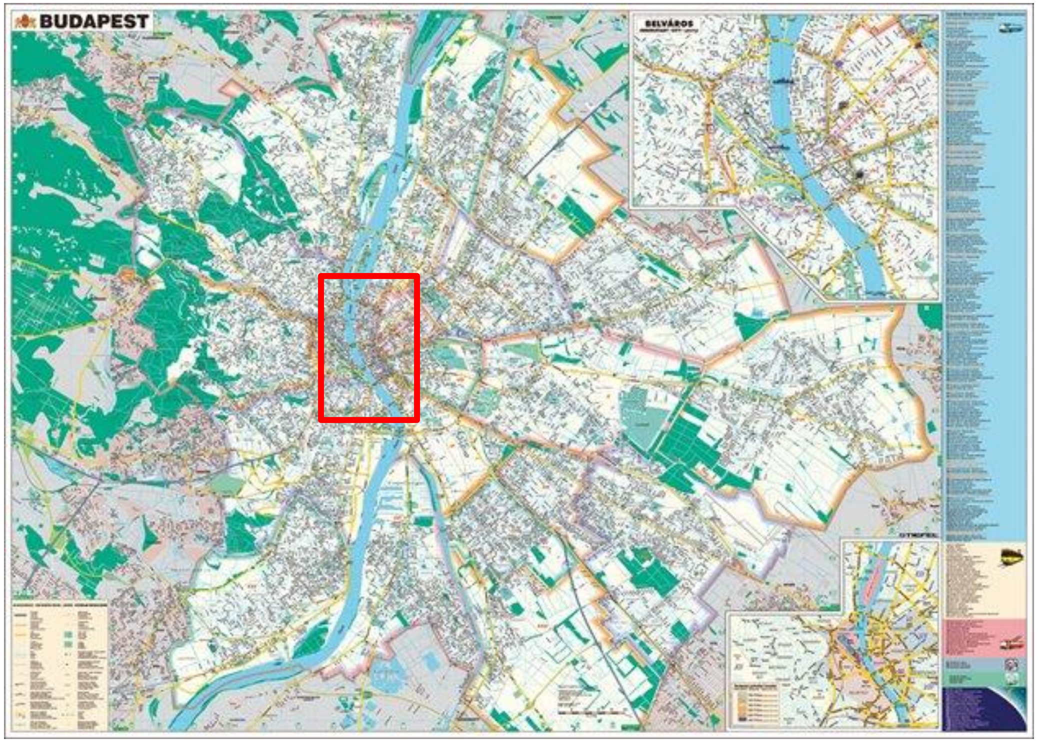


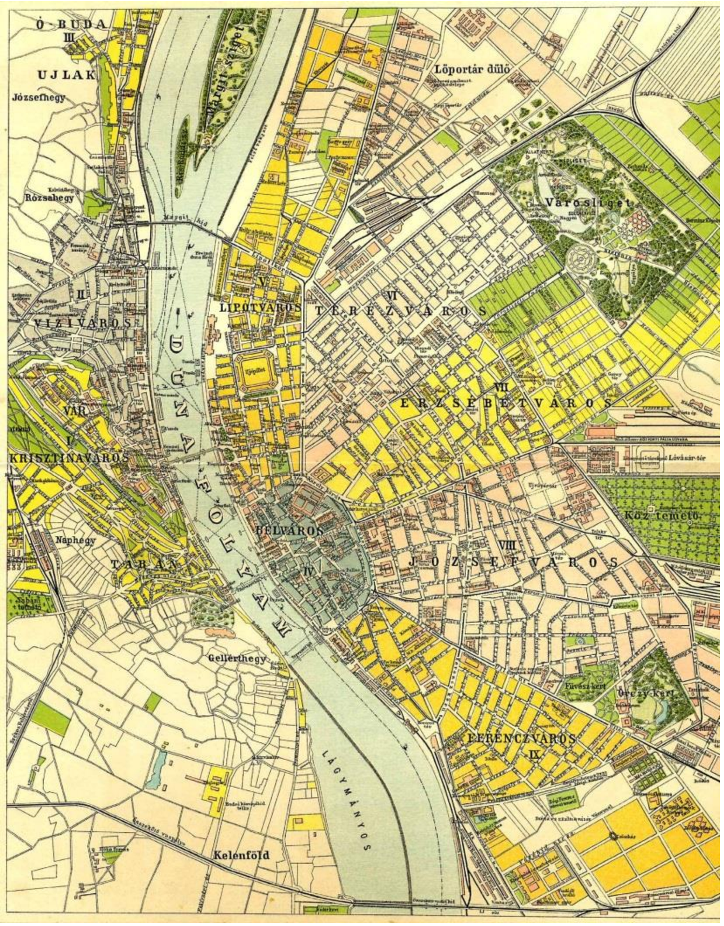
Developing city

- In 1873 three cities are unified:

  Pest + Buda + Óbuda = Budapest
- At the end of the XIXth century Budapest became a metropolis.
- In 1896 the country celebrated the thousand year anniversary of the statehood and the mayor's office wanted to raise the glare of the feast with an up-to-date technical solution**.**
- In 1873 more than 300.000 inhabitants lived in Budapest. This number was doubled in the next two decades.

1890 - 2010


BUDAPEST
BELVÁROS

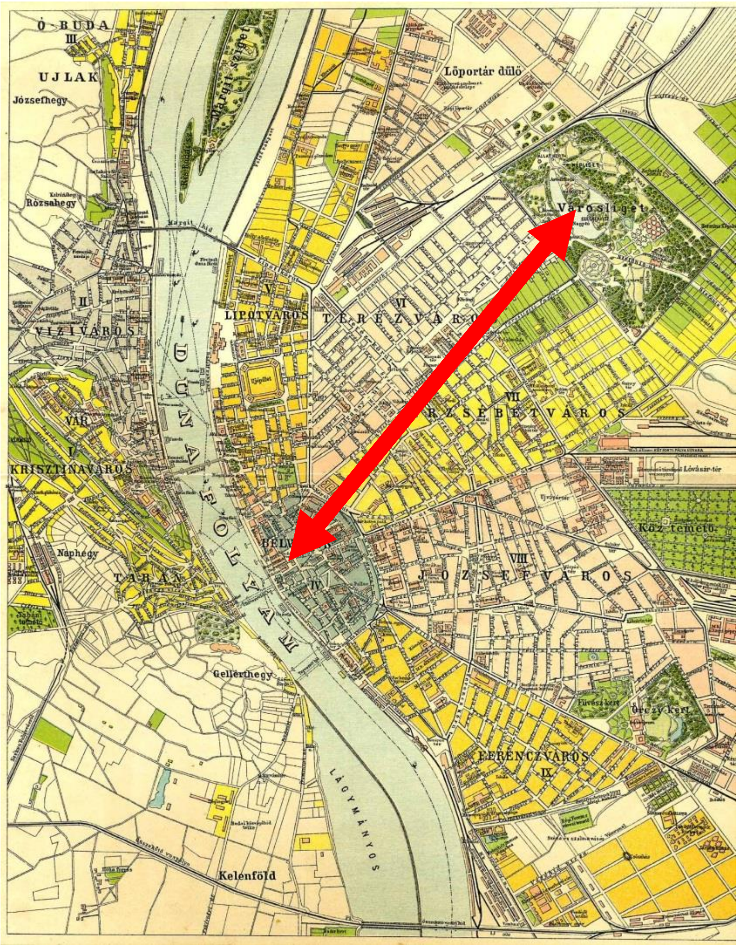

Ó-BUDA
III.
UJLAK
Józsefhegy
Rózsahegy
Lőportár dülő
Városliget
II.
VIZIVÁROS
V.
LIPÓTVÁROS
VI.
TEREZVÁROS
VII.
ERZSÉBETVÁROS
VÁR
I.
KRISZTINAVÁROS
DUNAFOLYAM
BELVÁROS
IV.
Naphegy
TABÁN
VIII.
JÓZSEFVÁROS
Köz temető
Gellérthegy
FERENCZVÁROS
IX.
LÁGYMÁNYOS
Kelenföld

World expo in 1896 for 1000 years anniversary

The need

- In 1875 a new representative avenue was built between the center and the city park.
- For esthetic reasons no horse-pulled or electric tram line construction was allowed in this street.
- Closing the date of the celebration of 1000 years old Hungarian Kingdom (Millenia in 1896)

Connecting the center and the expo site



The solution

- In January of 1894 a tender was issued to solve the problem by an electric underground tram.
- This was a joint action by the two competitors: *Budapesti Villamos Városi Vasút (BVVV – Budapest City Electric Train Company)* and *Budapesti Közúti Vaspálya Társasággal (BKVT – Budapest Municipal Train Company)*.
- The decision was made on 9th of August, 1894.
- The tunnel and stations were built by entrepreneur *Robert Wünsch*, the bogie carriages were produced by *Schlick Vasöntöde és Gépgyár (Schlick Forgery and Machine Factory)*, and the electric devices were made by *Siemens und Halske Co.*

Balázs Mór – the project owner
Wünsch Róbert – the entrepreneur

Technical solution

On-the-time finished project

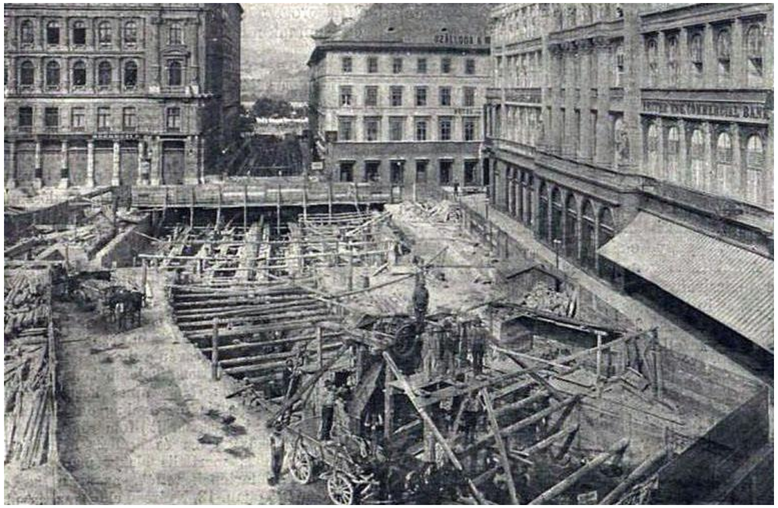
- The first electricity driven metro line in the continent was inaugurated on 2nd of May 1896 in the presence of Franz Joseph – Kaiser of the Austro-Hungarian Empire.
- On 8th of May Franz Joseph travelled on the whole line
- This royal course was driven by the great-great grandfather of the author.
- During the remaining 8 months of 1896 the metro carried 3 million passengers. This number rose to 11 million by 1917. The operating hours were between 6 AM and 11 PM with 4 min succession slots.

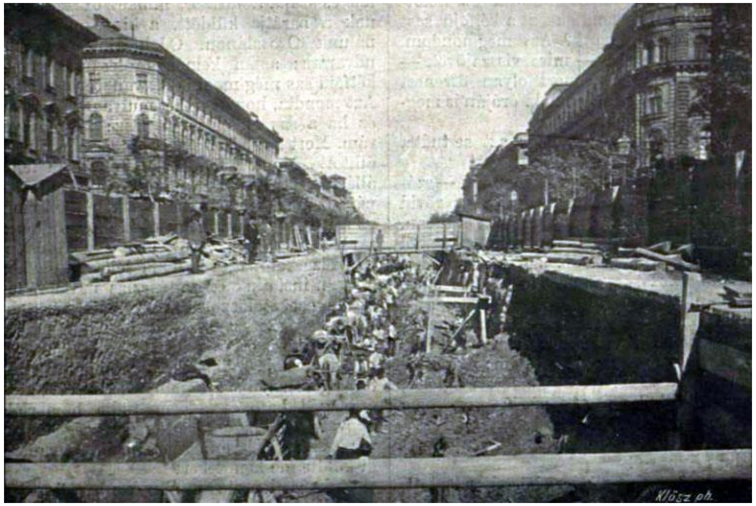
Ready for inauguration on 08/05/1896

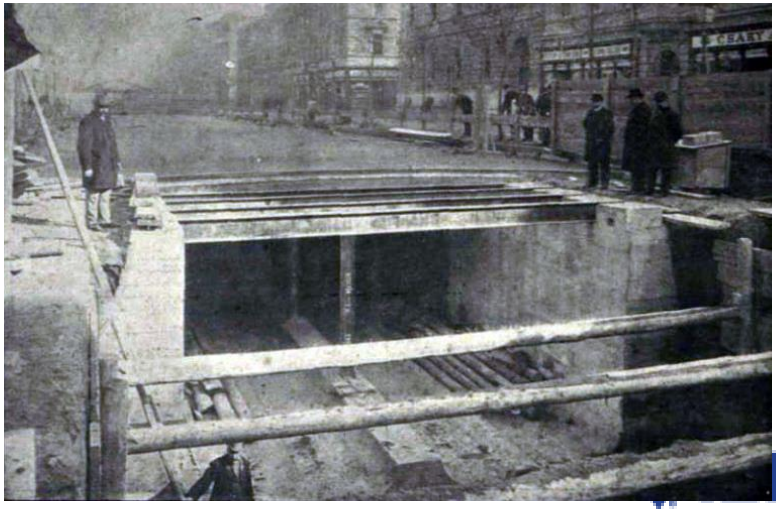
The tunnel

- The tunnel was made by “dig and cover” technique
- Two shifts with man and horse power. At the night shift electrical arc lightings were used.
- A total of 138,000 cubic meters of soil were excavated by hand, and 47,000 cubic meters of cement and 3,000 tons of iron were required for the support structure
- The leaking water was trapped into collecting wells and was pumped up by electric suction pumps.
- The construction works (3.22km tunnels with 9 stops and 0.46 km line on the surface with 2 stops)
- The inner height of the tunnel is 2,65 m (3,5 m till the surface), it is limited by the crossing of the main sewage canal. The average width is 6 m.

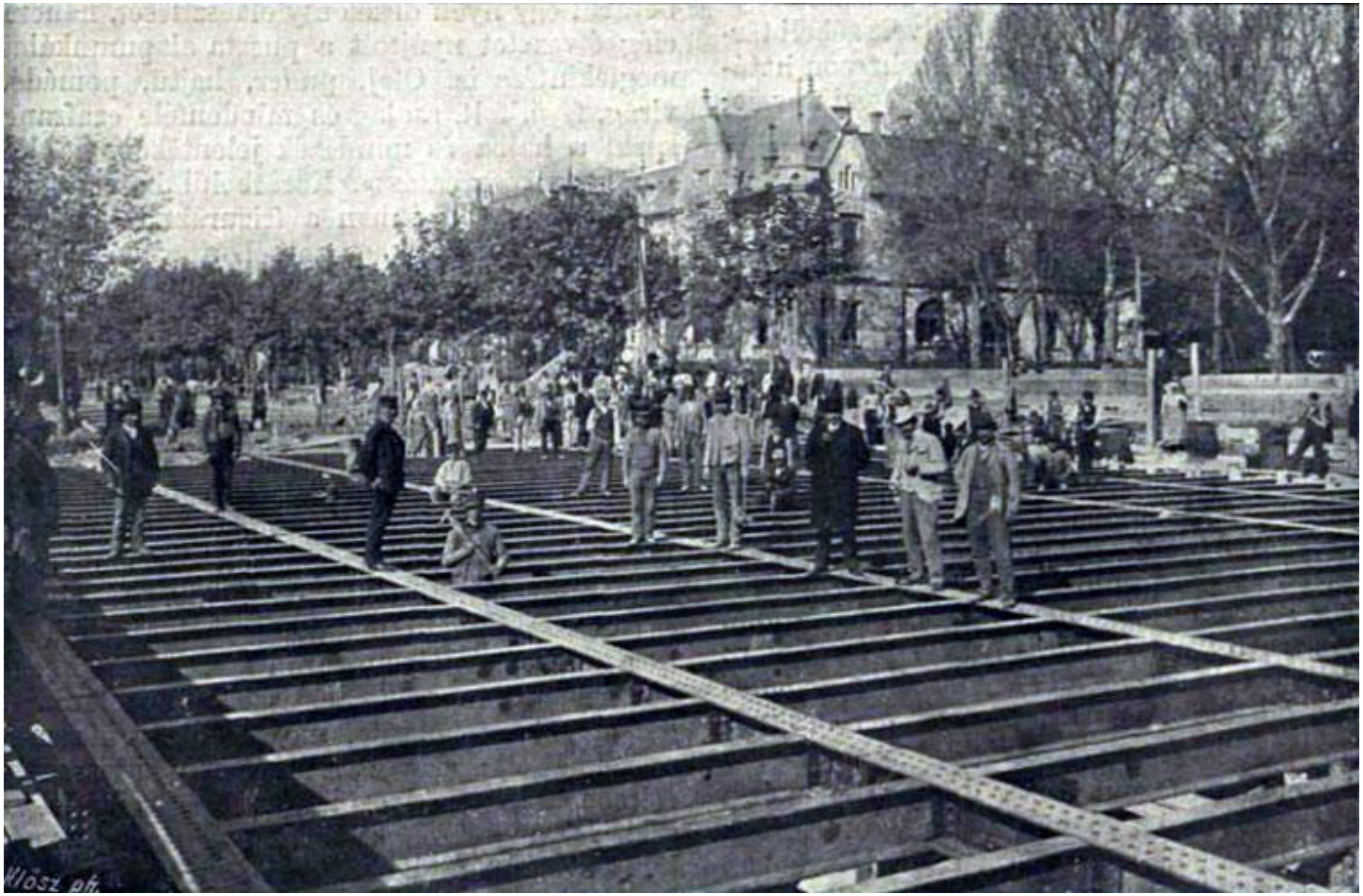
Tunel digging



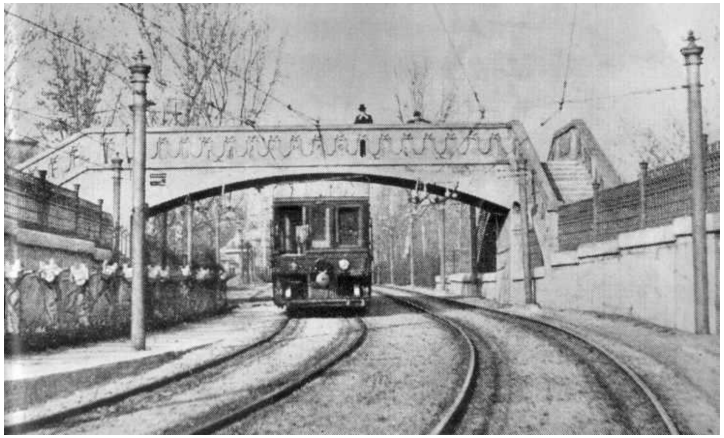




Covering



Surface section and bridge



- During the construction new materials were used. The concrete strengthened by iron was the invention of *Robert Wünsch*. The tunnel walls, the slab and a small bridge are built of ferroconcrete. The concrete was mixed by electrical mixers.

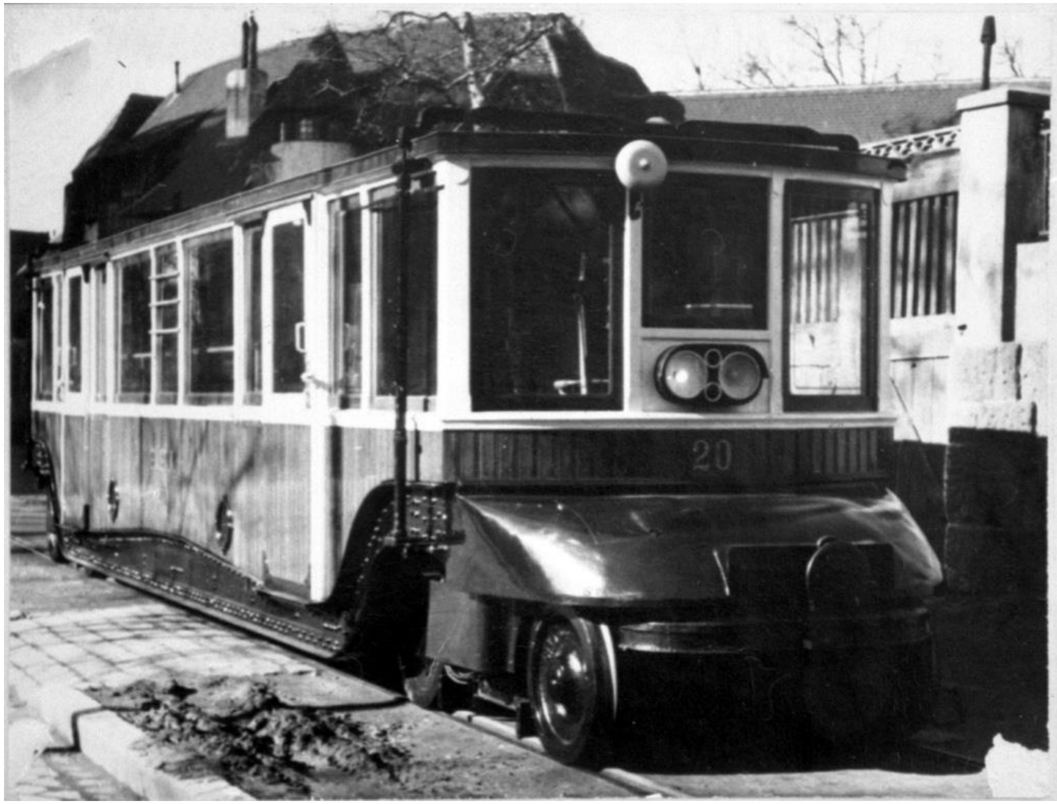
Carriages

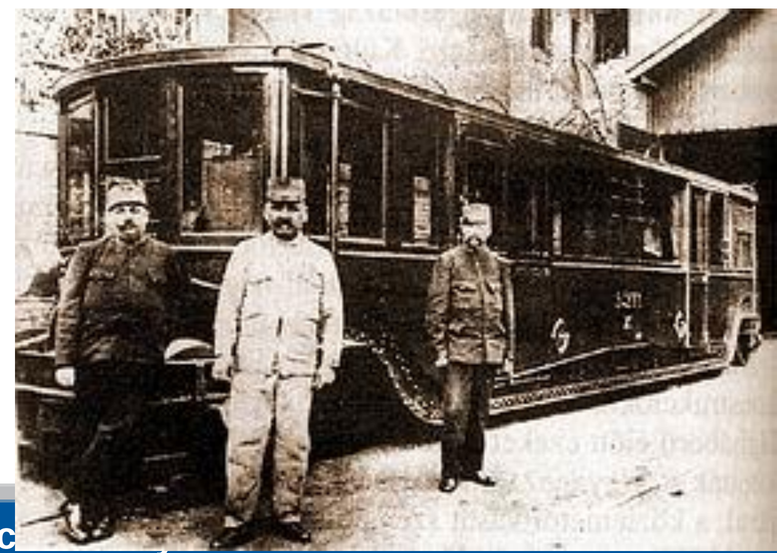
- The initial common fleet of the two operators consisted of 10 yellow metal covered carriages of *Budapesti Villamos Városi Vasút (BVVV)* and
- 10 brown wood covered railway carriages of *Budapesti Közúti Vaspálya Társaság (BKVT).* The royal carriage
- No. 20. had extra solutions with a saloon. It was used by Kaiser Franz Joseph, King Carl IV., Kaiser Wilhelm, etc.
- Trailers from 1950

Metal covered, No. 1.

Wood covered, No.19.

The royal wagon, No. 20.





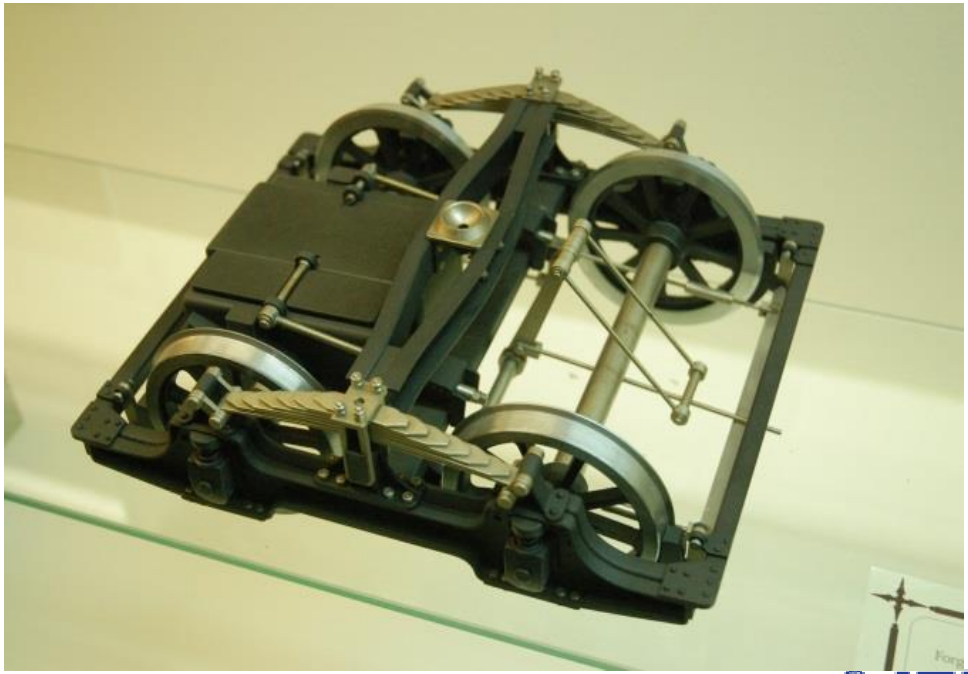
Trailers

Technical data

- Each railcar could accommodate 28 seated and 14 standing passengers.
- The original metal coated railcars had 11,77 kW LDo motors with Gall-chain for driving 650 mm diameter wheels.
- The old wood covering rail cars had 14,71 kW B 22/30 motors mounted on wheel-set axles with 800 mm diameter wheels

Bogie and producers

- Bogie carriages were produced by *Schlick Vasöntöde és Gépgyár (Schlick Forgery and Machine Factory)*, and the electric devices were made by *Siemens und Halske Co.*

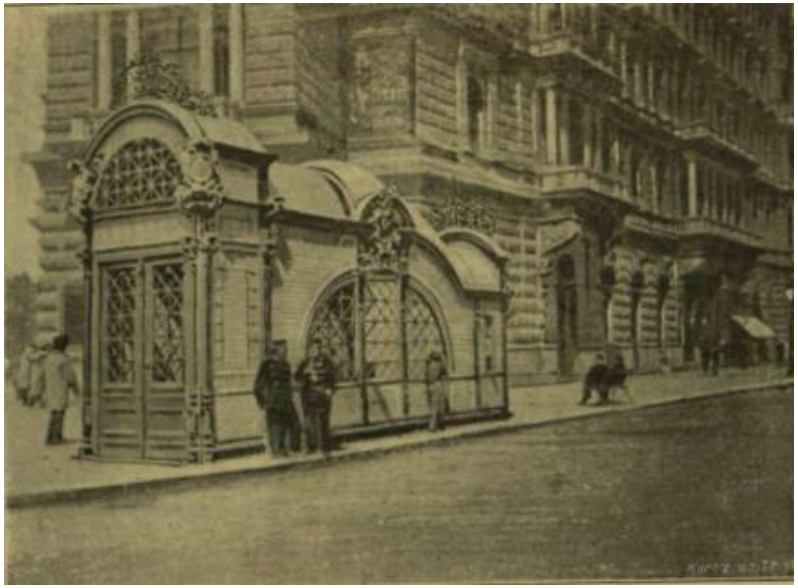


Stations

journey time in min	stops	remarks
0	Vörösmarty tér	Gizella square (nowadays Vörösmarty square)
1	Deák Ferenc tér	Deák Ferenc square
2	Bajcsy-Zsilinszky út	Váczi avenue (nowadays Bajcsy-Zsilinszky avenue)
3	Opera	Opera (Fig. 13. and 14.)
4	Oktogon	Oktogon square
5	Vörösmarty utca	Vörösmarty street
6	Kodály körönd	Köröndi (Kodály roundabout)
7	Bajza utca	Bajza street
8	Hősök tere	Aréna street (nowadays Heroes' sqare)
9	Széchenyi fürdő	Zoo (surface section - abandoned)
11	Mexikói út – new underground terminal	Artézi bath (surface section – abandoned, nowadays Széchenyi bath)

- The line has 8 original and 3 newly made underground stations

Old Stations



- Above the underground station attractive entrance halls designed by *György Brüggeman* and *“Schickendanz et Herczog”* were erected.

Today

Stations

- The ferroconcrete ceiling is supported by riveted iron pillars. In 1995 the stations were renovated, fixed, insulated and dyed by anticorrosive painting.

6. The stations

Stations

- The walls of the 8 old stations are covered by porcelain ceramics produced by the *Zsolnay Factory* in Pécs, Hungary.

The track

- The 1435 mm gauge track was built from iron cross-ties *'Banovits system'* containing asymmetric *Vignoles* rails (24,2 kg/m) that were connected with lap-seams (patent of *Hartman*). This solution provided noiseless traffic not to disturb the promenade on the surface, the inhabitants and it saved the motors.
- The *Siemens-Halske* signalization system showed red light if a train was in the next tunnel section. Free way was signalized by white light.
- In 1995 the rails were changed to 48kg/m *Vignoles* rails, the old wooden sleeps were re-sleepered by concrete holders (makes more noise).

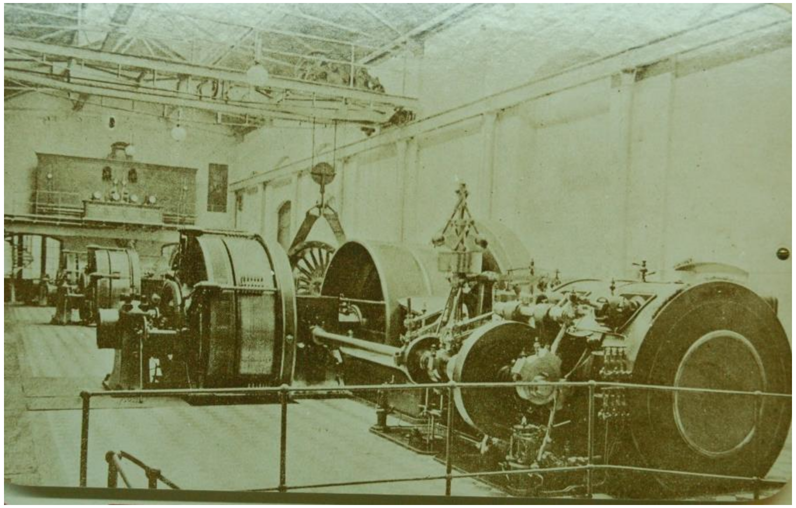
The track

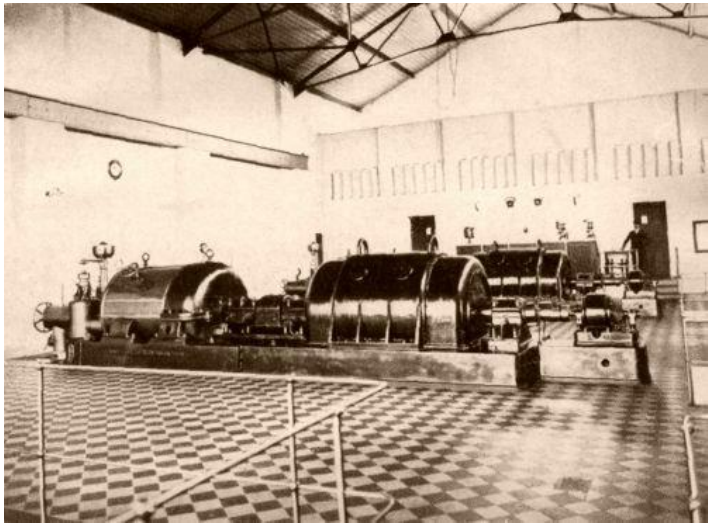
The depot

Power supply

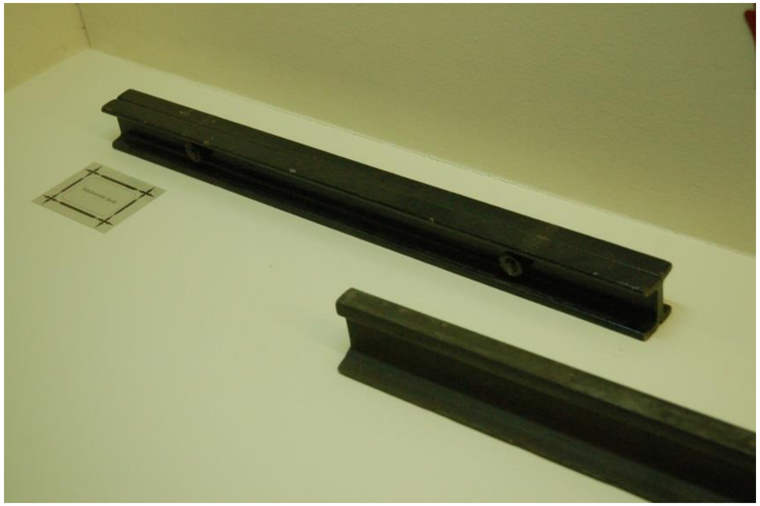
- In an early plan three rails were designed for lower current collector, but this idea was later abandoned.
- The 350 V DC hauling current was generated in the *‘Kertész utca – Gartner strasse’ (Akácfa utca)* power station.
- The overhead supply was solved by 50 mm height two-pole double rails (used in mines).
- In the twenties the supply voltage was raised to 550 V DC (nom. 600 V) and the double upper feeder rails was changed to a similar, single feeder rail with single pole feeding and lower rail feed-back

Old steam powered machines



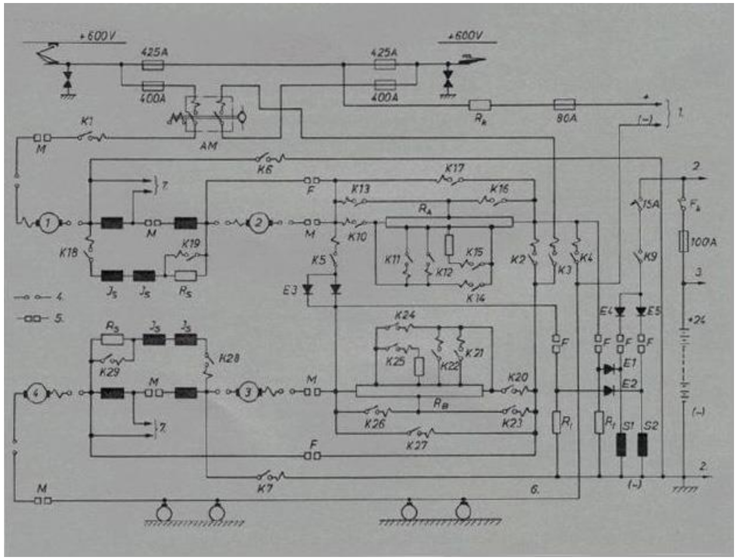


Upper feeding rails

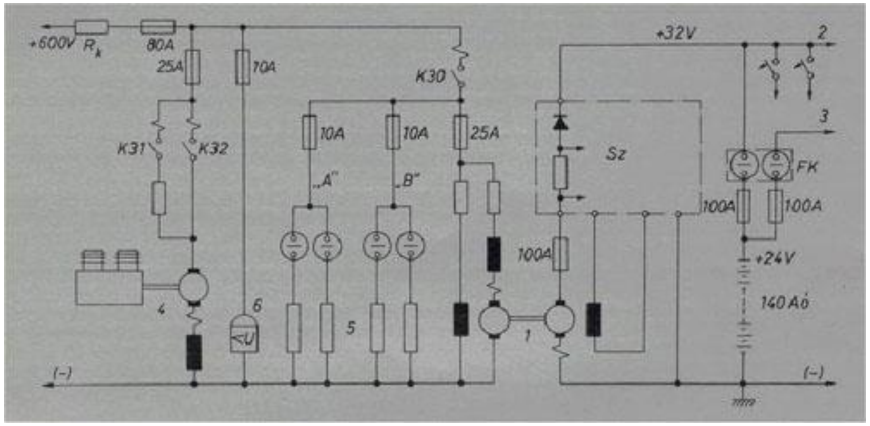


Present electrical circuit of the carriages

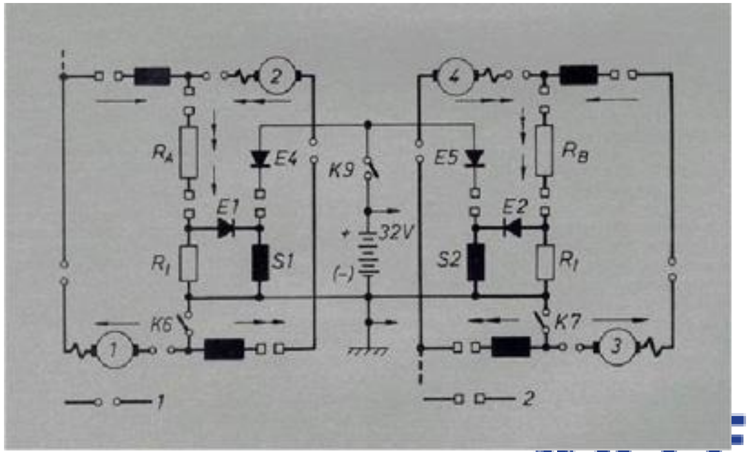
Mains



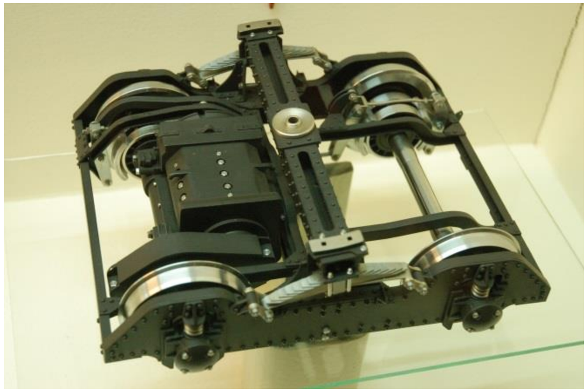
Auxiliaries



Brakes



Present wheels and bogies



Renewal after 77 years of operation, in 1973

- At the beginning of the seventies the emerging traffic of Budapest, the connection to the new metro line No.2. and the aged old line required further renovation.
- For the 100th anniversary of the unification of Buda, Pest and Óbuda (birthday of Budapest) the metro line No.1. was rejuvenated.
- In the reconstruction process the tracks, electricity system, carriages were changed. Also the tunnel, the stations were renewed in its original artistic design.
- The traffic changed from the original ‘keep to left’ to the ‘keep to right’. For housing a new, larger shed was built on a new site.
- Two new stations were erected and the former non underground section was pushed down to new tunnel

3 new stations, new shed, new track

Renewals – articulated carriages

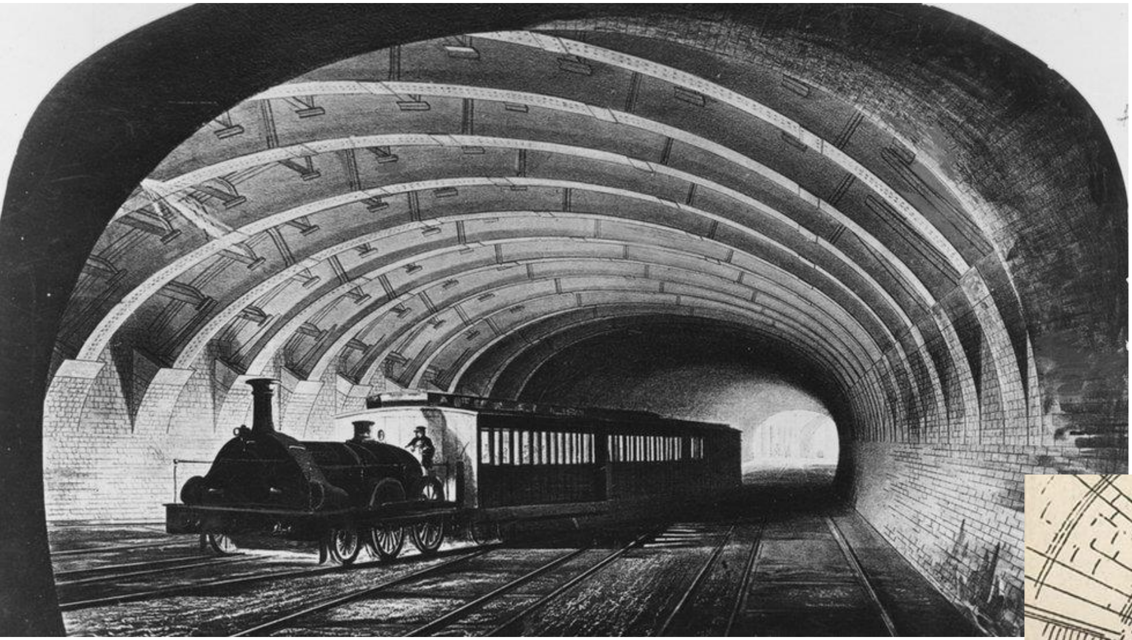
- After 75 years of operation from 1971-73 and 1987 the railcars were changed. The new 23 tripartite railcars were designed and build by the Hungarian Ganz Villamossági Művek (Ganz Electrical Works) and Ganz-MÁVAG (Ganz Hungarian General Wagon and Machinery Factory) in Budapest, Hungary. The Ganz articulated railcar available for 190 passengers is tracked by four 66 kW TK44 A type hauling motors. Nominal speed is 60 km/h. Total length is 30.37 m , weight is 37 tons, the wheels' diameter is 670 mm.

New articulated carriage

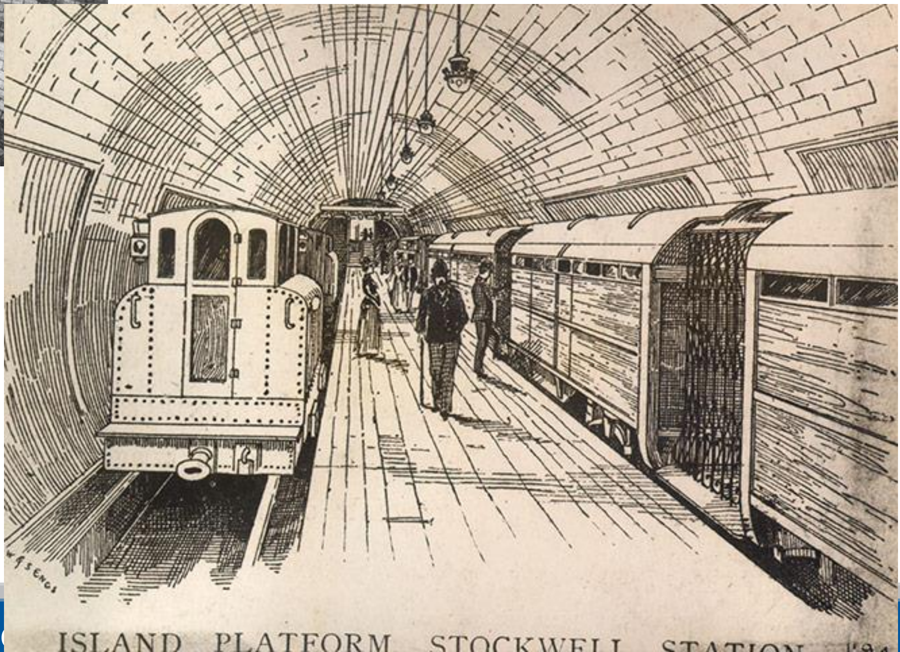
The first electrical underground is in London
The **first** electrical underground in the **continent** is in Budapest

- The **first underground** line in the world the London metro was powered by **steam** engine. It was changed to electric only a decade later, in 1907.
- The London Underground began operating **electric services** using a fourth rail system in **1890** on the City and South London Railway (C&SLR), now part of the Northern line, between Stockwell and King William Street station. This is **the first electrical underground metro (train) in the world.**
- The prime-metro of Chicago began revenue service on June 6th of 1892 by a small steam locomotive pulling four wooden coaches. In 1893, trains began running on the Lake Street Elevated Railroad and in 1895 on the Metropolitan West Side Elevated. The Metropolitan was the United States' **first** non-exhibition rapid transit system powered by **electric traction** motors. **But** it wasn't underground…

London



1863



1890

Project on time and new materials

- A huge project that ended
  - in the time frame (21 months!) and
  - within the planned budget
- New materials
  - Ferroconcrete with large scale iron beams
- New technical solutions
  - upper current collector

In operation

- In operation since 1896
- The original carriages were used till 1973
- One of them operates as nostalgia wagon

Existing museum

- From the fifties a 40 m long part of the old tunnel was separated and closed. In 1973 it was converted into the museum of the first Budapest underground metro

Innovation

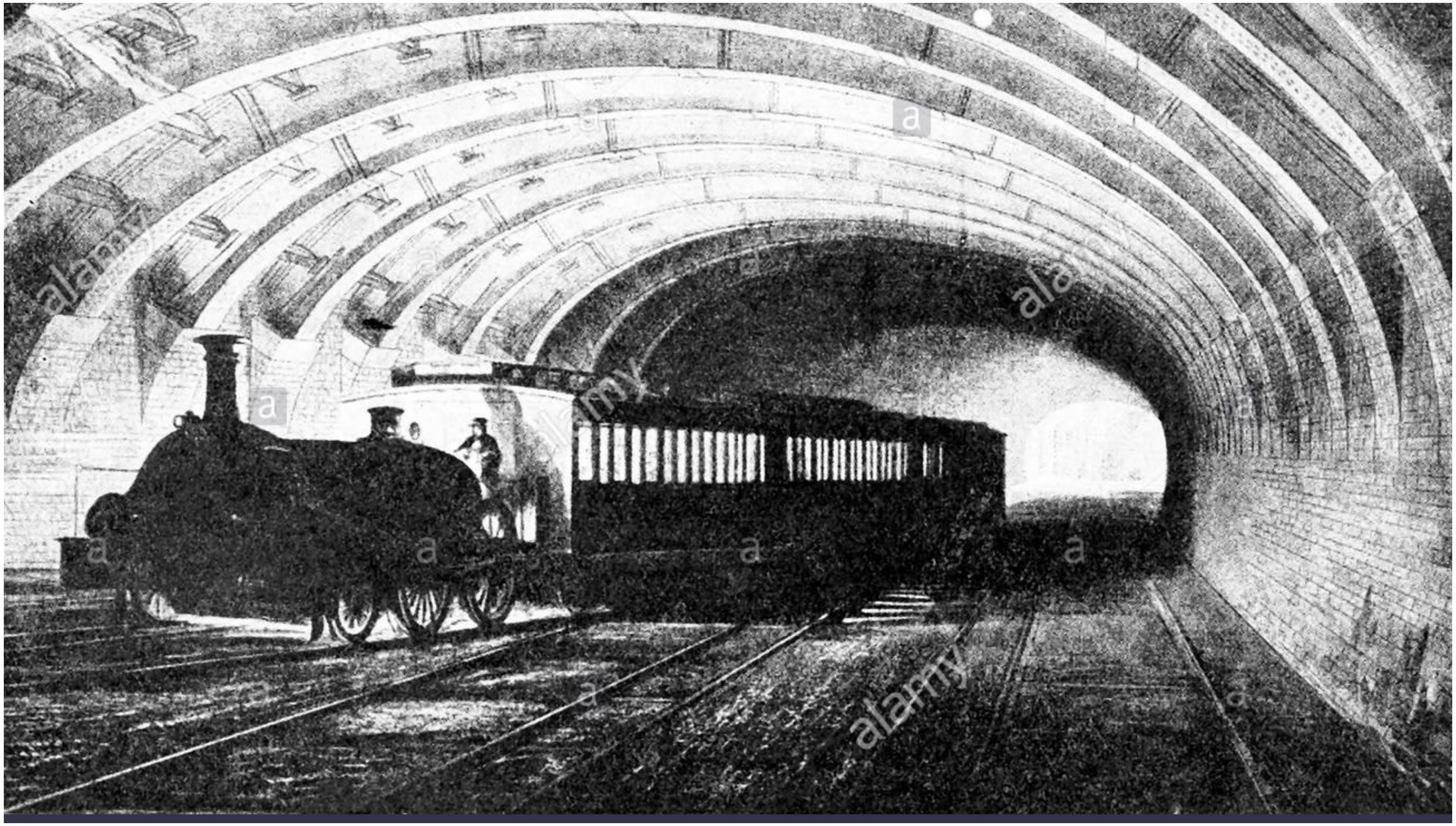
- “**Innovation** is the successful exploitation of new ideas.” UK Department of Innovation and Skills.
- According to Alois Schumpeter **innovation** is to “launch a new product or a new species of already known product”
- Existing product in a new environment, in a new context

First – No.1.

- **First** Metro – London – 1863 – Tunnel – steam locomotive – underground **TRAIN**
- **First** electric Street car (tram) – Siemens 1883
- Electric locomotives were **first** used on the London Underground when the first deep-level tube line, the City and South London Railway (C&SLR), was opened in 1890
  - **First** well established as electrical underground **TRAM**:

    Budapest – 1896

First Metro in London 1863 train with steam locomotive

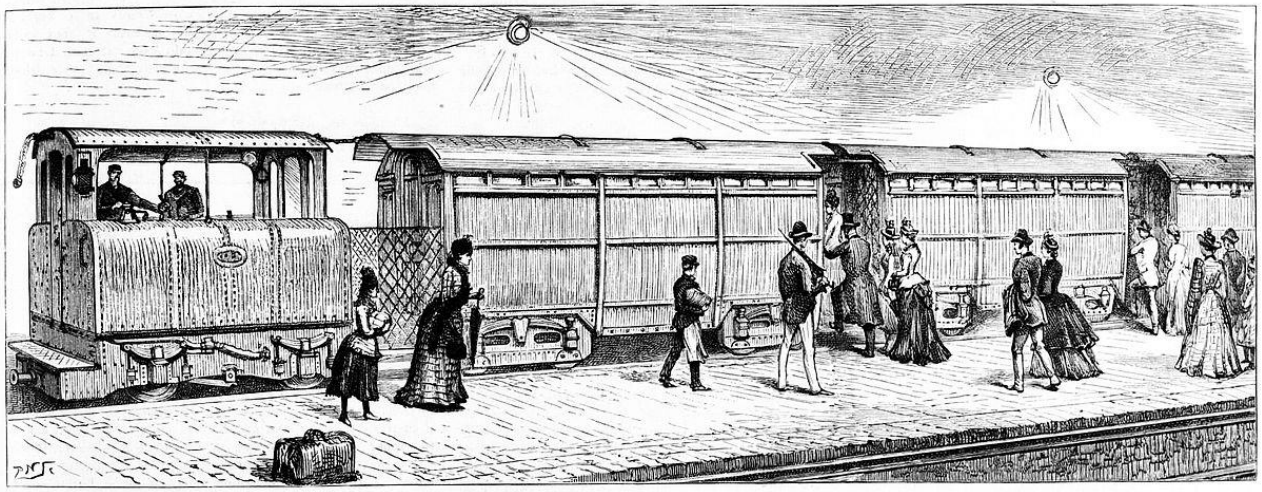


First electric street car 1881 of Siemens

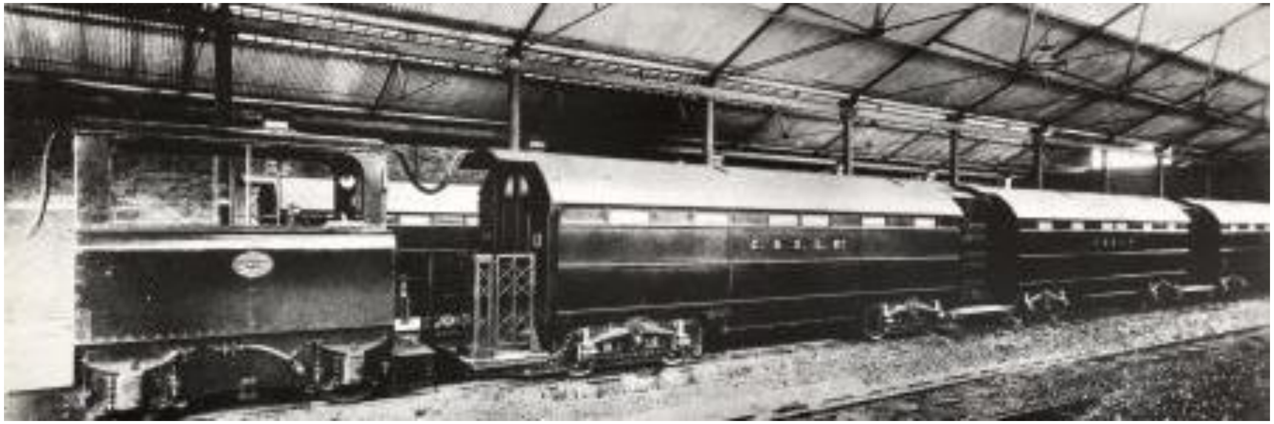
London Metro

- The London Metro had split locomotive with short axle-base and passenger carriages with bogies. It comes from the organic advancement, but at the end terminals the locomotive should have passed round the carriages. In the Budapest solution there wasn’t an external locomotive because the locomotive with its electric drive was built in the passenger car

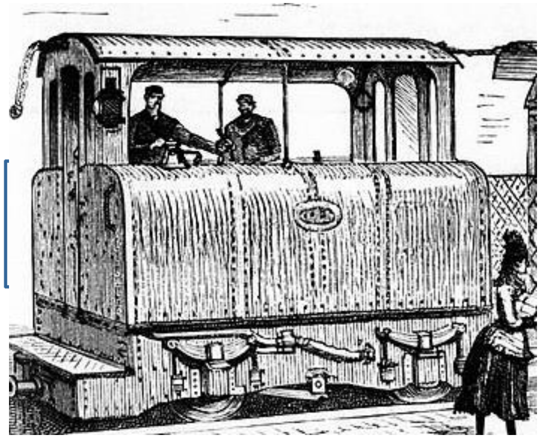
C&SLR 1890-electric locomotive no 1 and cars in the depot in 1890



ELECTRIC RAILWAY TRAIN.



BUDAPEST – All in one – Unification concept Unifying the locomotive and the passenger car



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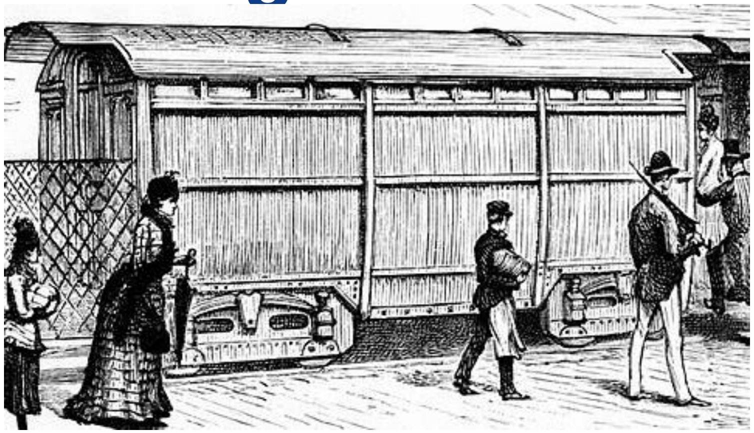

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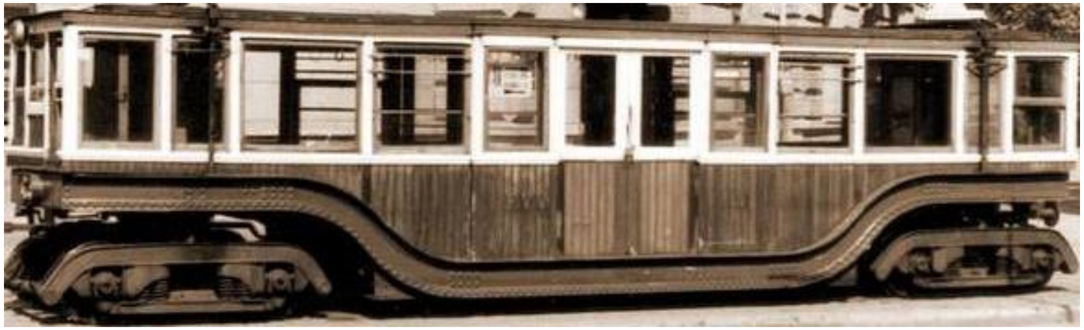

Goose neck chassie – height compression

- Because of the low vertical distance between the canalization channel and the surface of the main road (3 meters) the maximal height of the tunnel was only 2.6 meters. It required to “press” the normal tram carriages, keeping the ceiling height close to 2 meters. However, the wheel diameter is over 600 mm! The solution is the goose-neck chassie, the first low floor public vehicle in the world!

Goose neck chassie – height compression

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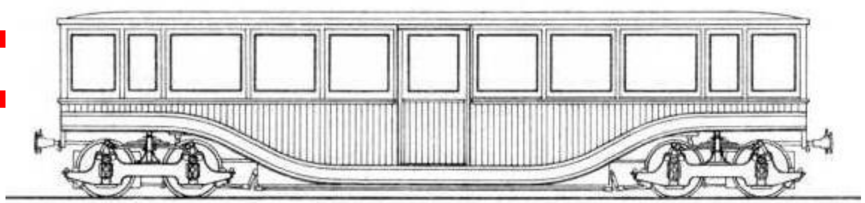
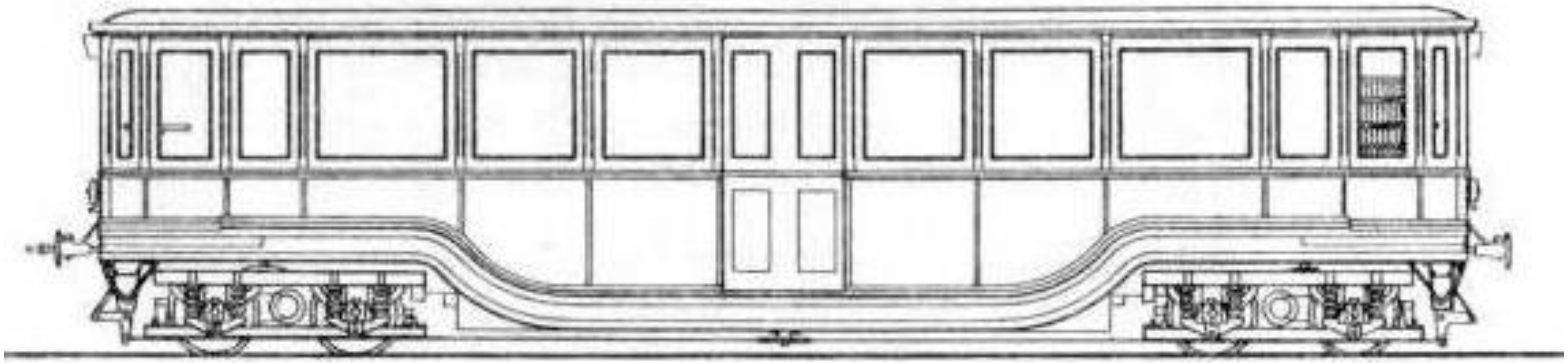
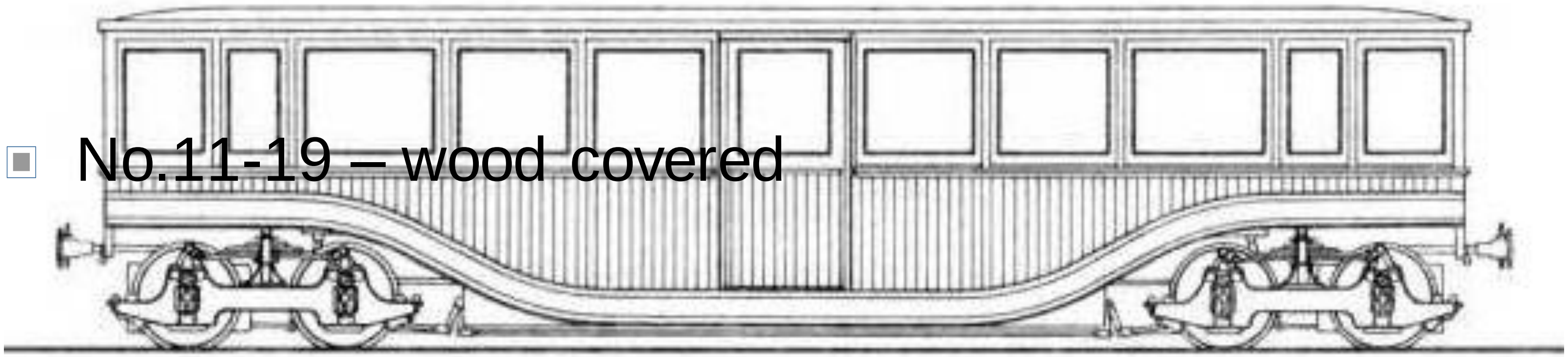


The Goose neck carriages

- No. 1-10 – metal covered



- No.11-19 – wood covered

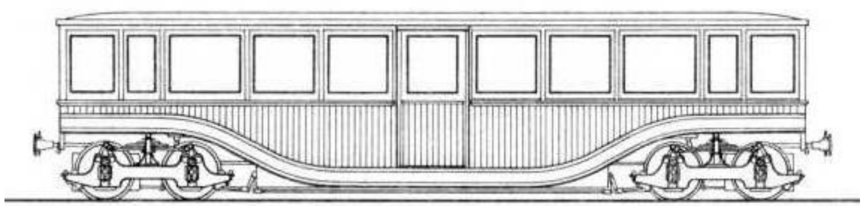


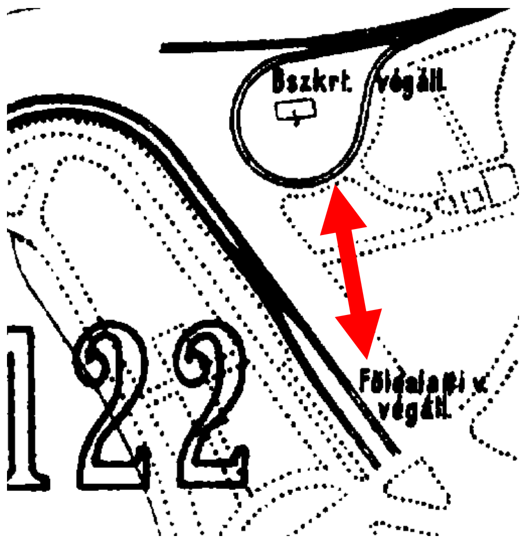
Bidirectional operation

- To change the locomotive’s direction, or simply to reconnect from the end of the railway train to the front takes time. It was not feasible due to the strict timetable (tracking time 3 min!). Another solution is to form a large loop where the train can turn back. It can be achieved only in larger space or in a long tunnel somewhere under the dense built city. There were bi-directional carriages with two driver’s cabins built to overcome these restrictions. (Of course these cabins were far lower built because these were placed over the bogies).

IEEE

Bidirectional operation

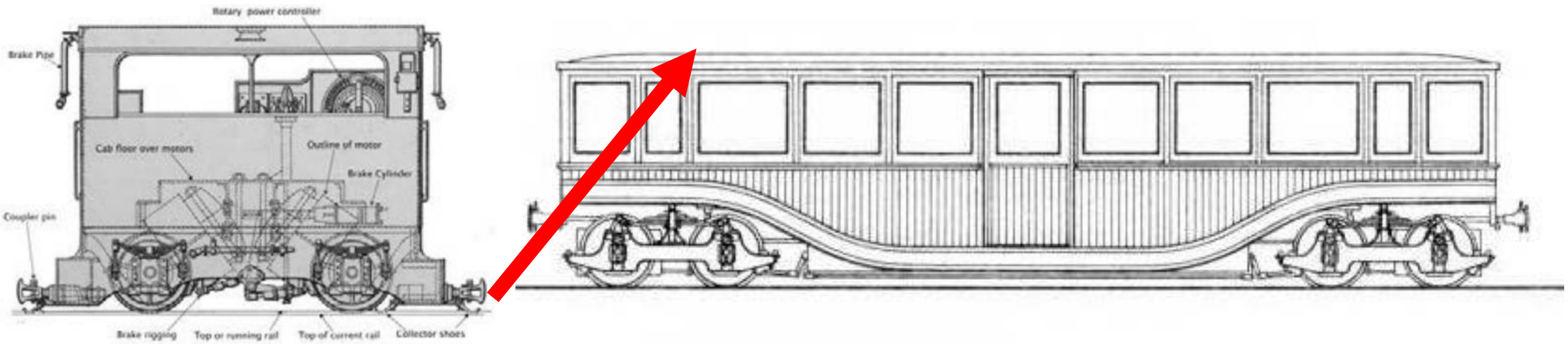




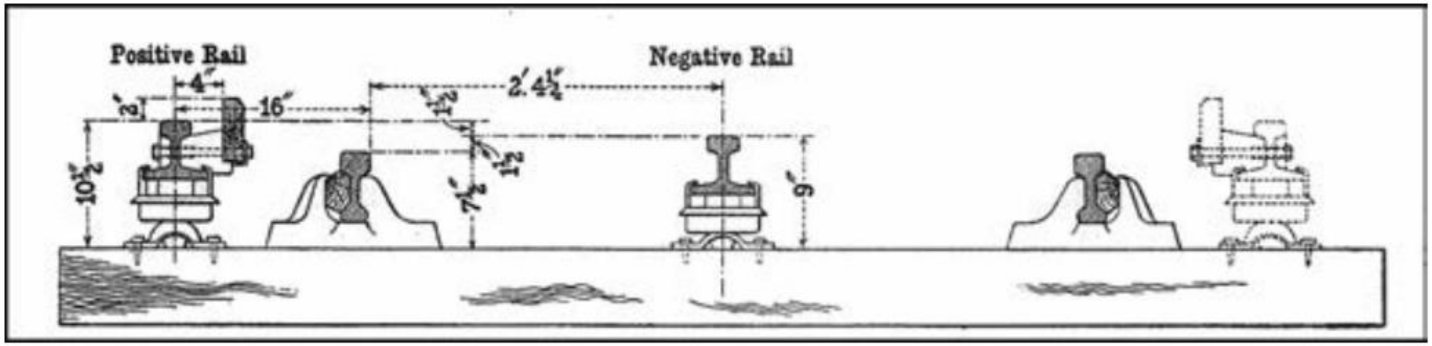
The current collector

- In Great Britain, at the beginning the lower four-rail current supply spread over. It is a clear structure but is really dangerous in the narrow tunnels (350 V DC, later 550 V and 600 V). In 1888 the surface tram was also introduced in Budapest, on the “Budapest collector system” – mounted 0,5 meter under the surface. Although a nice idea it wasn’t practical because of the fallen dirt. The two 50 mm mine rails of the current conductor were pushed up to the ceiling. The original insulators were made of wood, the current collector was formed from a pantograph. Several original equipment and three carriages are exhibited in the Underground Railway Museum (URM) in Budapest, Hungary.

(lower) 4-rail system -> upper current collector



(lower) 4-rail system -> upper current collector

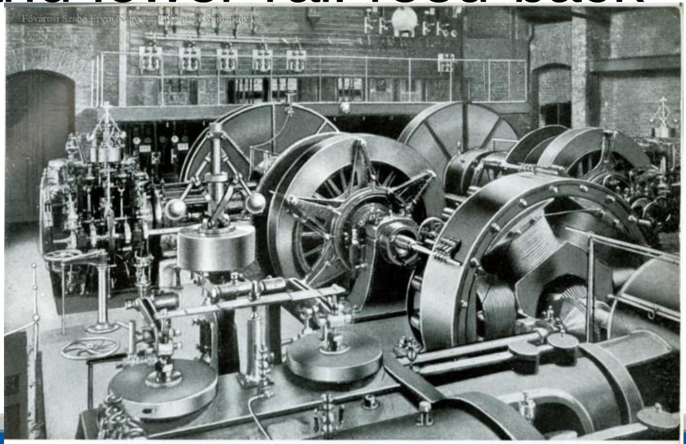


Sliding contact and wooden insulators and spark-gap at the entry to the carriage-body (URM)

The original pantograph and the „spring-in-tube” type collector in operation in 1951

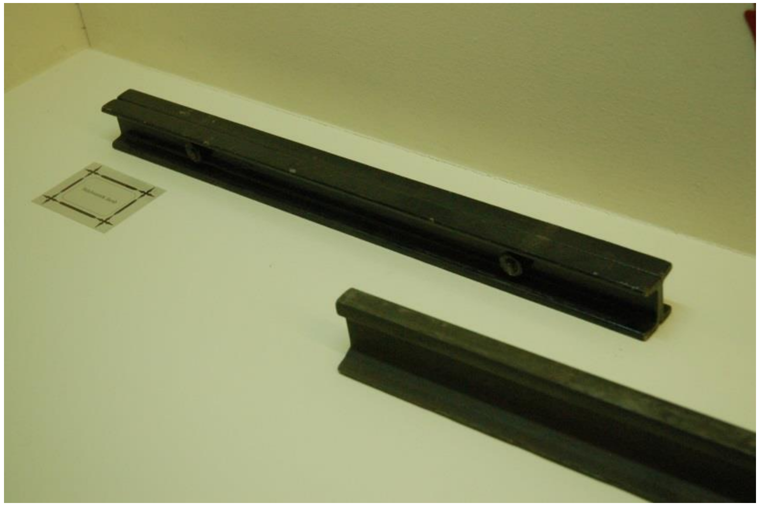
Power supply

- The 350 V DC hauling current was generated in the *‘Kertész utca – Gartner strasse’ (Akácfa utca)* power station.
- The overhead supply was solved by 50 mm height two-pole double rails (used in mines).
- In the twenties the supply voltage was raised to 550 V DC (nom. 600 V) and the double upper feeder rails was changed to a similar, single feeder rail with single pole feeding and lower rail feed-back



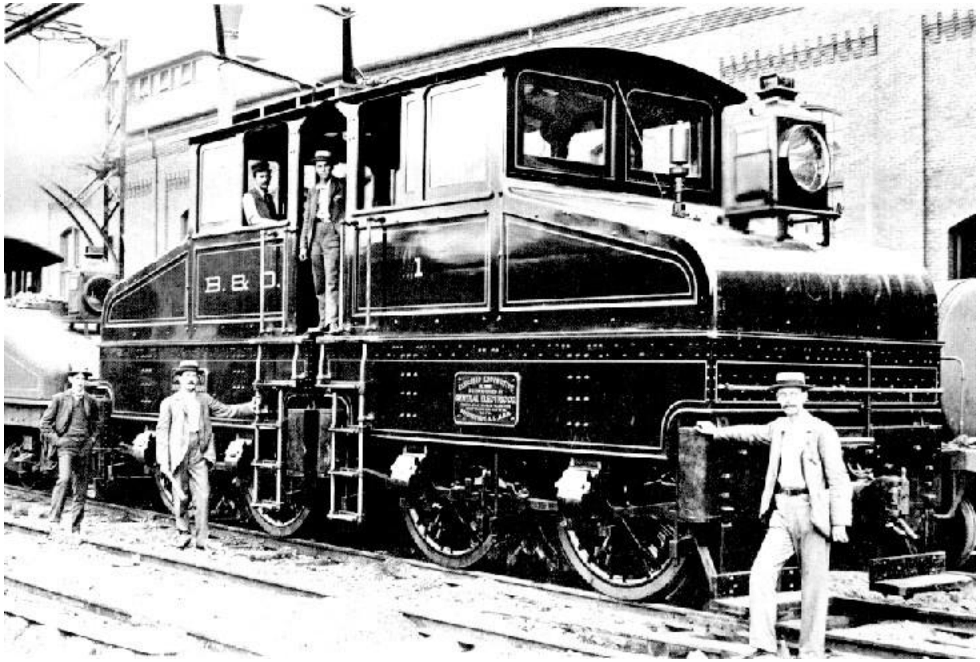
A BVVV Kertész-utcai áramfejlesztő telepének gépháza 1897-ben (Négy, egyenkint 200 lóerős gőzgéppel)

Upper feeding rails



Fixed axle - double locomotive

- The **first** standard gauge British **railway** to build coaches with **bogies**, instead of rigidly mounted axles, was the Midland Railway in 1874.
- **IEEE Milestones:** Mainline Electrification of the Baltimore and Ohio Railroad, 1895 - ***No bogie!***

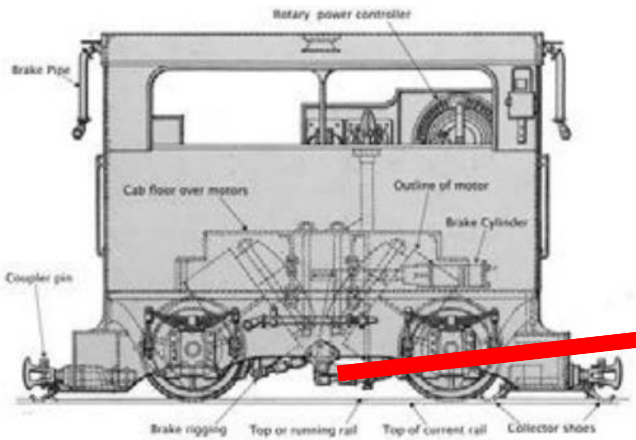


The Pioneer Stage of Railroad Electrification
Carl W. Condit
Transactions of the American Philosophical Society
Transactions of the American Philosophical Society
Vol. 67, No. 7 (1977), pp. 1-45 (45 pages)
Published by: American Philosophical Society

Bogie

- The two iron wheels fixed to an axle caused huge friction in the curves of the rails. To install more rigidly mounted axles was possible only with short axle-base, avoiding being stuck in the small radius curves. The long coaches were mounted with small rotating bogies at the front and the back of the long carriages at the Midland Railway first in 1874.
- In Budapest, the relatively long carriage and the small radius curves required small bogies to each carriage. Each contained the electric motors with Gall-chain, later with direct drive. Bogie carriages were produced by Schlick Vasöntöde és Gépgyár (Schlick Forgery and Machine Factory), and the electric motors were made by Siemens und Halske Co.

Fixed axle -> bogie with motor



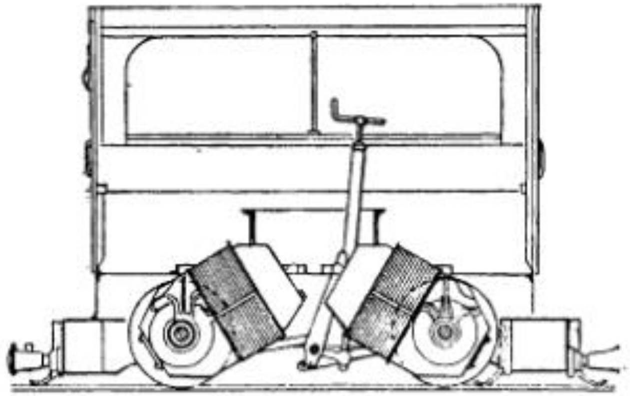
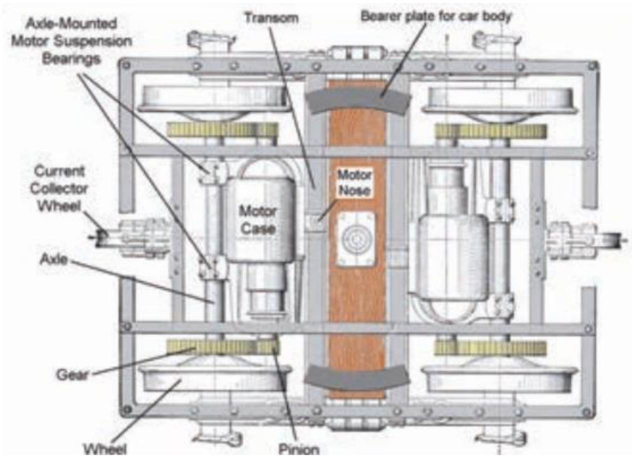


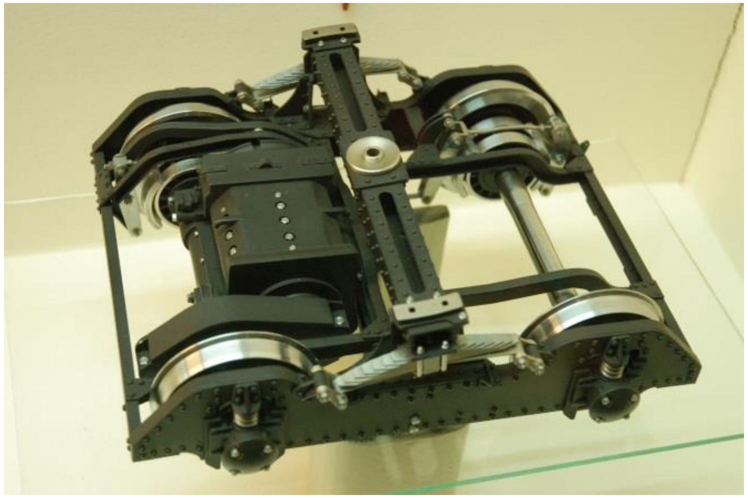
FIG. 3. Longitudinal section of the locomotive built for the City and South London Railway, 1887–1890. (Dunsheath, *A History of Electrical Engineering*)



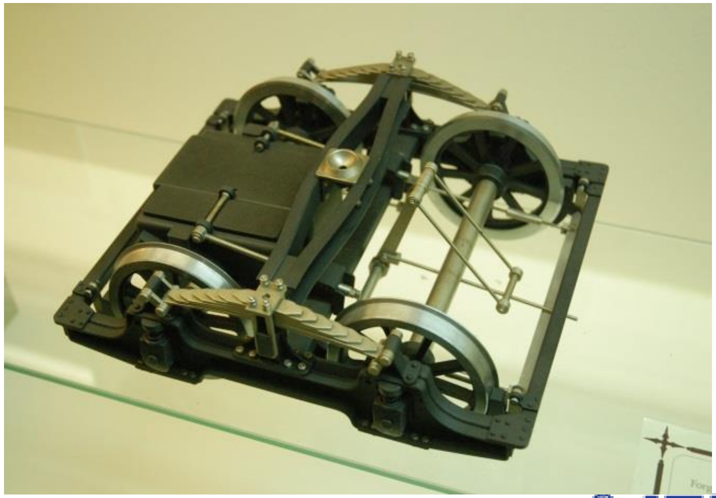
Bogies and producers

- Bogie carriages were produced by *Schlick Vasöntöde és Gépgyár (Schlick Forgery and Machine Factory)*, and the electric devices were made by *Siemens und Halske Co.*

Gall chain bogie



Direct drive bogie

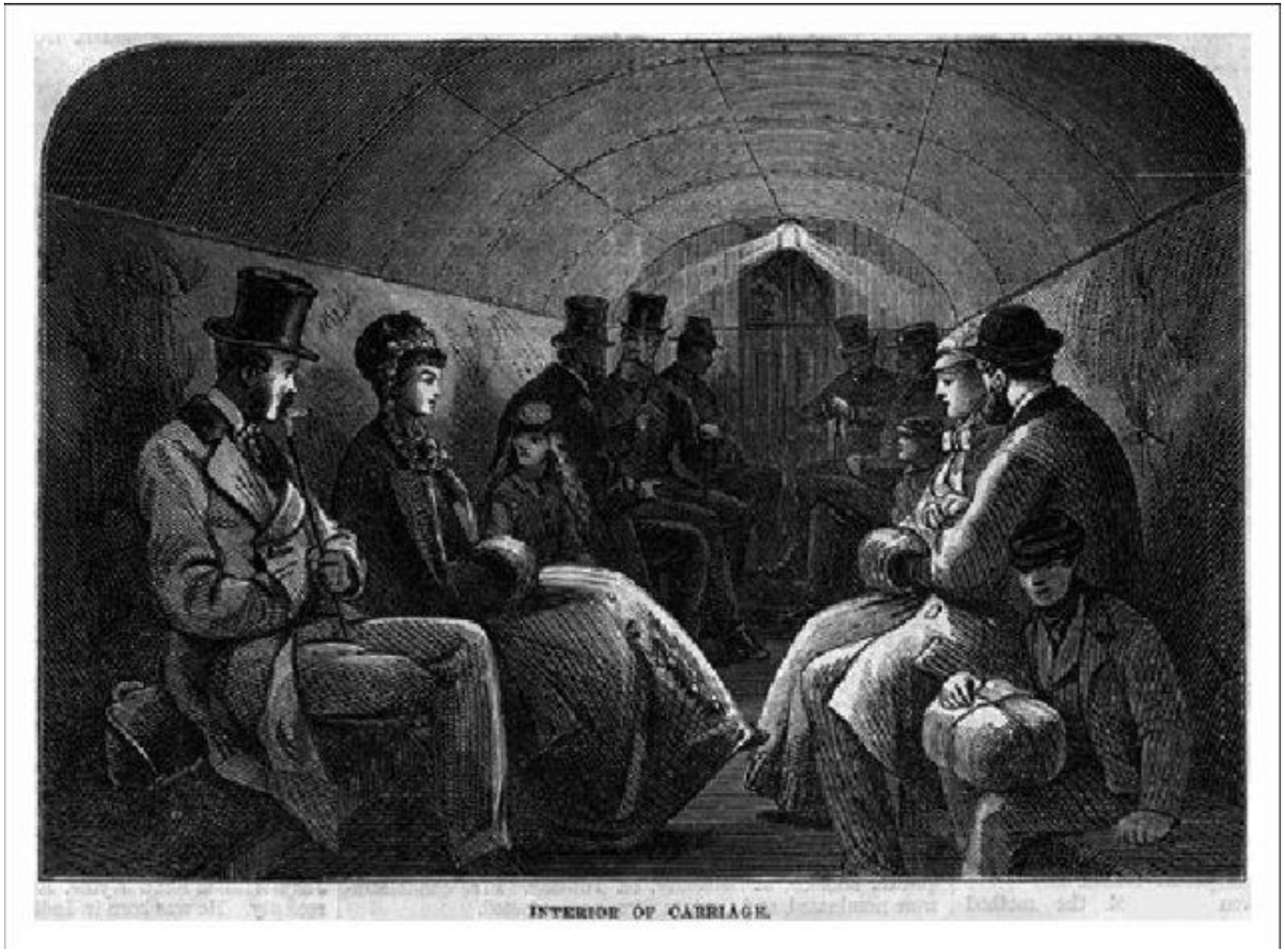


Electric lighting

- In the XIXth century candle, petroleum, later gas lighting were used in the train carriages. Electricity was first used in 1870 for station lighting, but the e.g. the Metropolitan and District Railways used gas lighting until 1917. In spite of the electric drive of the City & South London Railway from 1890, the station platforms were lit by gas. The Metropolitan Railway carriages were mounted by dynamo generating power for the lighting bulbs and batteries only in 1900.
- In the Budapest Metro both the carriages and the stations were illuminated by electric bulbs

Lighting in the „tube”

- The London Underground opened in 1863 with **gas-lit**



INTERIOR OF CARRIAGE.

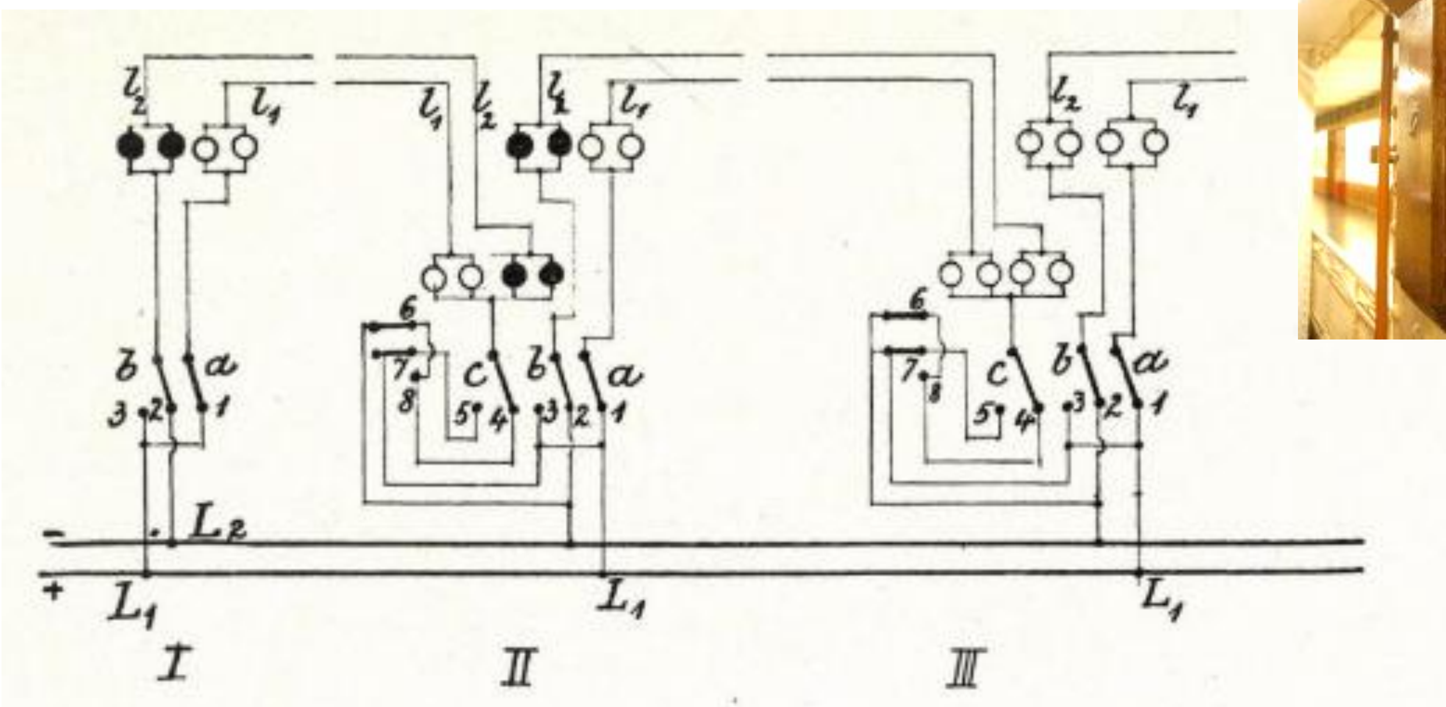
Electric lighting

- From the late 1870s, there were experiments with electric lighting, first on station platforms and then in carriages, but the Metropolitan and District Railways remained essentially dependent on gas lighting until 1917
- Even the City & South London Railway, opened in 1890 and electrically powered from the outset, relied on gas lighting on station platforms T.C. Barker and Michael Robbins, A History of London Transport,…
- When the first (free) electric lights were installed in Metropolitan Railway carriages in 1900, Stone's system was employed, powering the lights by a dynamo on the train when it was in motion, and by batteries when it was stationary Alan Jackson, London's Metropolitan Railway, op. cit.,…

Signalisation

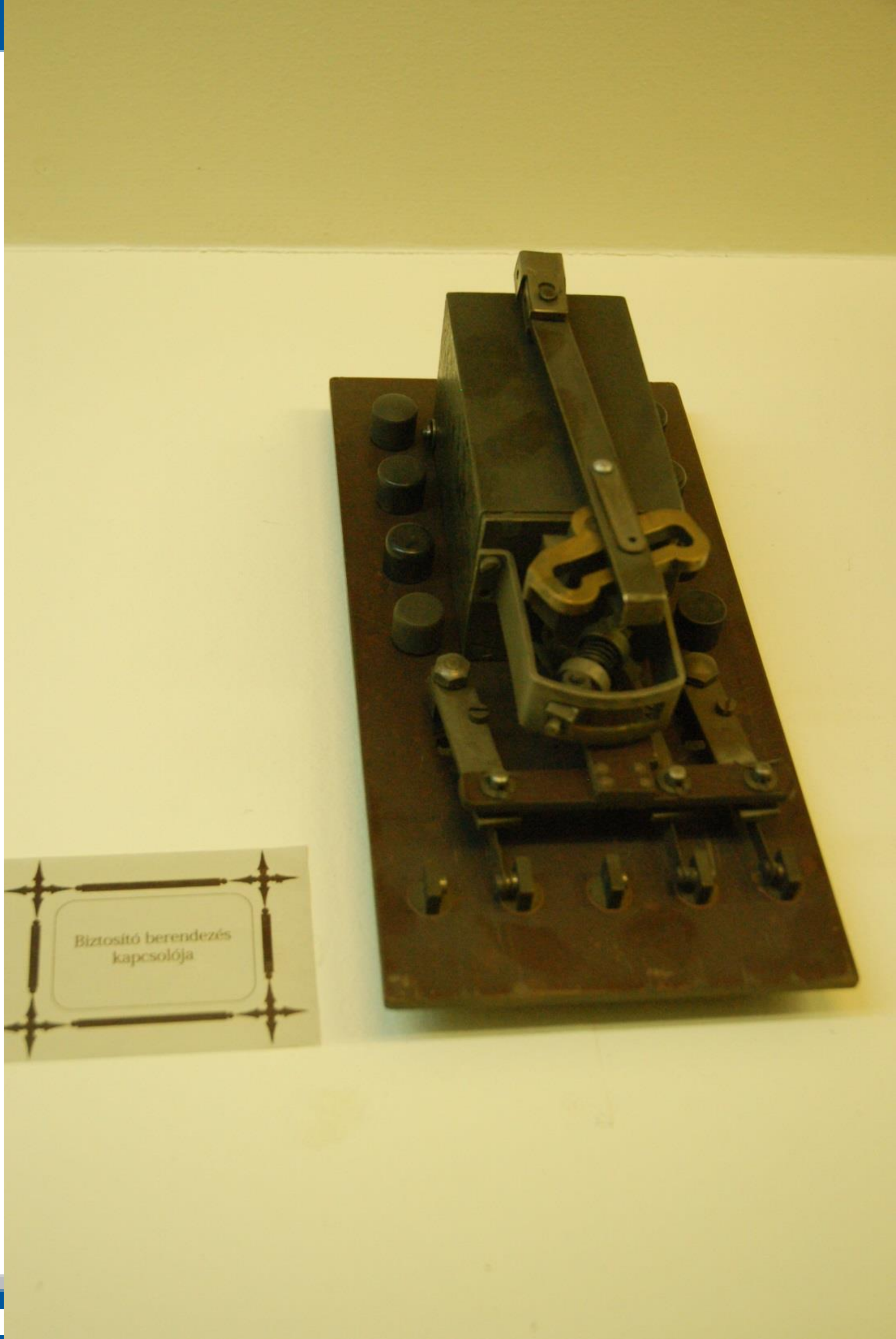
- One of the most important topics in rail traffic systems is safety. Having no previous experience with underground safety systems the Siemens-Halske company applied its most modern “surface” light signaling system. When a carriage left the station the pilot set the light red by a mechanical switch. Its meaning was: „The tunnel is occupied”. As soon as the train at the next station the white lamp lit up „The tunnel is vacant”. „Slowly” was signalized by green light. Of course the platform guards could communicate by telephone too.

Circuit diagram of the signalisation system and the signaling lamp



Safety switch

- Original switch



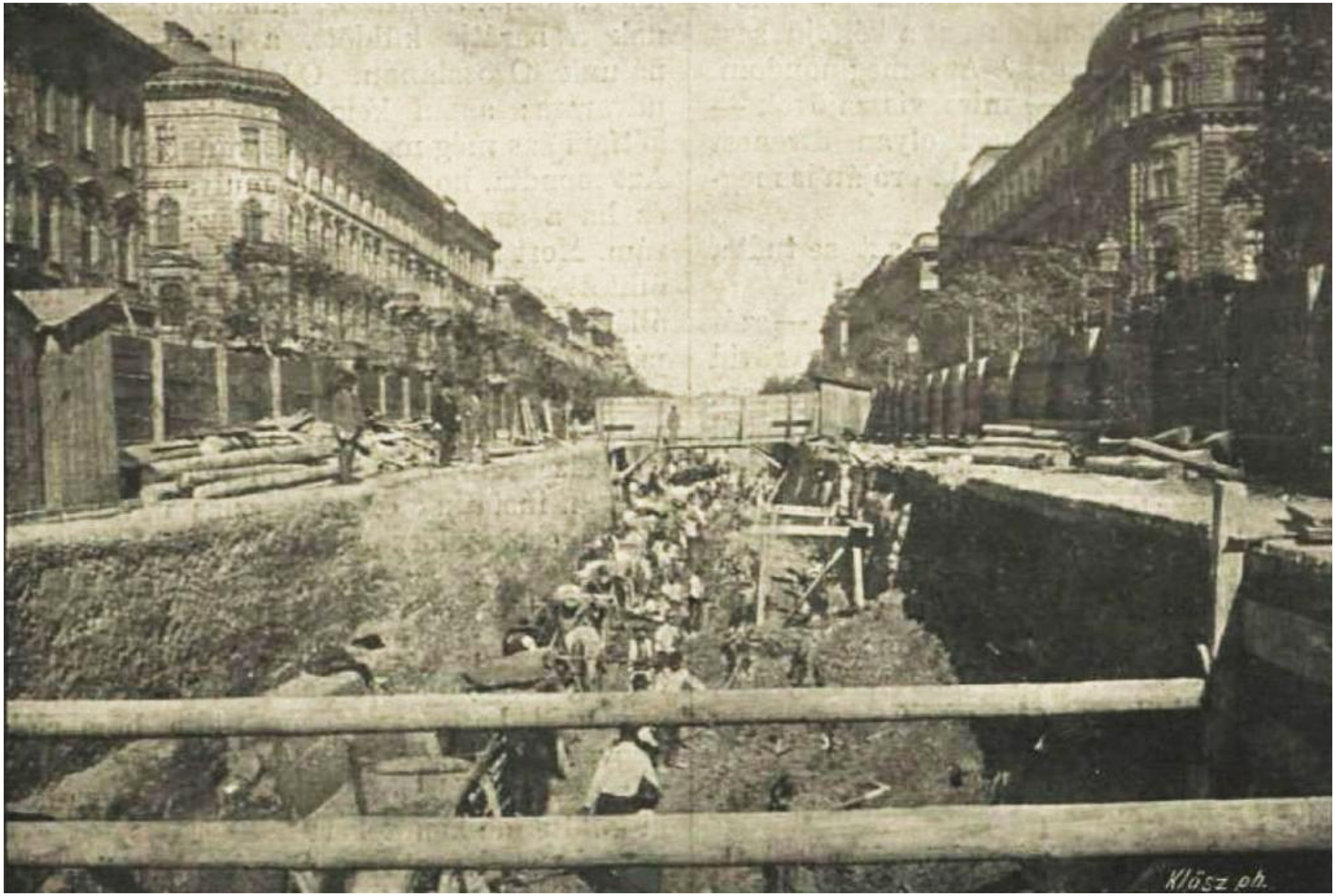
Alarm rod – emergency breaker – loudspeaker (URM)

- Passenger signaling is also important in a moving carriage. Passengers could send alarm signals to the driver by means of a long rod operating a signal switch in the cab. Another direct switch could break the electrical current in case of emergency. From the thirties the driver had a loudspeaker to inform the riders.

Cut-and-cover technology

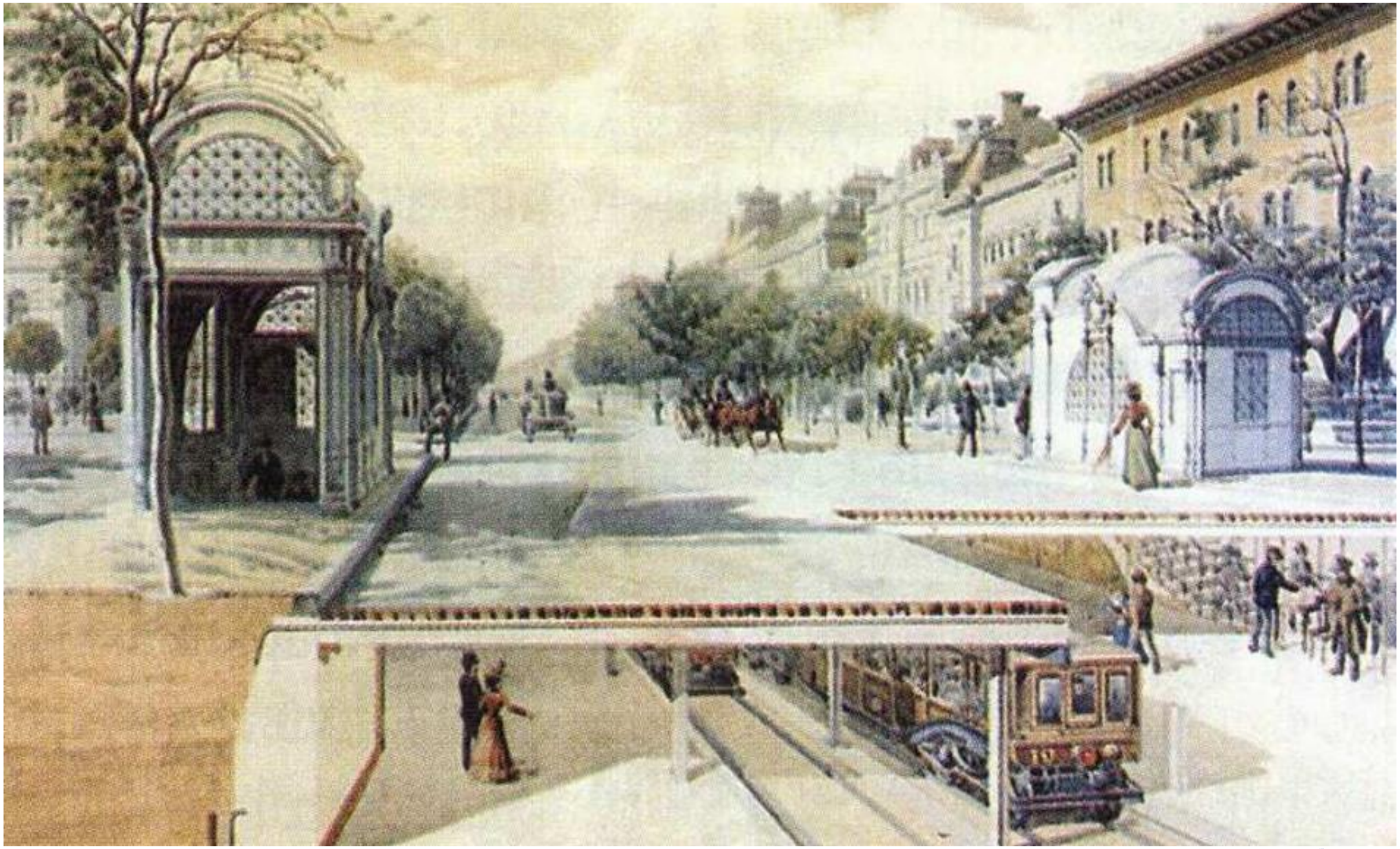
- Carving the tunnel is an old technology. It requires a special technique in sand but it is not worth doing close to the surface. To operate close to the “skin” was a dangerous game in the densely built city. The London metro runs 10-15 m deep under the surface. In Budapest and later in the follower cities the “cut and cover” technology was applied, where a stayed ditch was dug and later covered by special joists. The coping was strengthened by steel pillars.

Cut-and-cover, Budapest



Cut-and-cover, Budapest

Cut-and-cover, Budapest

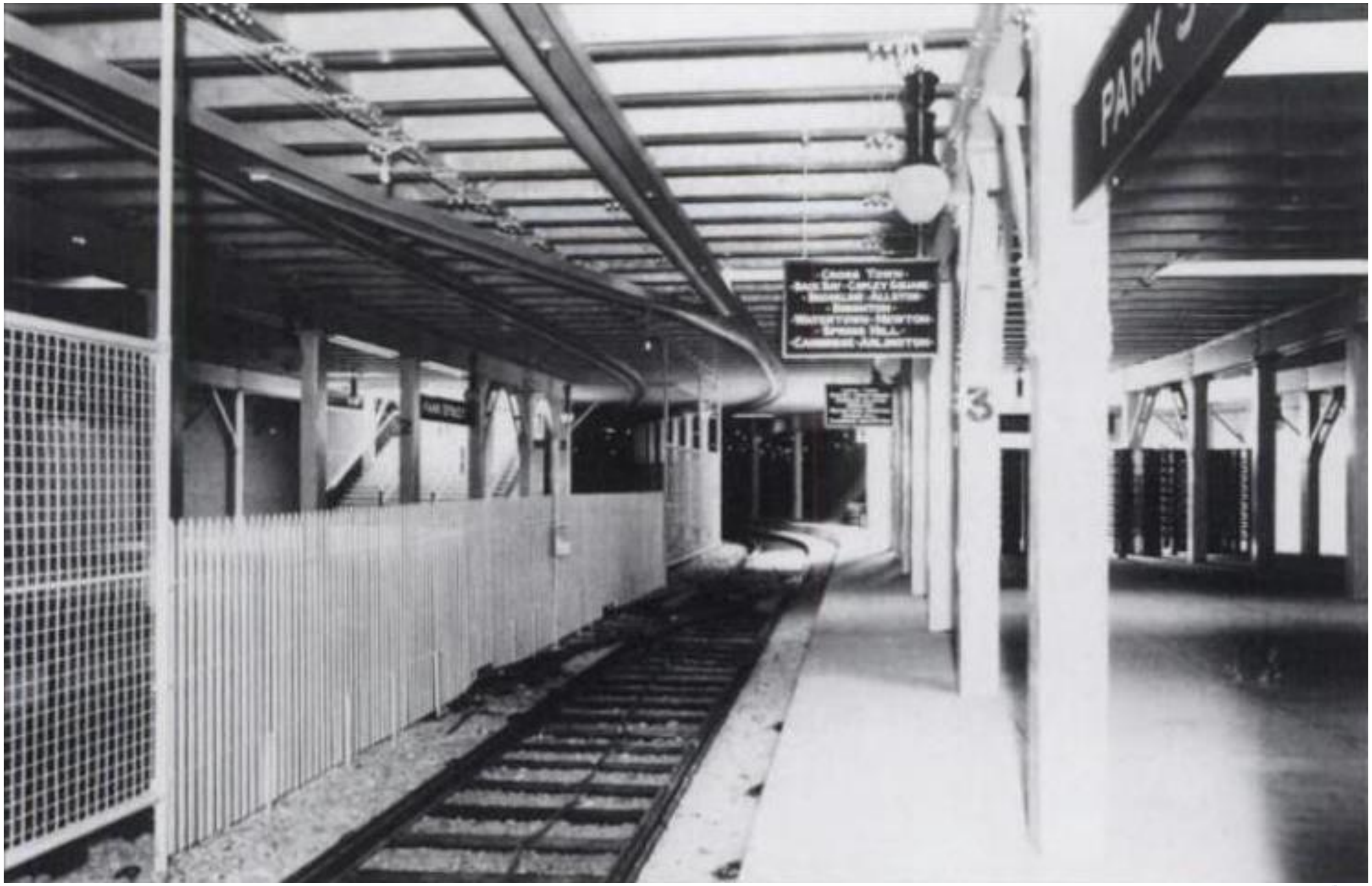


A new standard

- The Budapest metro, as the second oldest still in use worldwide to exclusively use electric traction, became a pattern for many follower undergrounds, such as the
  - Boston Tremont Street Subway September 1, 1897
  - Paris Metro July 19, 1900
  - New York City Subway October 27, 1904
  - Berlin U-Bahn May 14, 1906
  - Buenos Aires Underground December 1, 1913
- One can see the similar cut-and-cover technique, the steel pillars, the horizontal steel enforced concrete coping, the low tunnel height. The track gauge and the formation of the carriages were also similar

Cut-and-cover, Boston

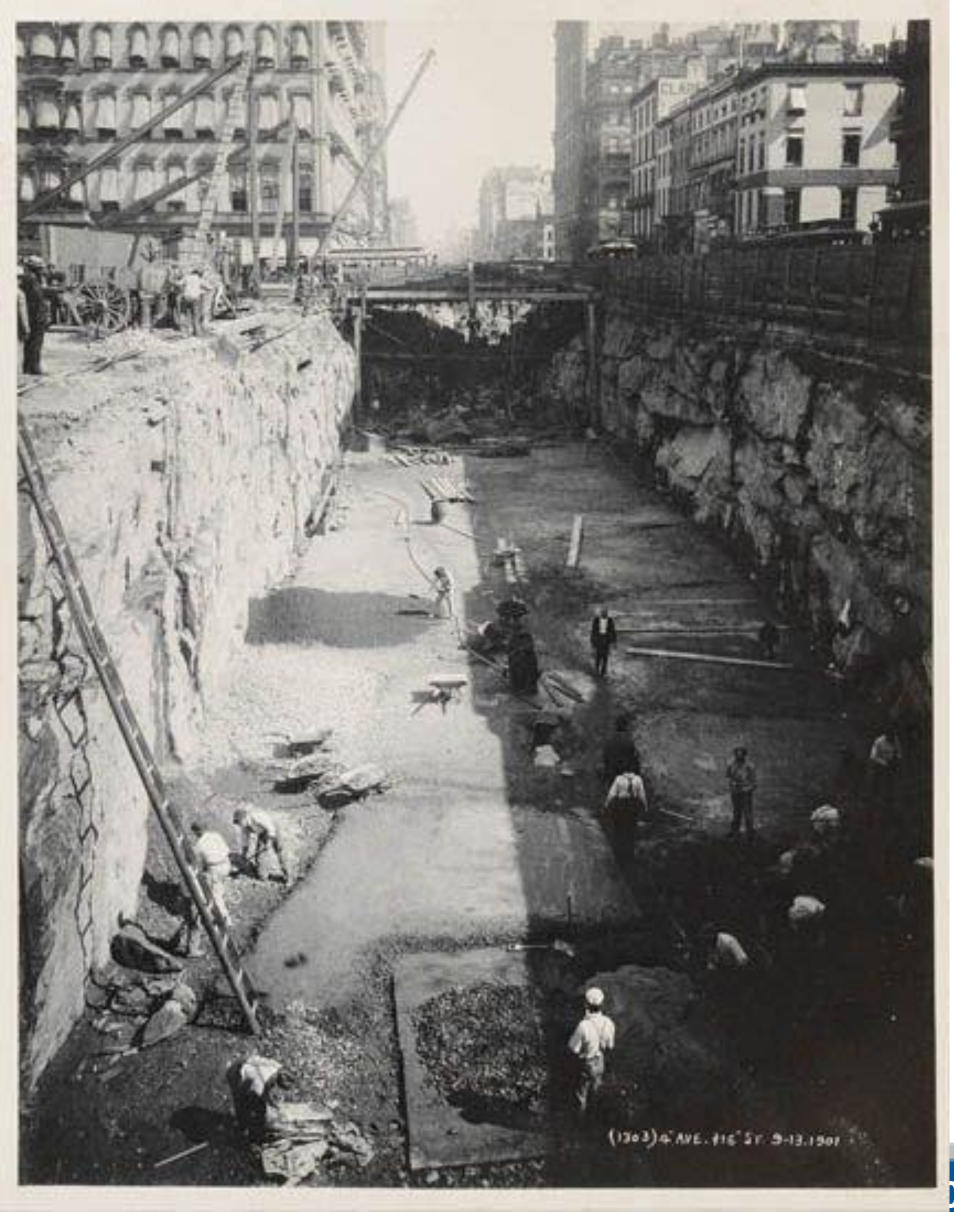
Pattern for Boston, 1897



Cut-and-cover, Paris

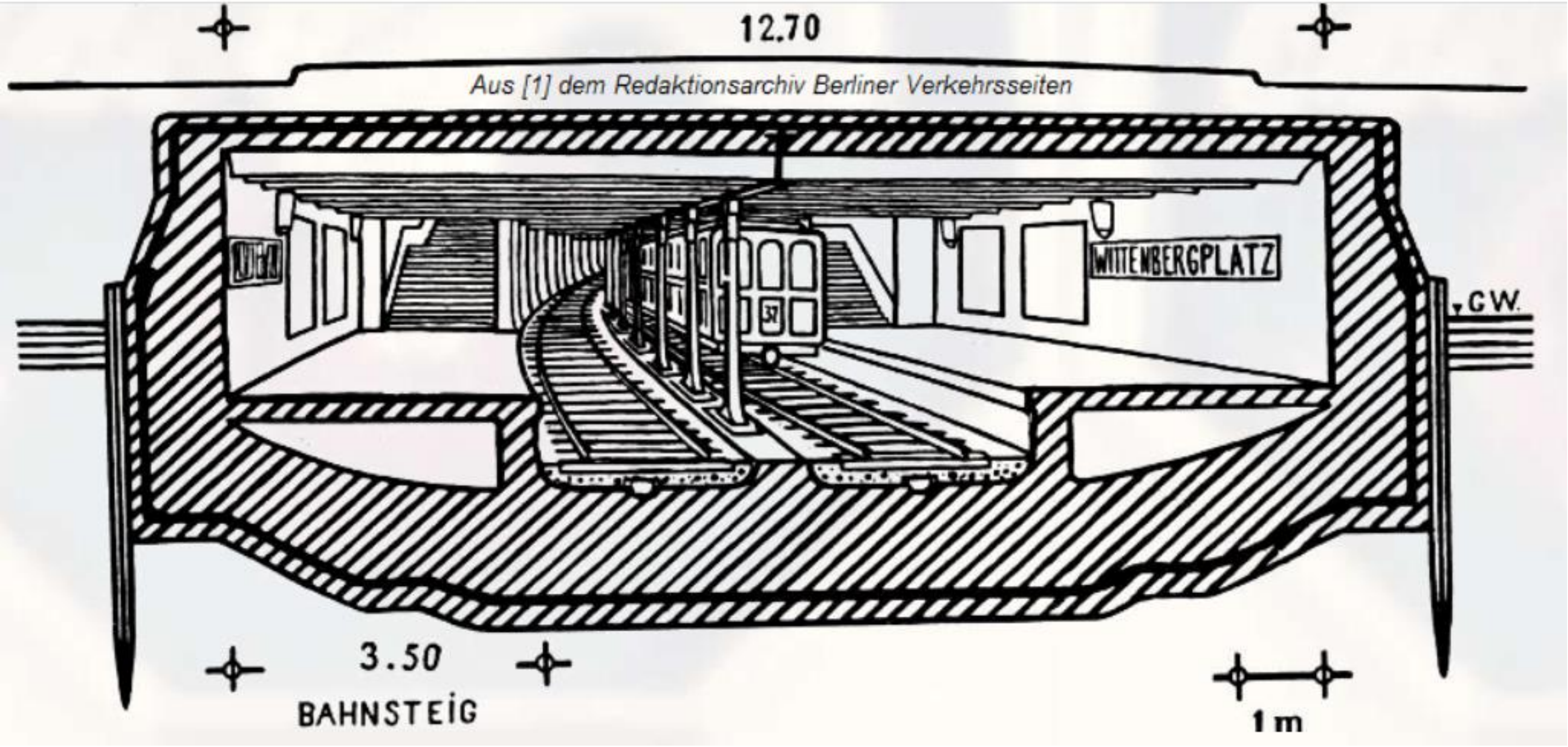
Pattern for Paris, 1900

Cut-and-cover, New-York



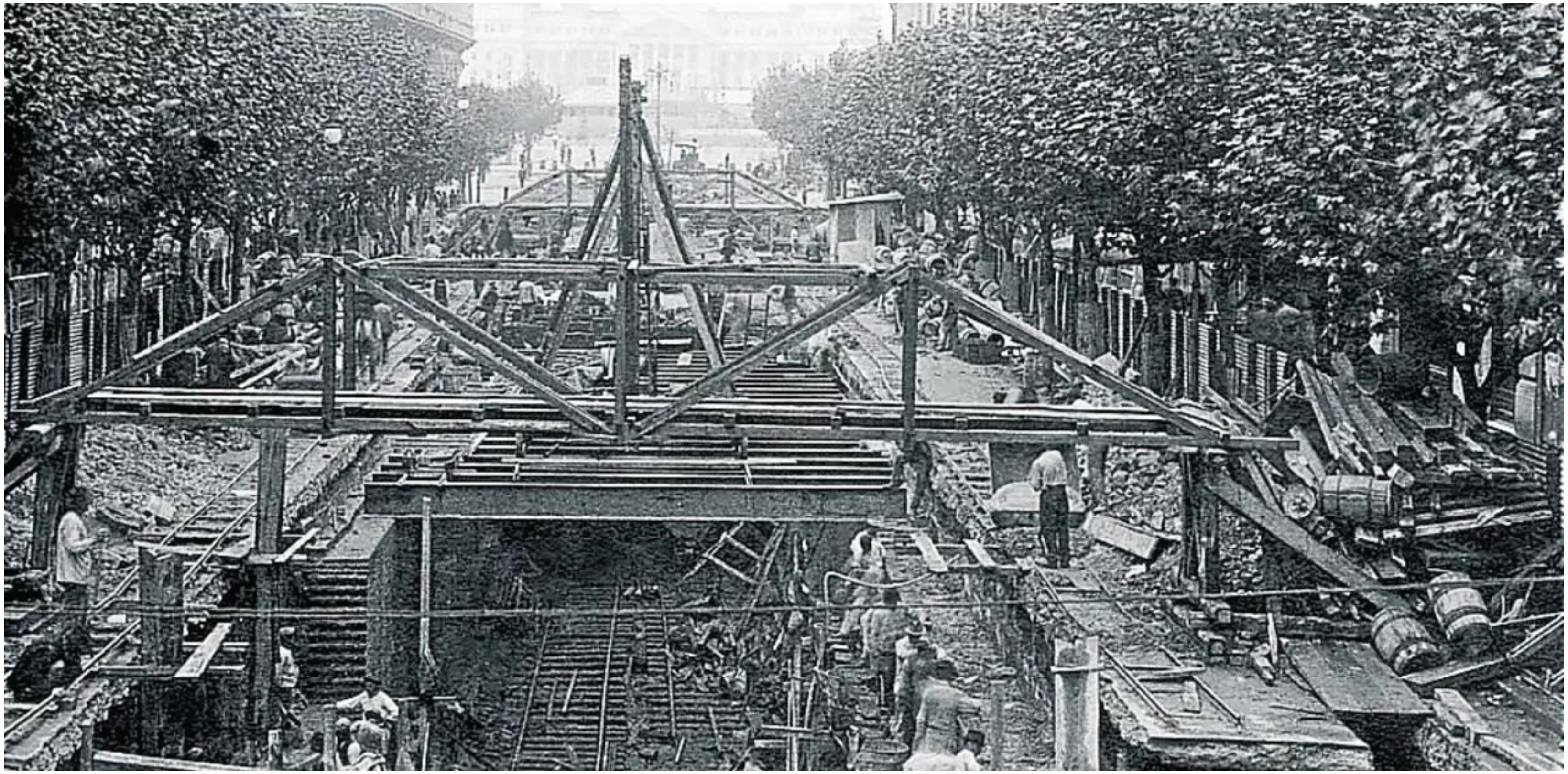
Pattern for New York, 1904

Cut-and-cover, Berlin



Pattern for Berlin, 1906

Cut-and-cover, Buenos Aires



Pattern for Buenos Aires, 1913

Conclusion

- The Metro line No.1. of Budapest has a significant role today transporting more than 20 million passengers per year. The memories of early underground transportation have been carefully preserved by the Underground Museum. It is located in an old tunnel section out of service today.
- ***The 125 (126) years of operation demonstrated that the dozens of innovation helped to develop something new, something enduring and also something aesthetic for centuries.***

Thanks for the attention!