Innovative solutions in the 125 years' old Budapest Metro No.1.

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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

(+Electric water pumping and 21 months project in time, in budget)

Budapest, Hungary in Central Europe, 1896

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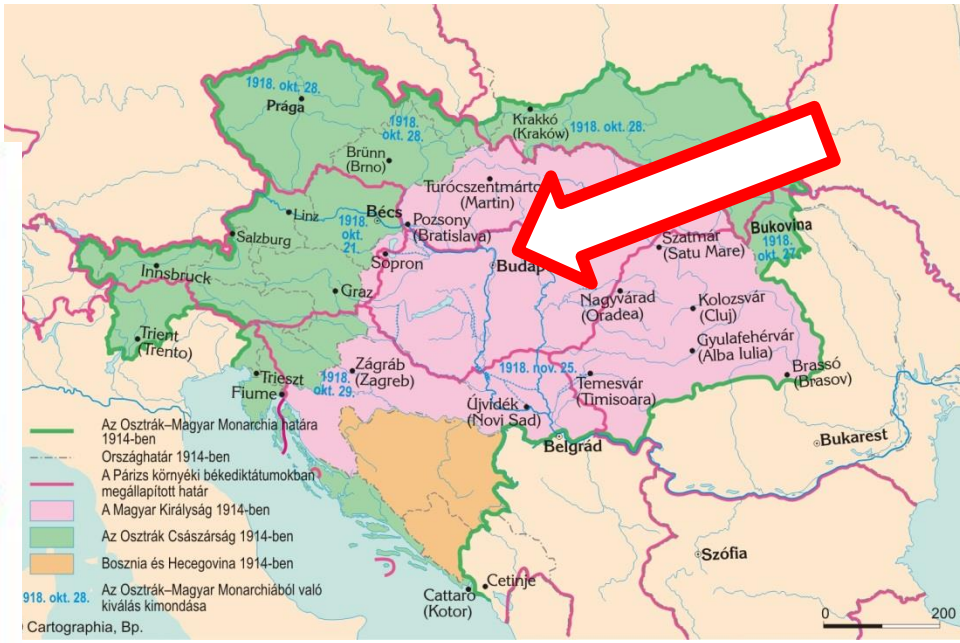

Innovation

- "**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
- **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 railway system:

Budapest – 1896

First Metro in London 1863 steam locomotive

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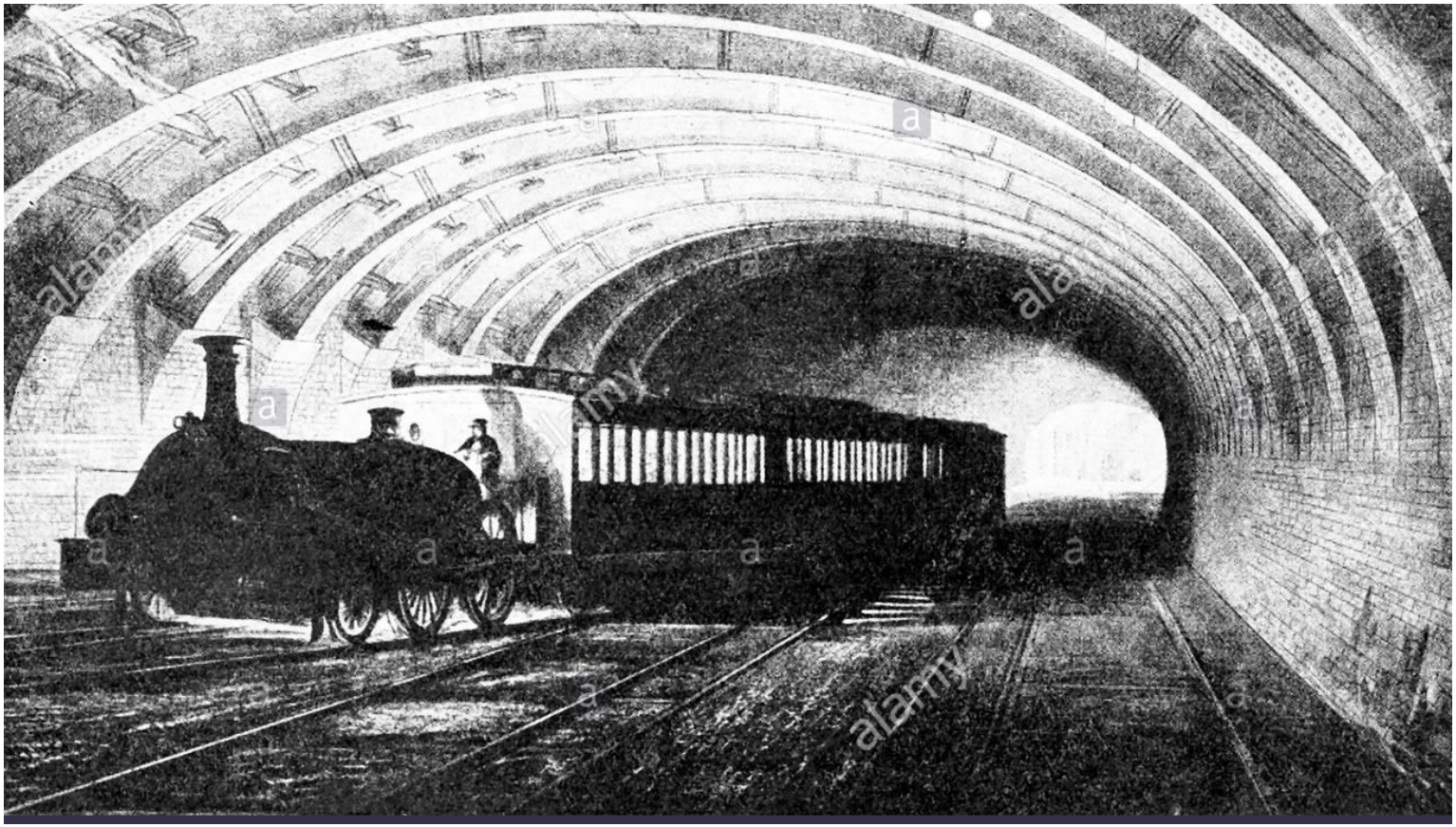
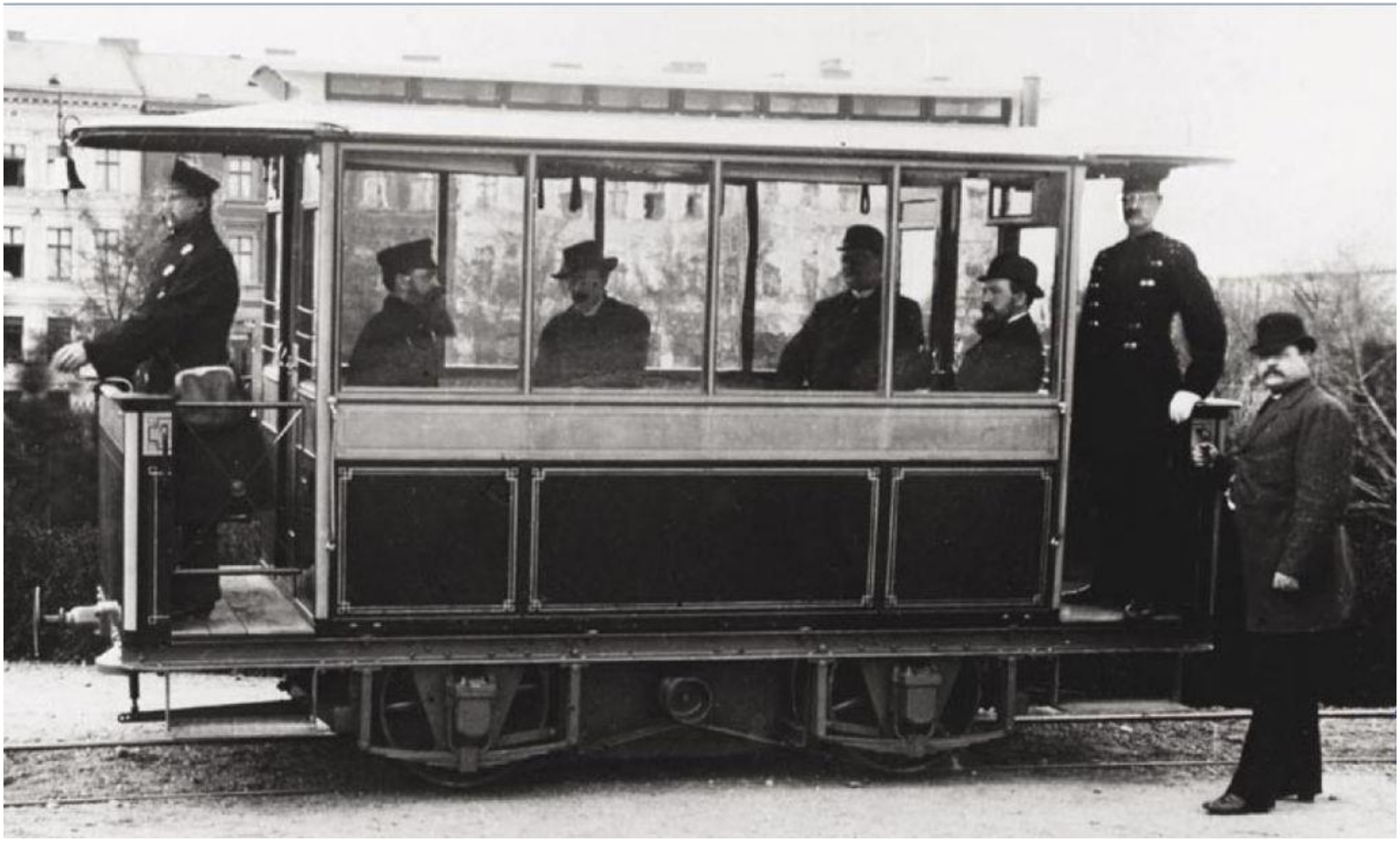


First electric street car 1881 of Siemens



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

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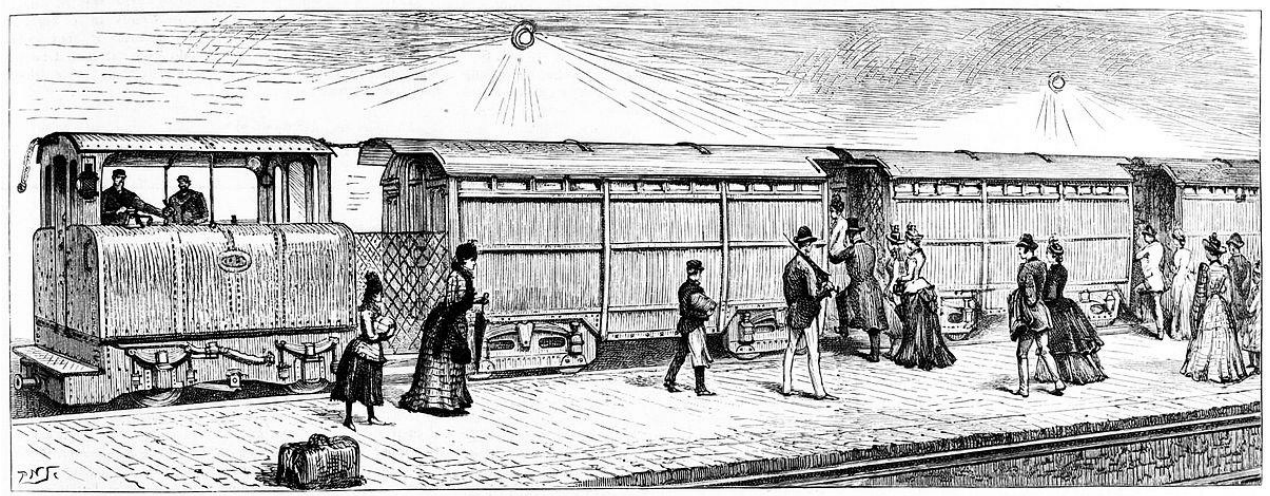
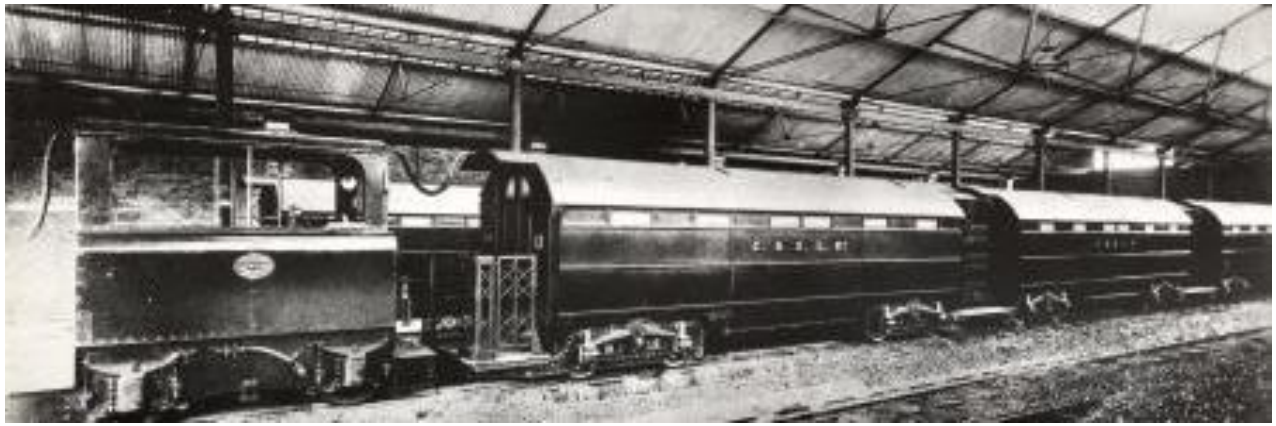
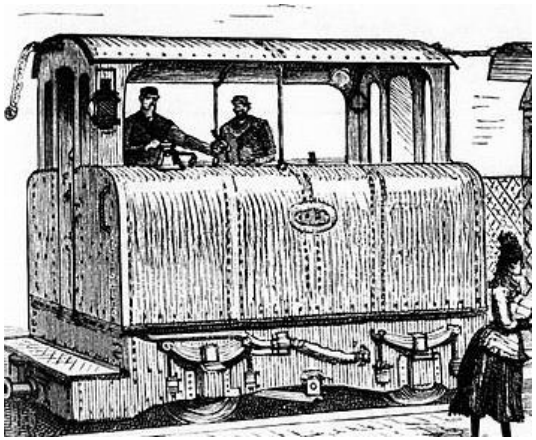


ELECTRIC RAILWAY TRAIN.



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



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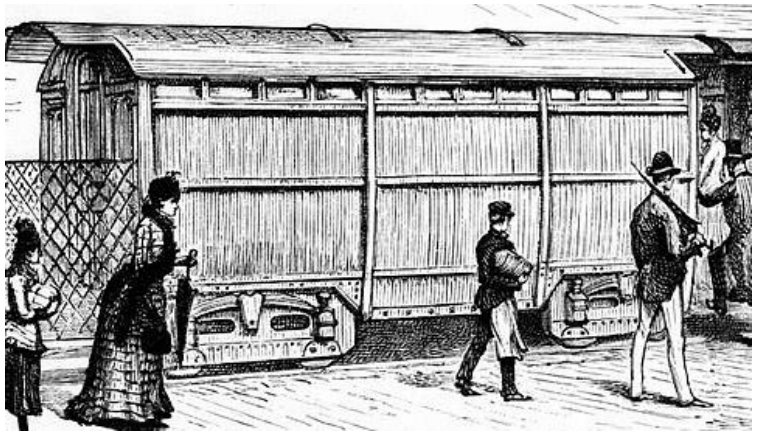

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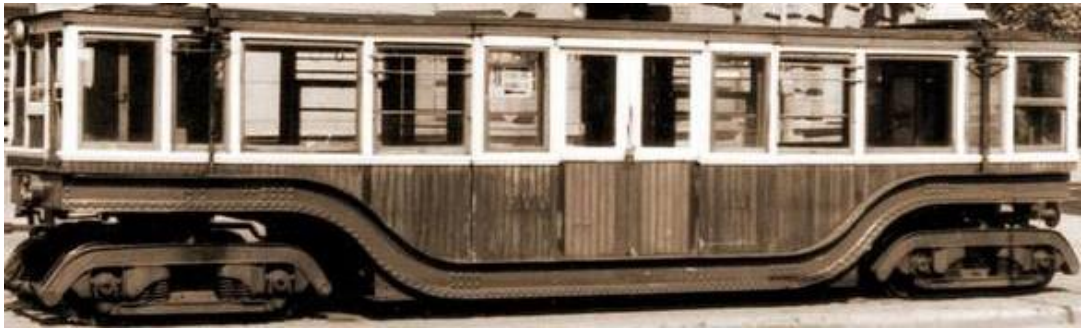
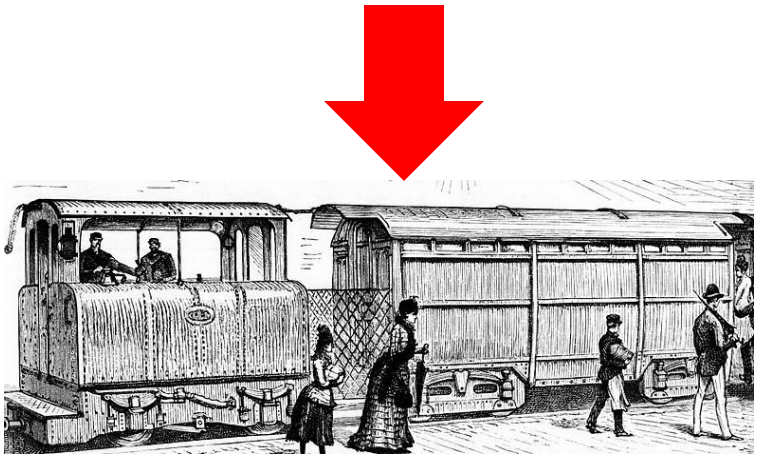


Goose neck chassie – height compression

- 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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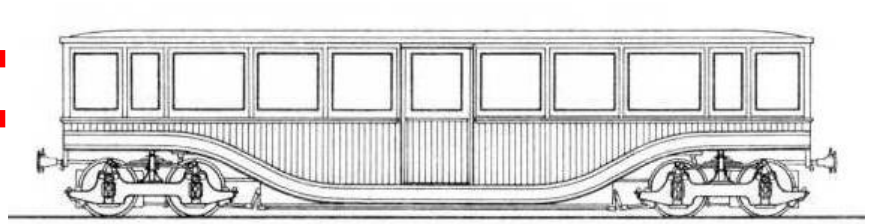
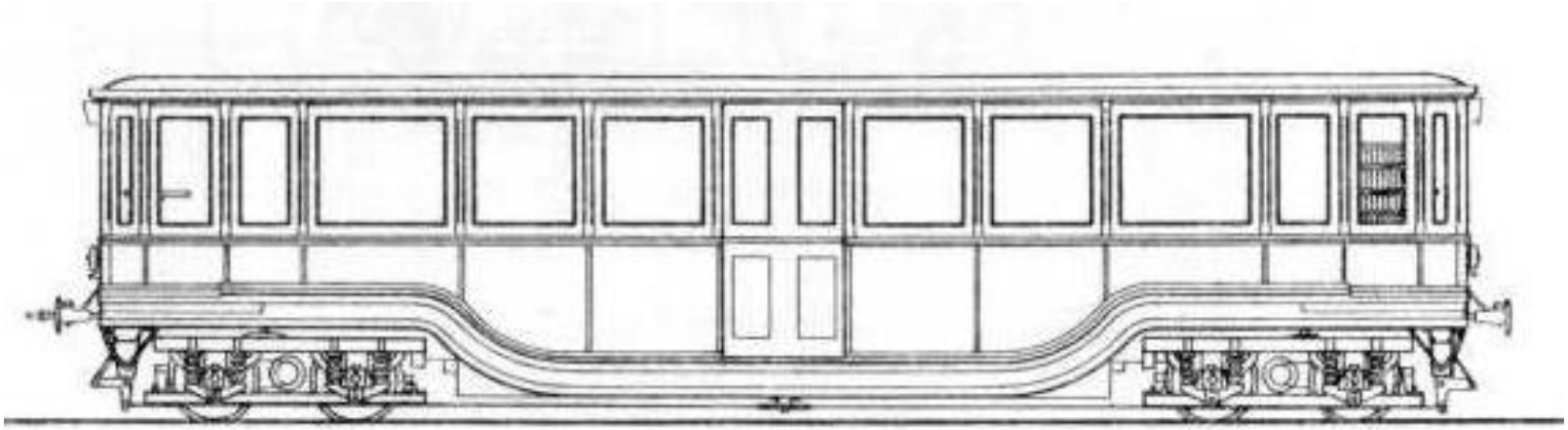
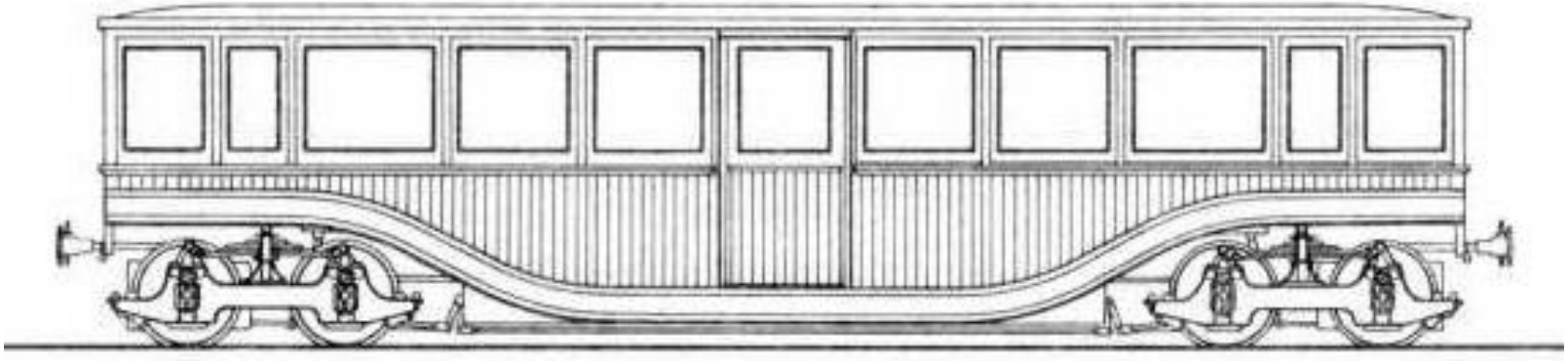


The Goose neck carriages

- No. 1-10 – metal covered



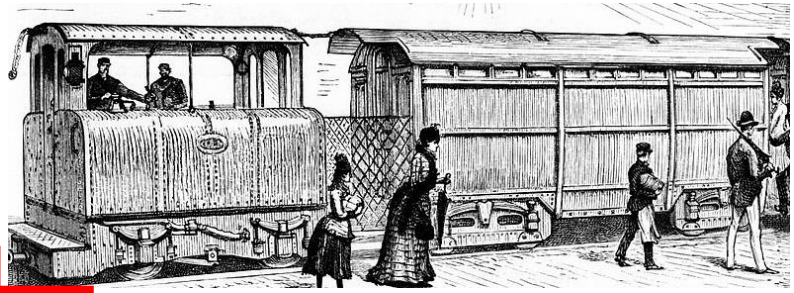
- No.11-19 – wood covered

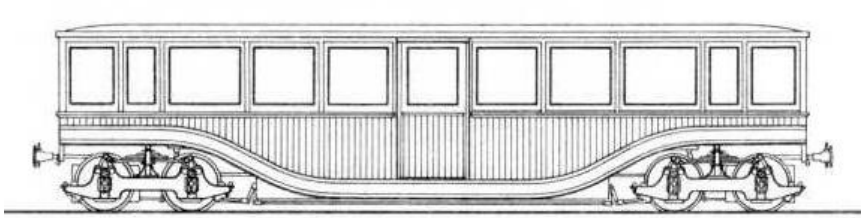


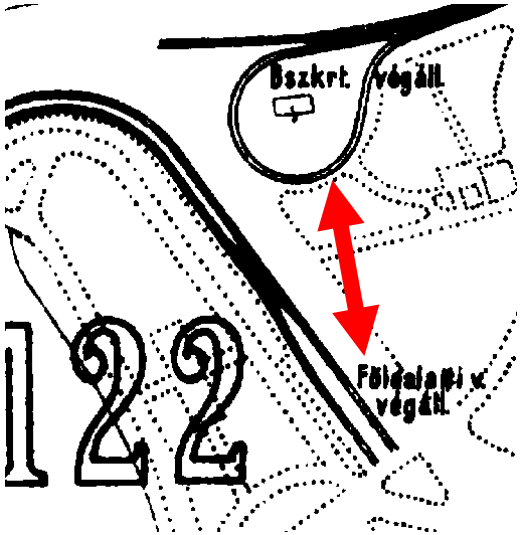
Bidirectional operation

- 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).

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

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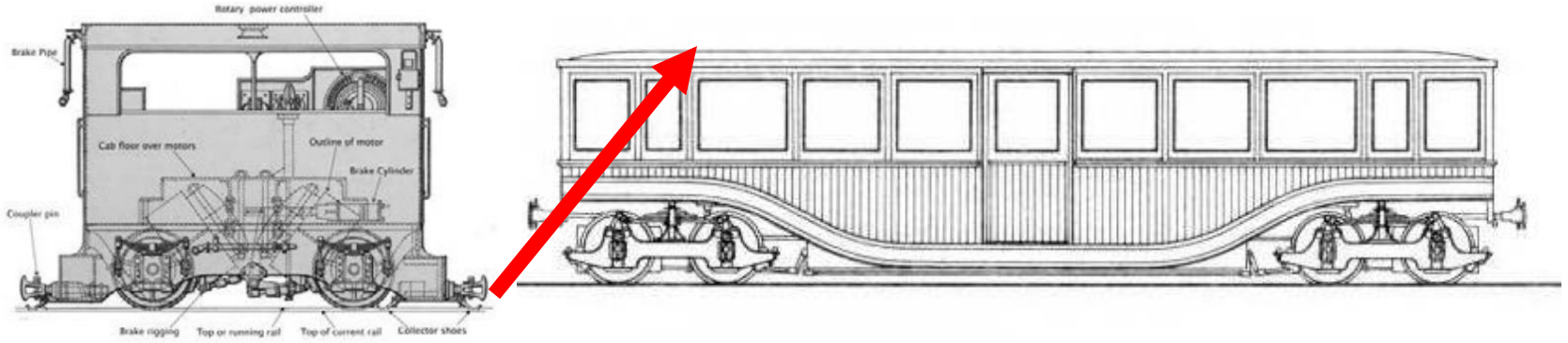
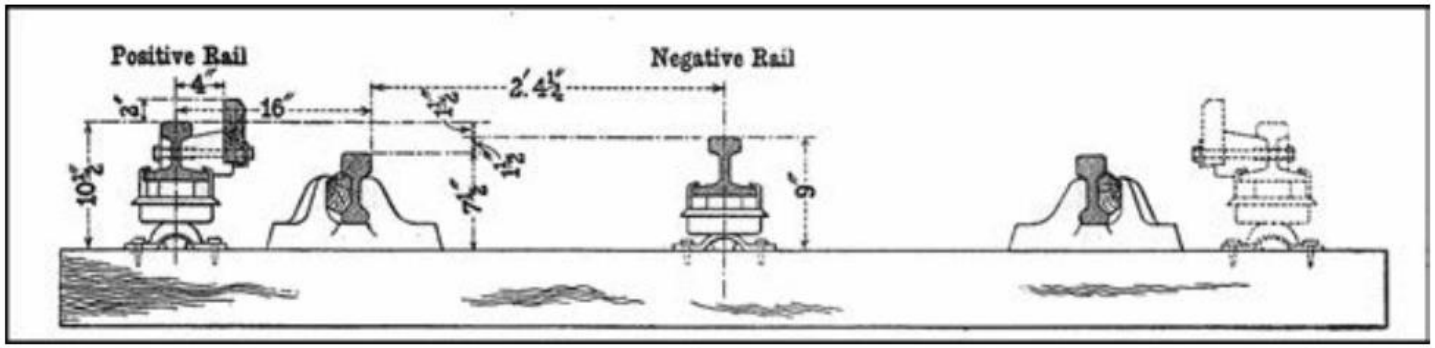


(lower) 4-rail system -> upper current collector

Power System Department



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

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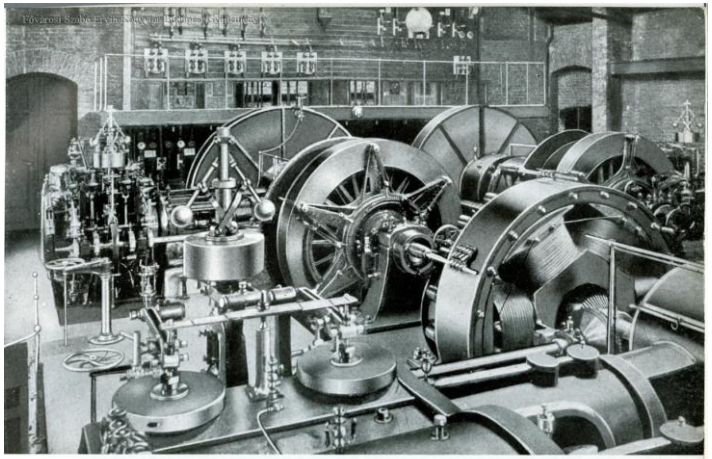
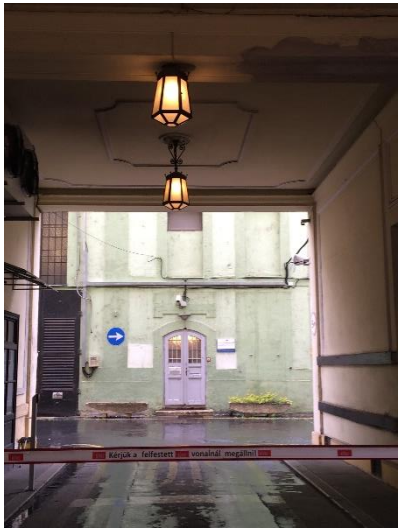
Power supply

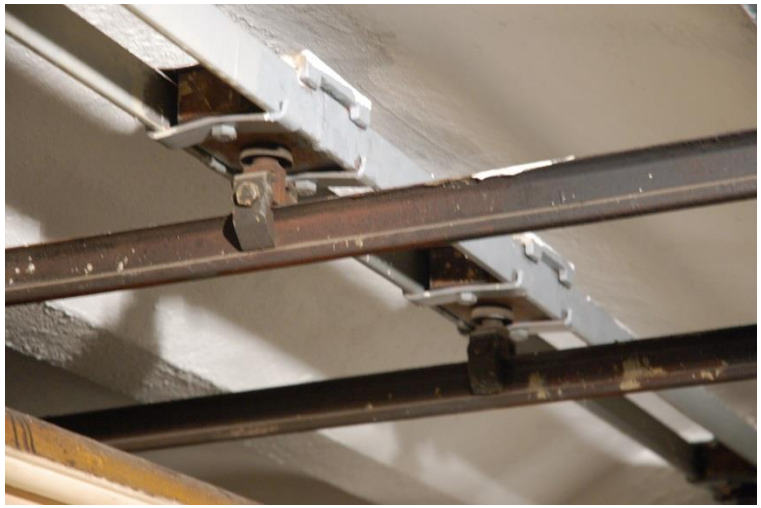
- The 350 V DC hauling current was generated in the *'Kertész utca – Gartner strasse' (Akácfa utca)* power station.
- The overhead supply was solved by 50 mm height two-pole double rails (used in mines).
- In the twenties the supply voltage was raised to 550 V DC (nom. 600 V) and the double upper feeder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

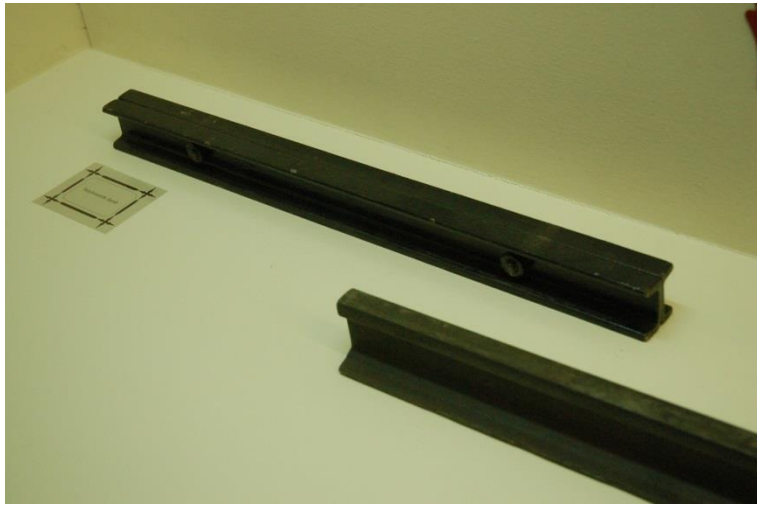


A BVVV Kertész-utcai áramfejlesztő telepének gépháza 1897-ben
(Négy, egyenkint 200 lóerős gőzgéppel)



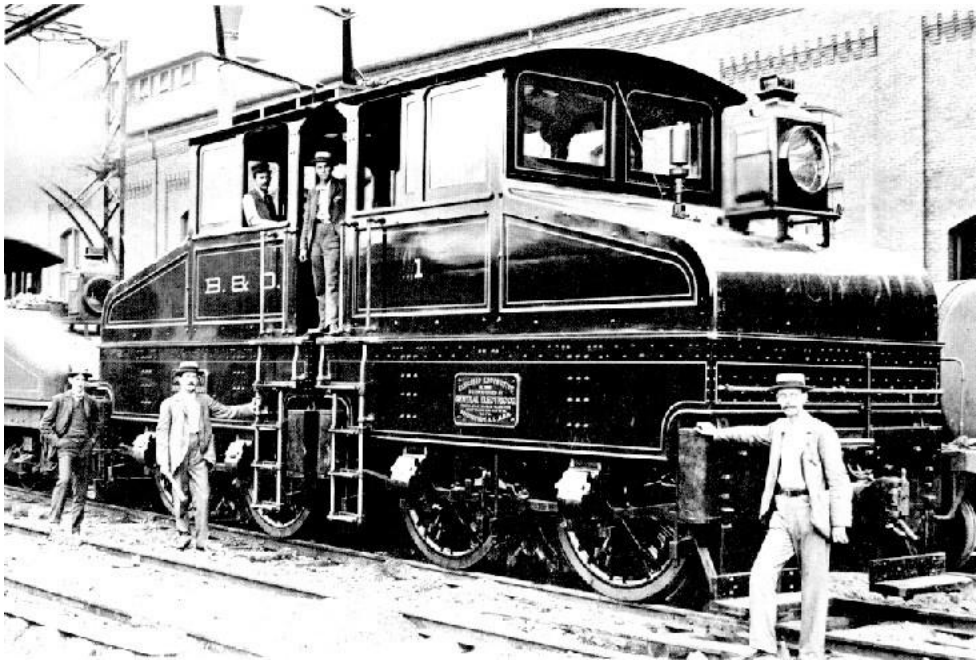
Upper feeding rails





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!***

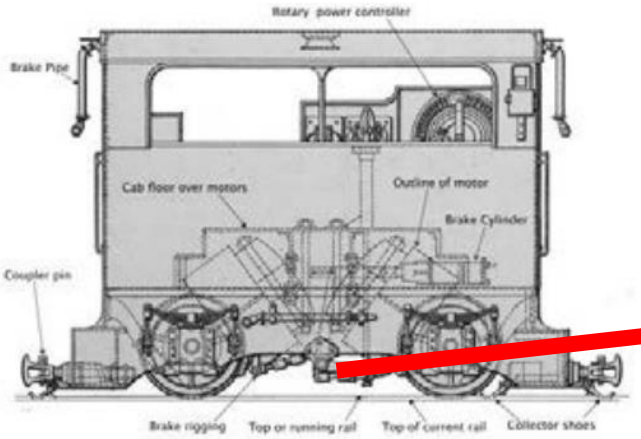


The Pioneer Stage of Railroad Electrification
Carl W. Condit
Transactions of the American Philosophical Society
Transactions of the American Philosophical Society
Vol. 67, No. 7 (1977), pp. 1-45 (45 pages)
Published by: American Philosophical Society

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



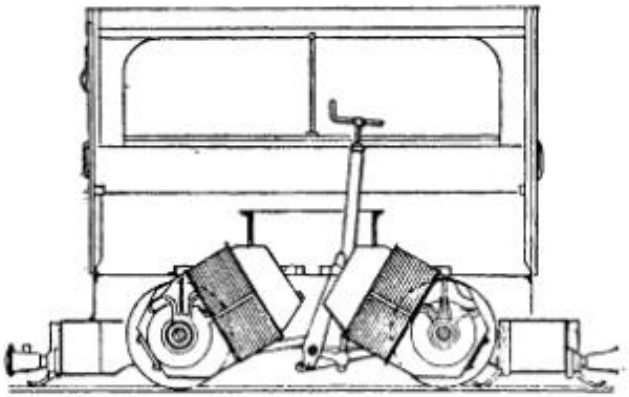
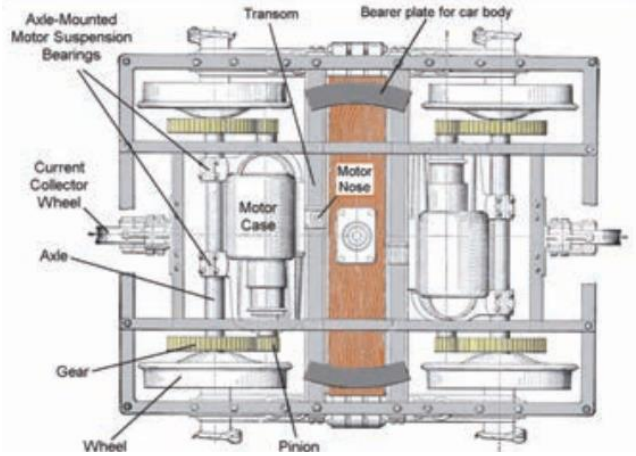


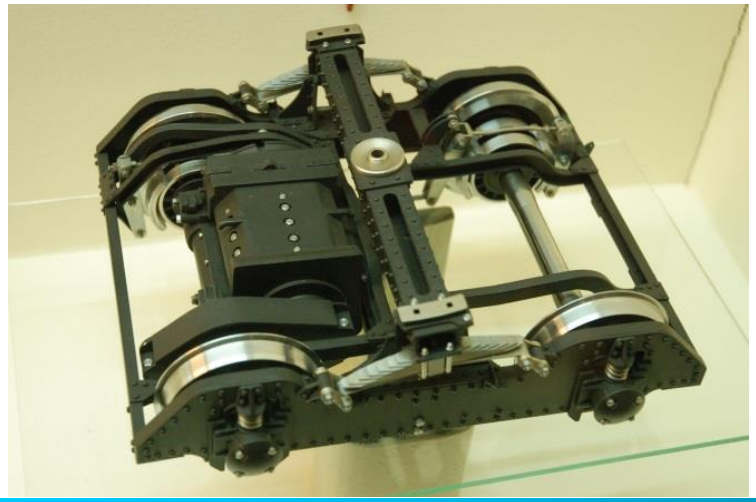
FIG. 3. Longitudinal section of the locomotive built for the City and South London Railway, 1887–1890. (Dunsheath, *A History of Electrical Engineering*)



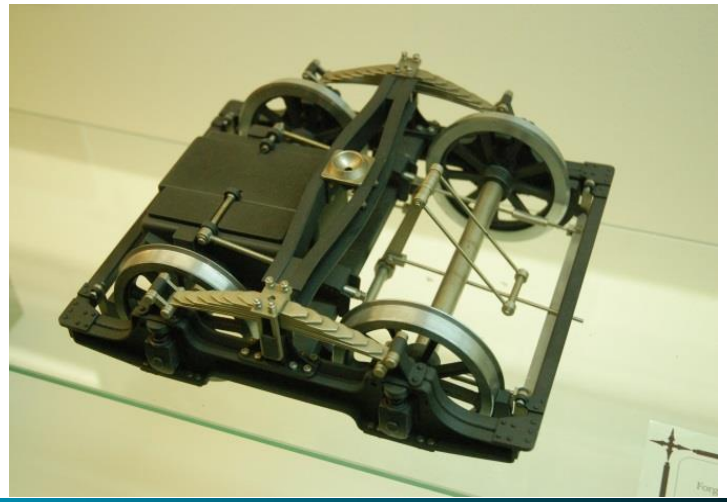
Bogies and producers

- 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

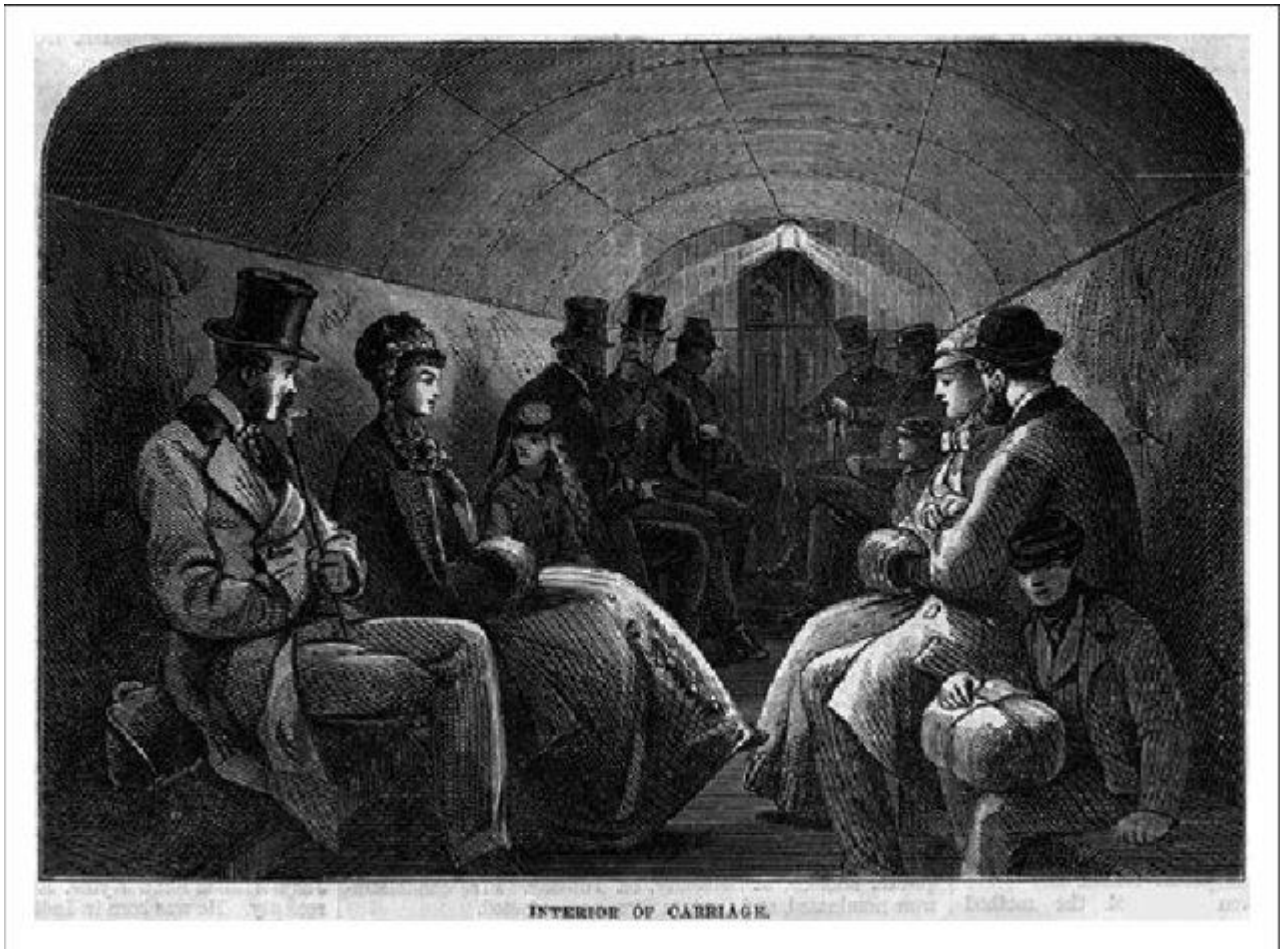


Electric lighting

- 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

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



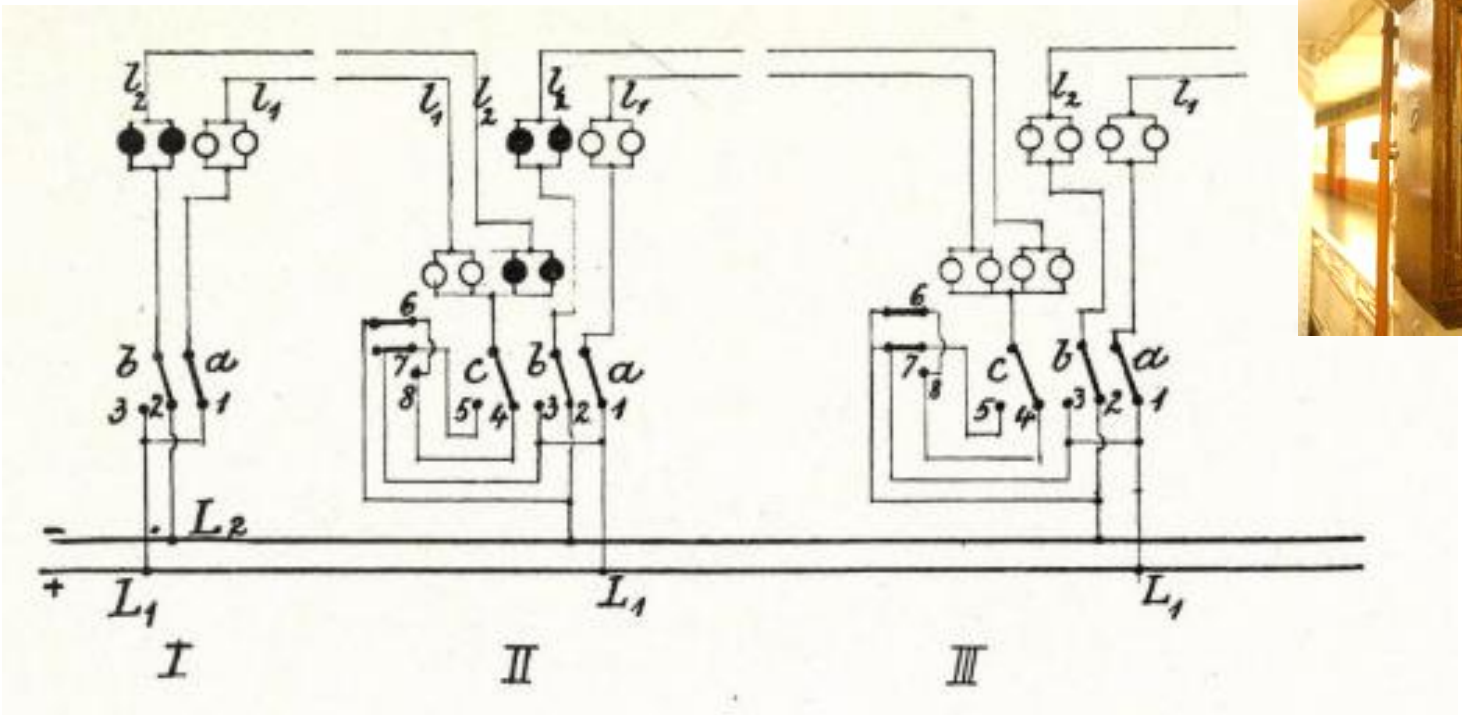
Electric lighting

- 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

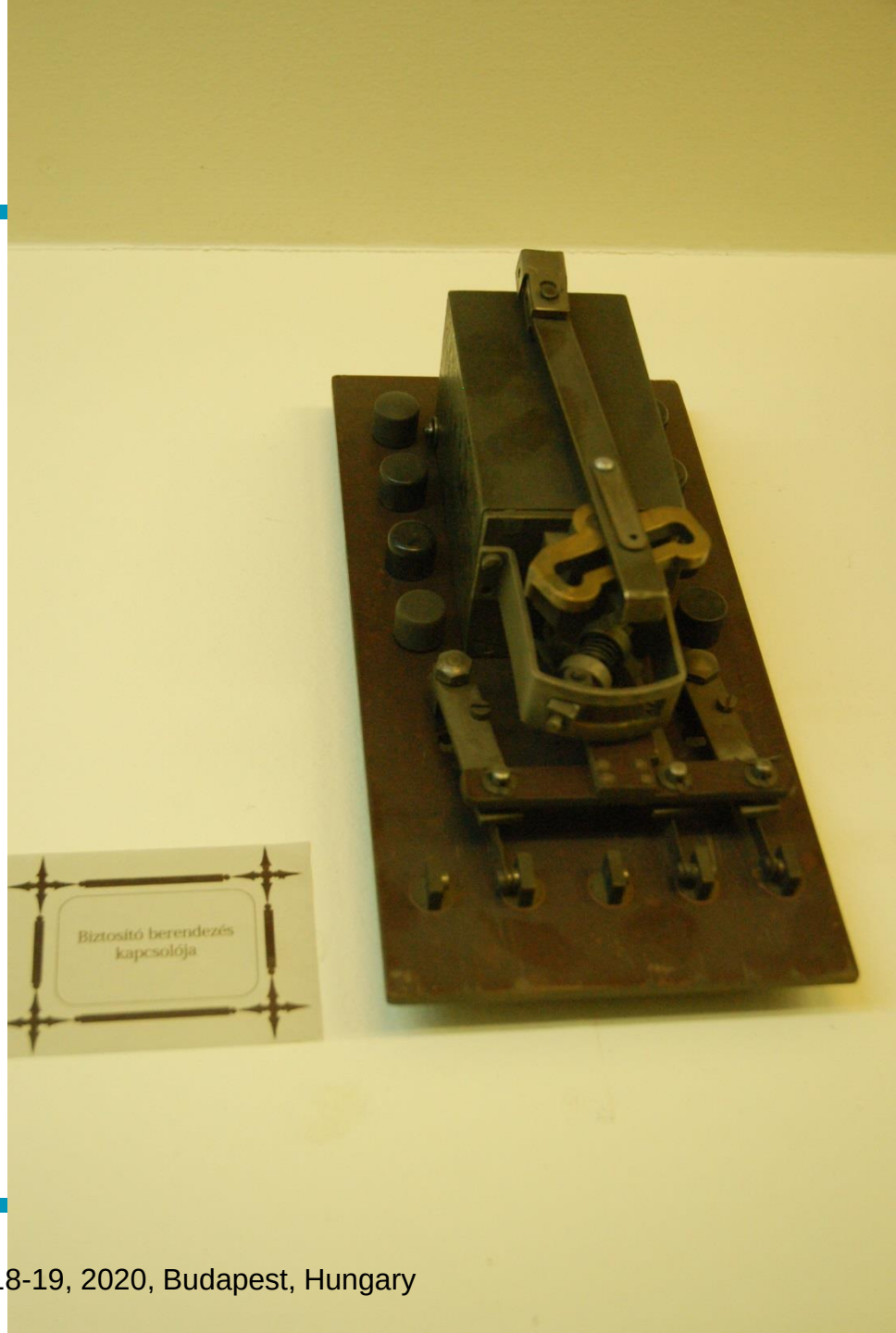
- One of the most important topics in rail traffic systems is safety. Having no previous experience with underground safety systems the Siemens-Halske company applied its most modern “surface” light signaling system. When a carriage left the station the pilot set the light red by a mechanical switch. 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

- 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

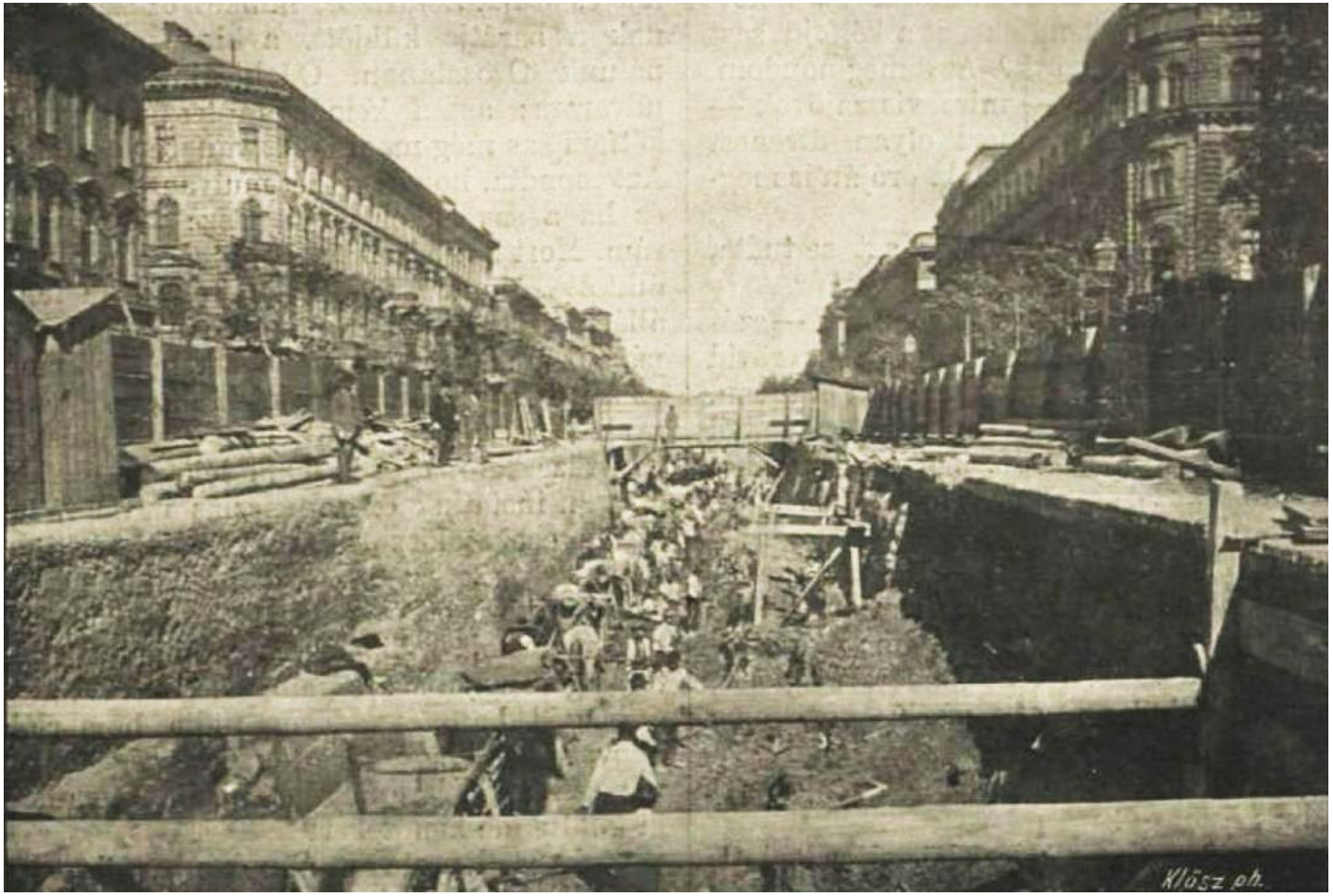
Cut-and-cover technology

- 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

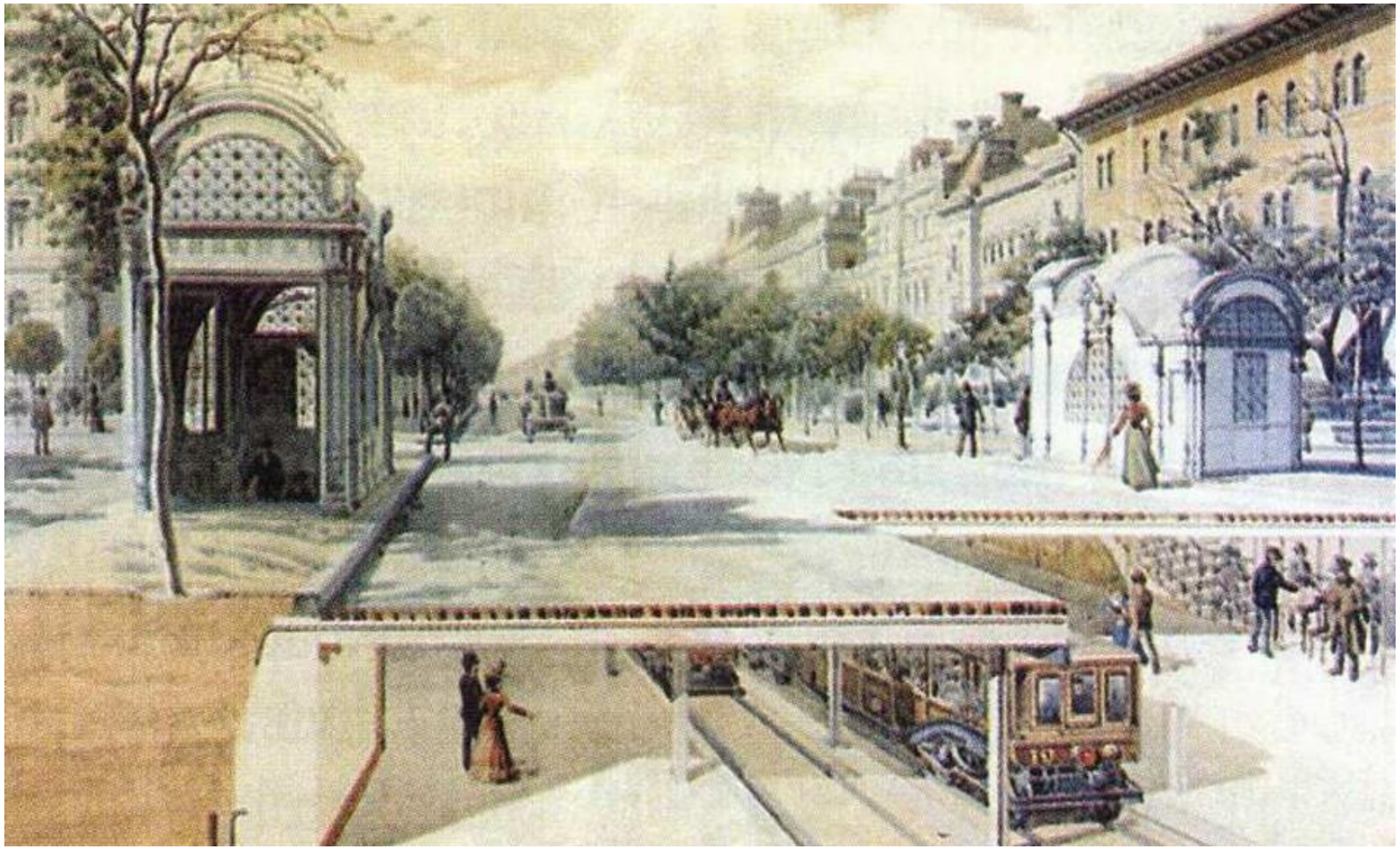
- London, Metropolitan Line, 1863

Cut-and-cover, Budapest



Cut-and-cover, Budapest

Cut-and-cover, Budapest

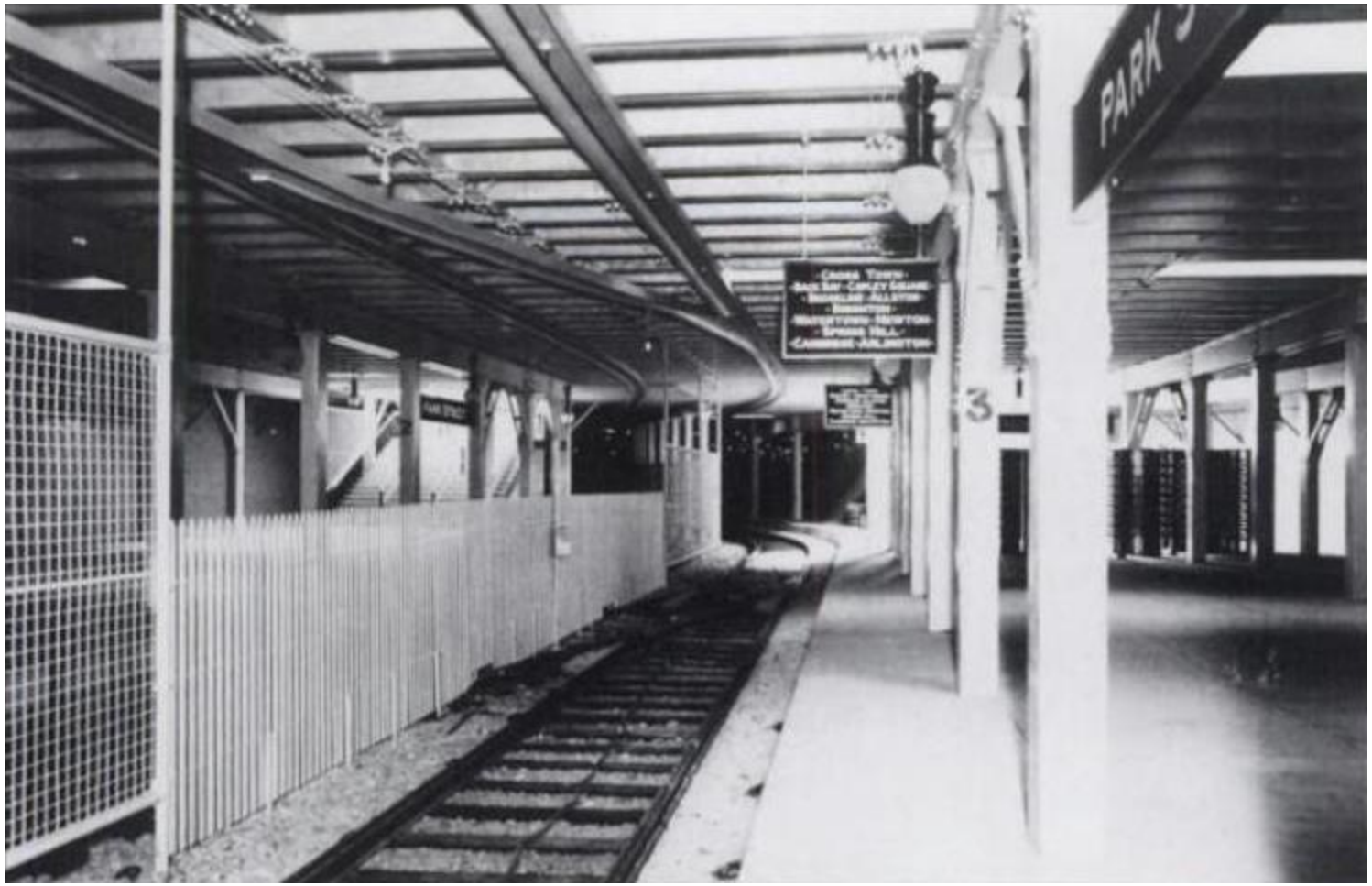


A new standard

- 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
- Looking at figures 16-20 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

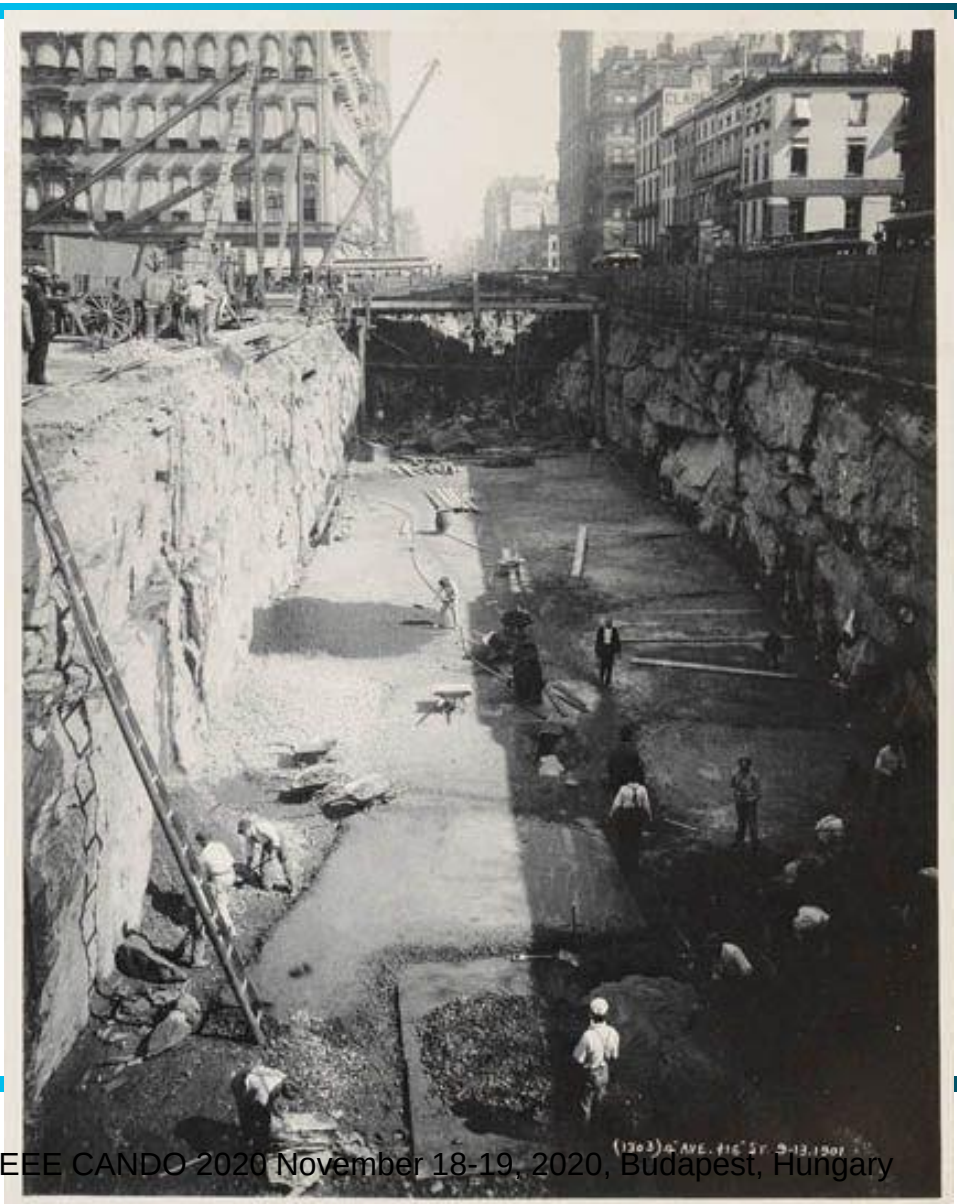
Pattern for Boston, 1897



Cut-and-cover, Paris

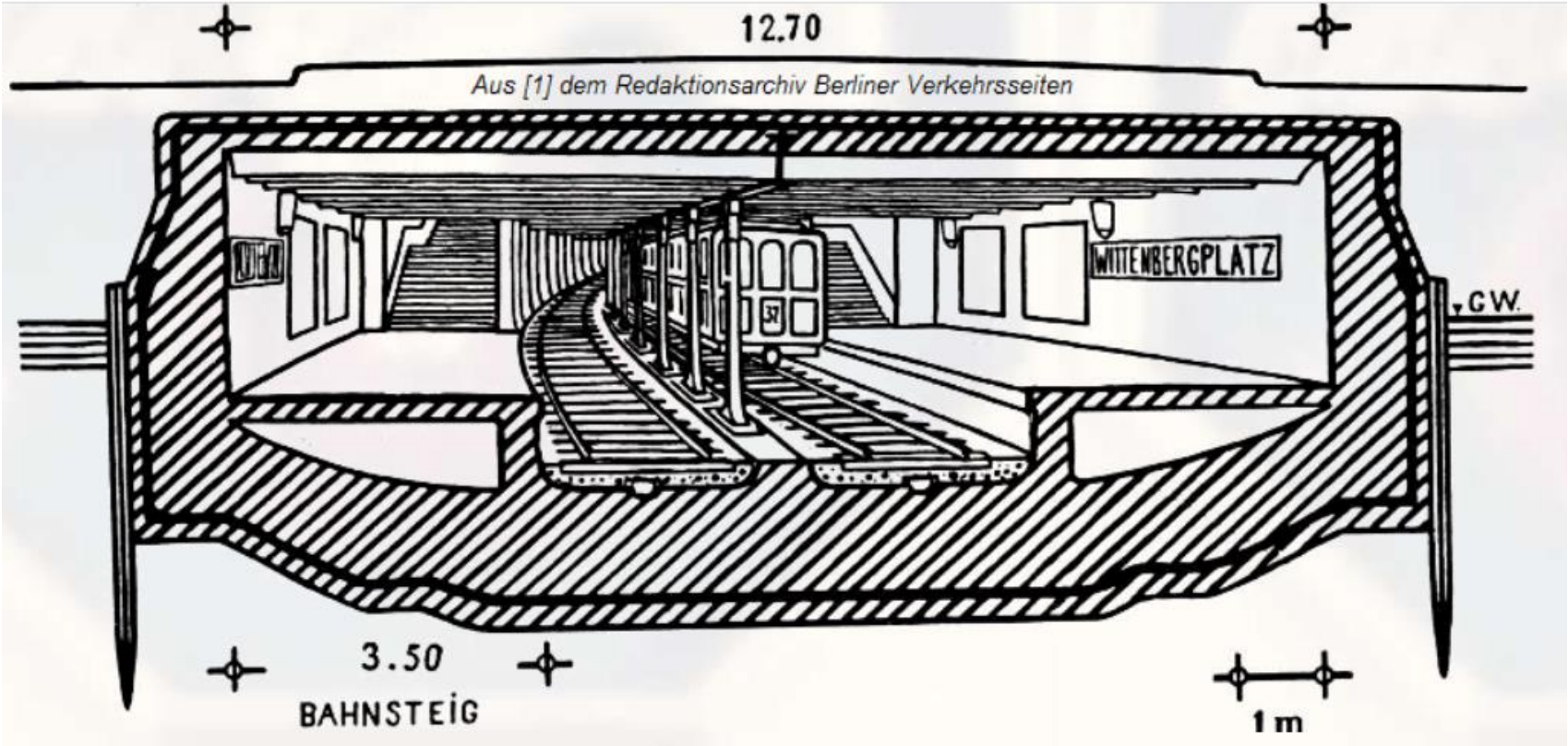
Pattern for Paris, 1900

Cut-and-cover, New-York



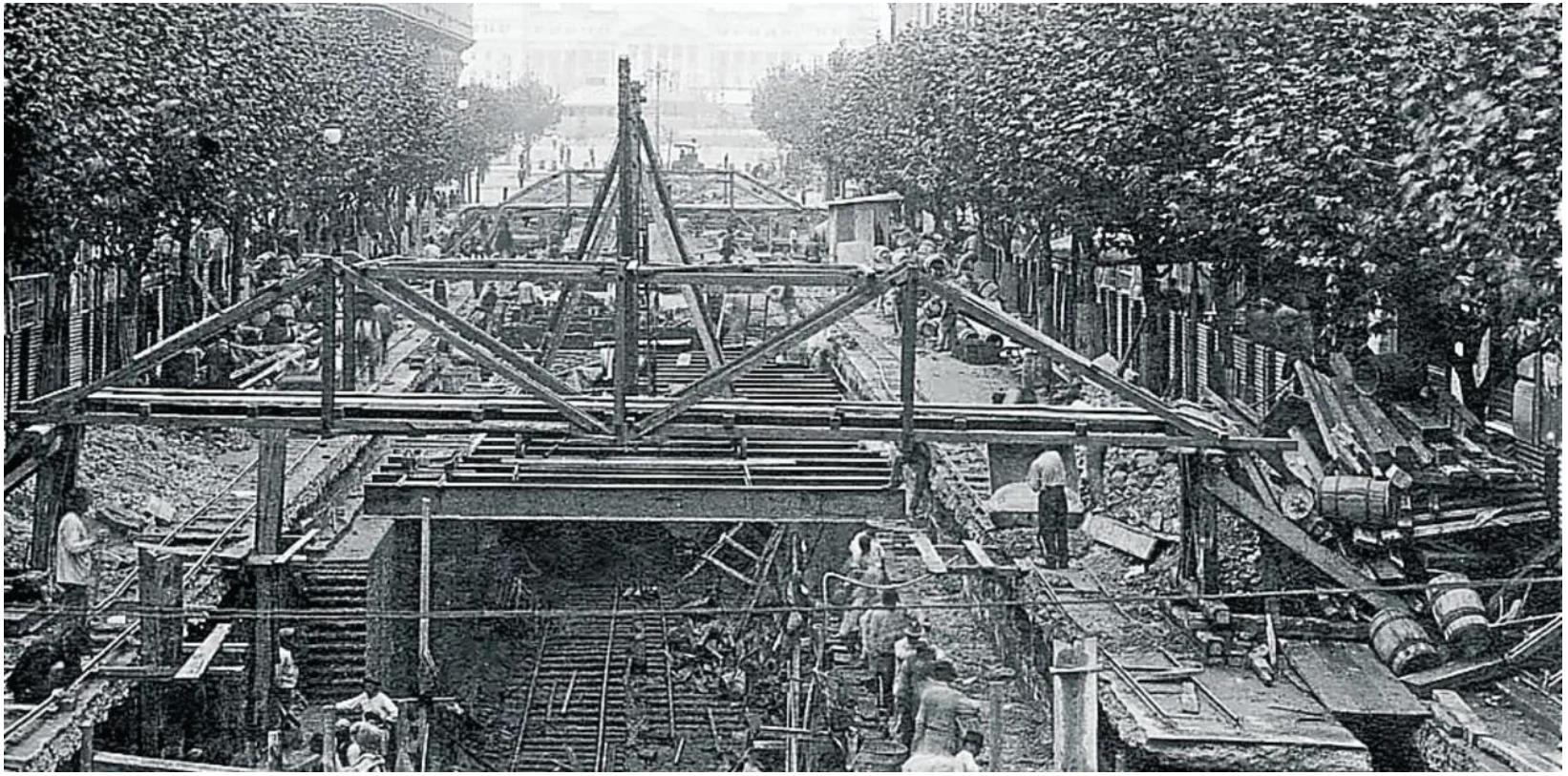
Pattern for New York, 1904

Cut-and-cover, Berlin



Pattern for Berlin, 1906

Cut-and-cover, Buenos Aires



Pattern for Buenos Aires, 1913

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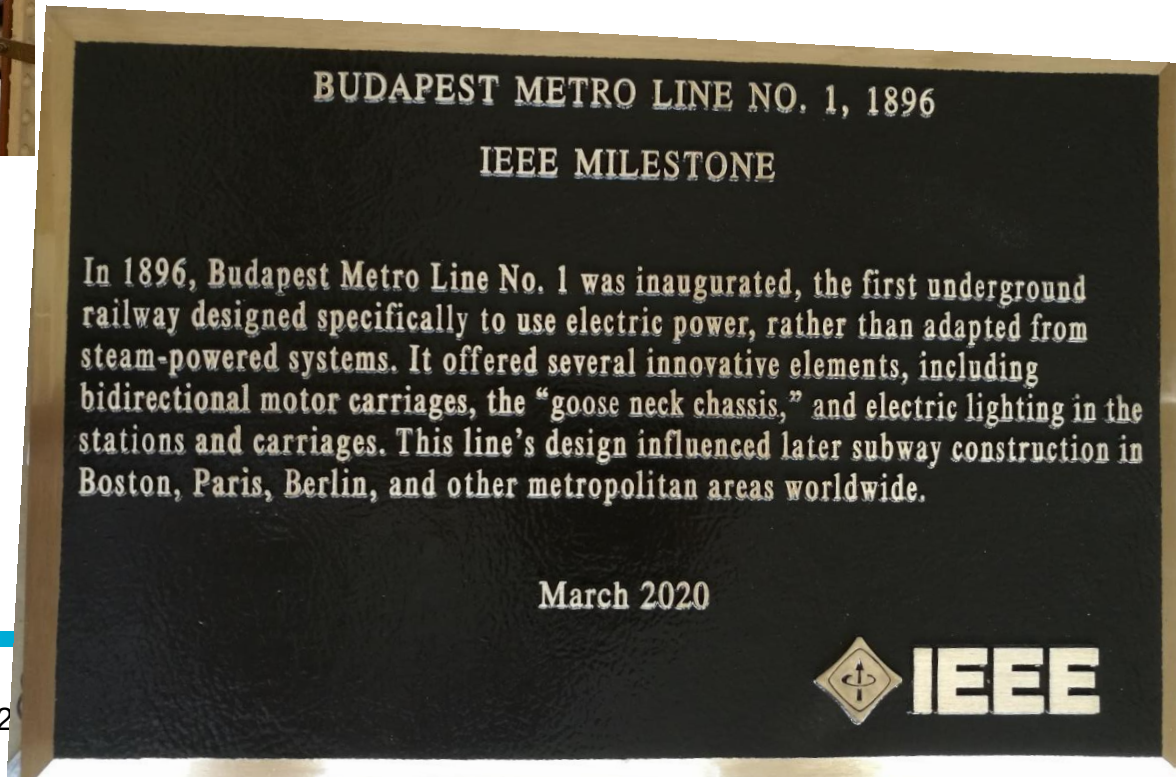
Conclusion

- 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 years of operation demonstrated that the dozens of innovation helped to develop something new, something enduring and also something aesthetic for centuries.***

The first IEEE Milestone in Hungary

The Milestone plaque will be displayed at the entrance of the first station, which is the site of the Budapest Underground Railway Museum. The plaque reads:



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Thanks for your attention!