



The Copenhagen Metro – with a view on Environmental Challenges

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COWI Denmark**



Contents

- History of the Metro in Copenhagen
- Cityringen Metro Project
- Environmental Challenges and Risk Mitigation Solutions
- Looking Ahead



The Bridge between Denmark and Sweden – Parliamentary law of 1991

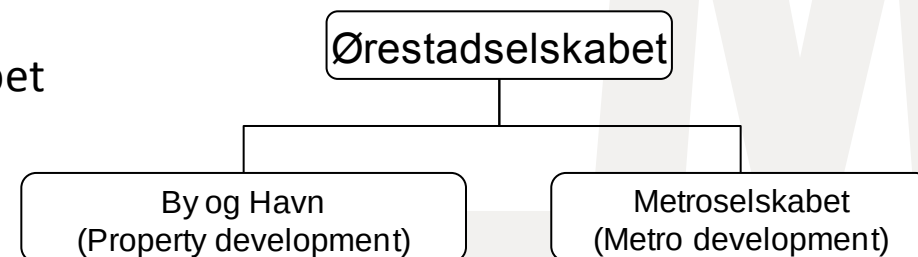
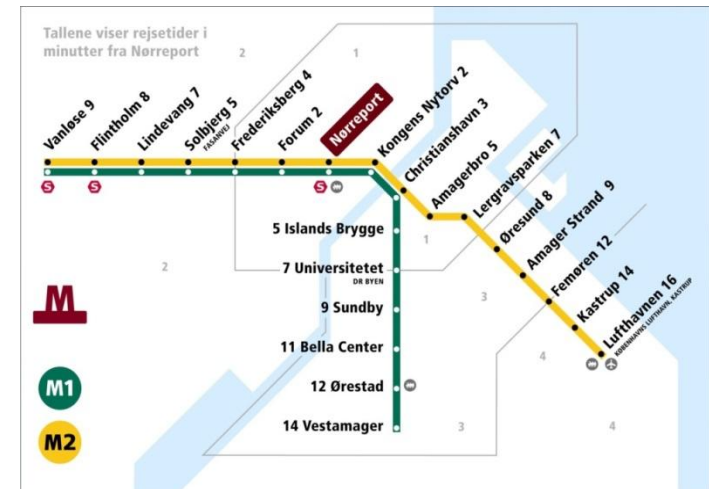




A brief history of mass transit in Copenhagen

- 1993 Ørestadsselskabet
- 1994 System choice
- 1996 Main contracts
- 2002 Phase 1 -
Metro opens to Ørestad
- 2003 Phase 2
Frederiksbergs Railway opens
- 2007 Phase 3
Metro line to airport opens
Law on Cityring and Metroselskabet founded
- 2011 Cityringen construction starts
- 2019 Planned operation of Cityringen

Current metro lines





Metroselskabet I/S - Ownership

50%

Copenhagen Municipality

41,7%

Danish State

8,3%

Frederiksberg Municipality

Tasks: Operate existing Metro and construct Cityringen

Organisation: 300 employees (Administration, Operation, Construction)



Financing principles

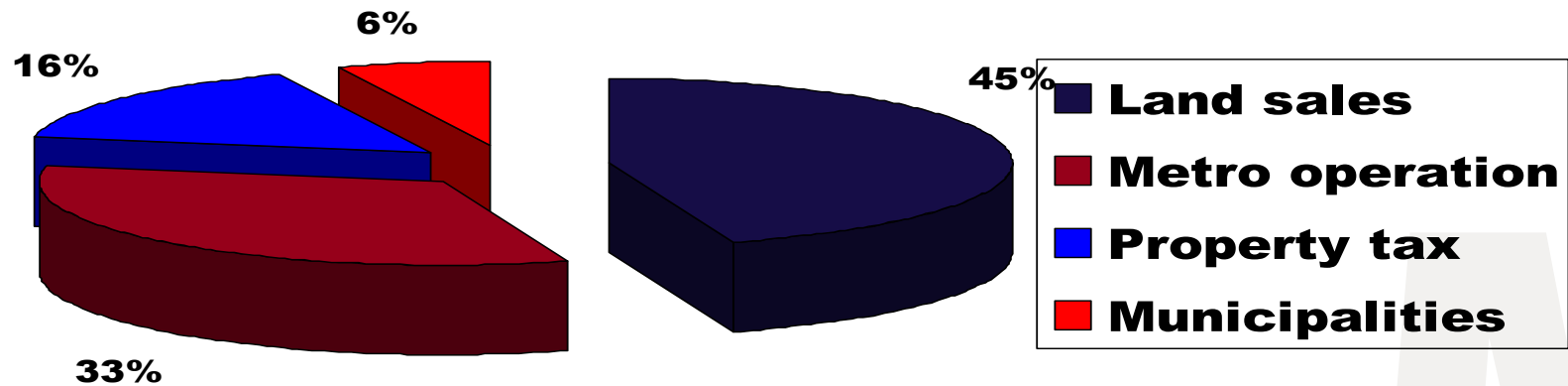
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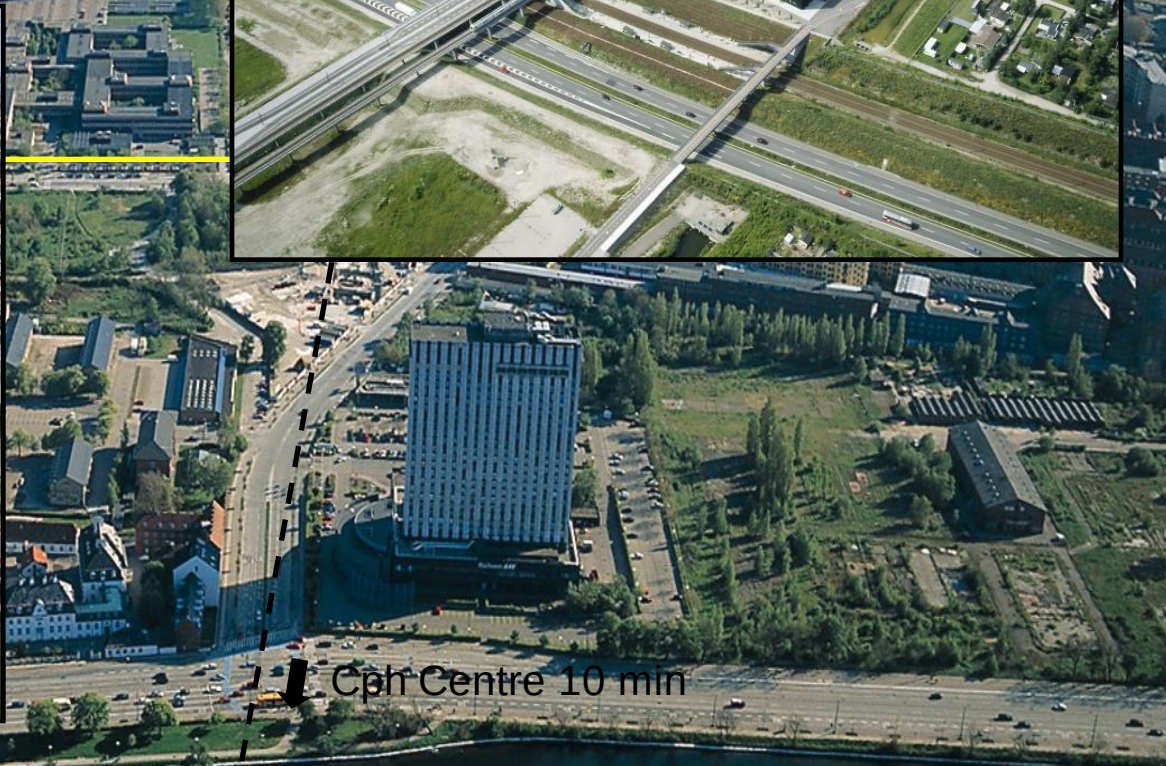
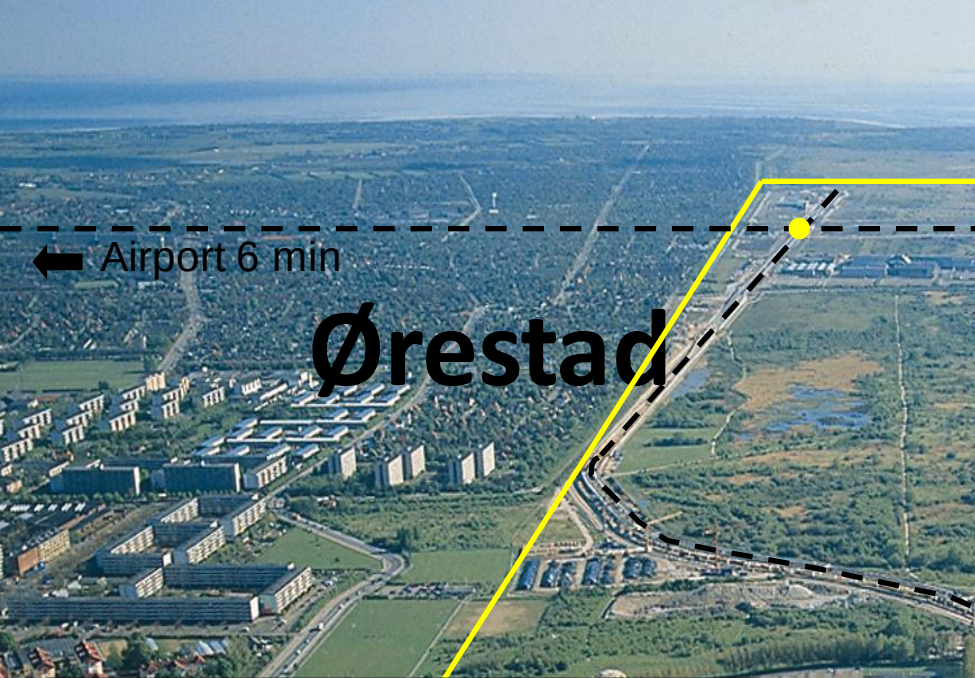
- Undeveloped land given as assets to Metro Development Company
- Take up loans
- Build the Metro
- The Metro raise value of land
- Develop and sell the land
- Pay back loans





Project Funding: The Newtown Principle







2010.06.19

10

Ørestad



Malmø

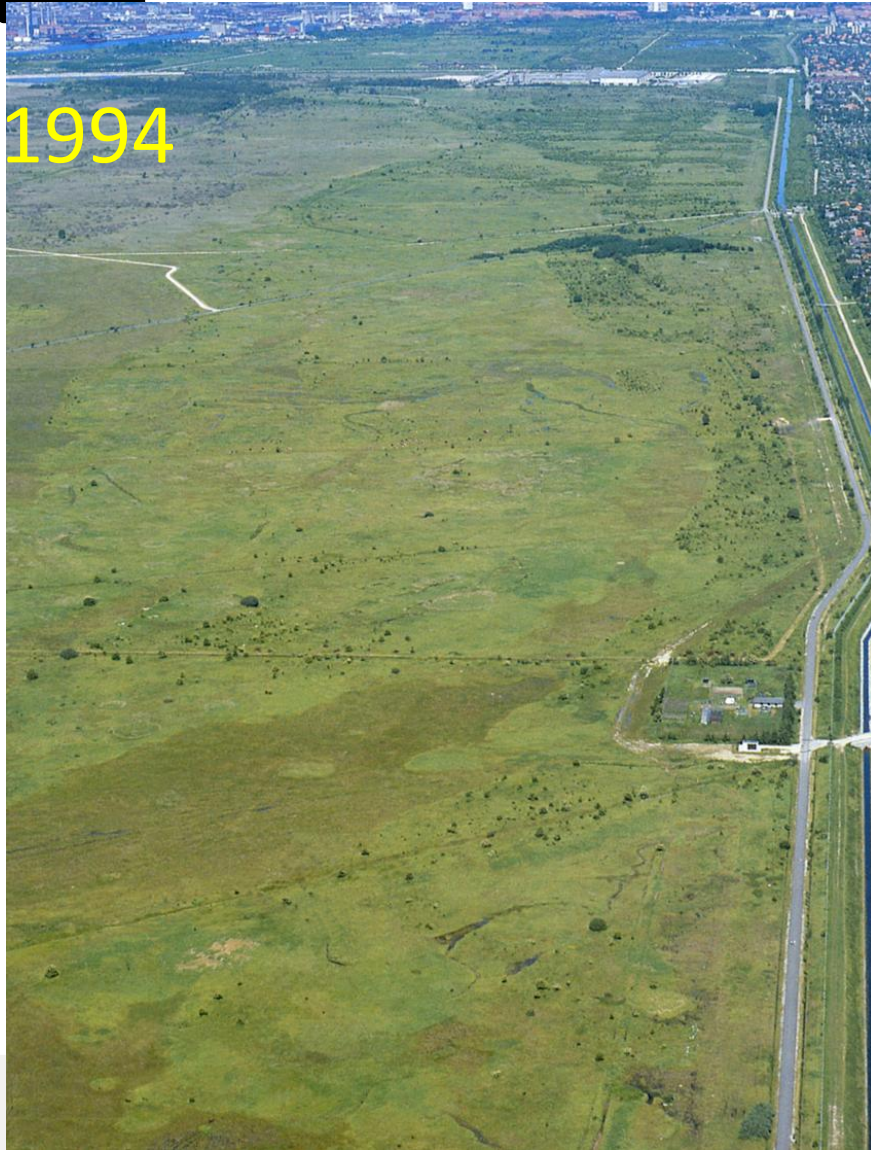
Airport

City Centre

Main Railw St

M From Vision to Development

1994



2002





After Metro construction





- History of the Metro in Copenhagen
- **Cityringen Project**
- Challenges and Risk Mitigation Solutions
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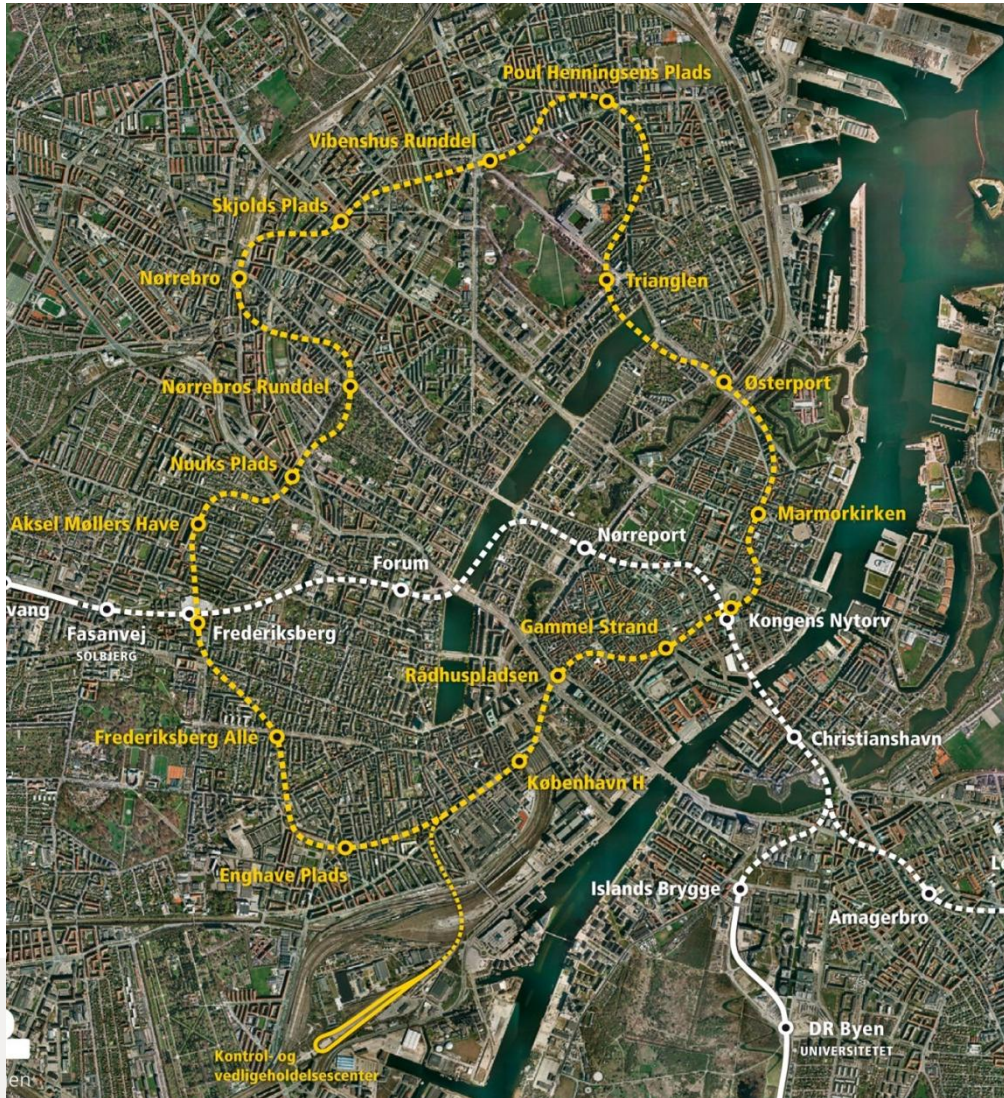


Cityringen

Copenhagen Metro
- - - Existing Metro
- - - New Circle Line

Central Copenhagen:
600.000 inhabitants
Greater Copenhagen
1,5 mil. inhabitants

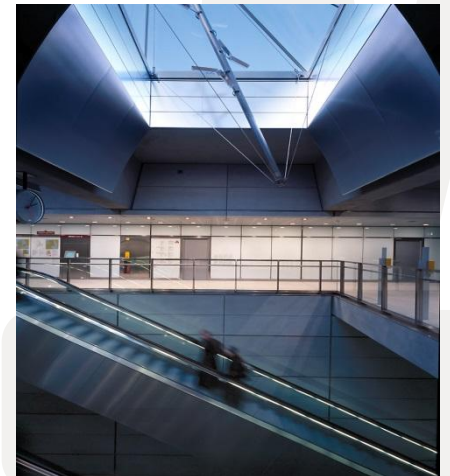
Medieval city centre with
houses from 17th century





Cityringen Mission – “more of the same”

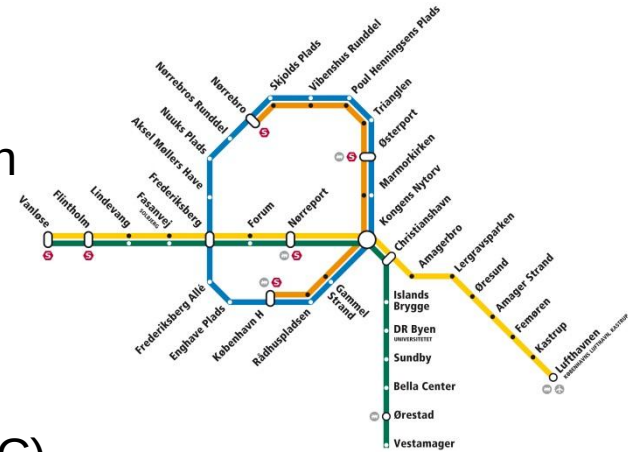
- **Lightweight, fully-automated driverless metro system with high level of reliability >98%**
- 24/7 operation with frequent service during peak hours, meeting highest standards of passenger comfort and safety
- High level of customer service - and passenger information
- **Strong architectural identity with close links to other means of transportation**
- Least possible environmental impact during construction, operational sustainability, energy efficient, with low life cycle cost
- High quality working environment for staff





Cityringen Facts

- 2 single track tunnels each approx. 17 km in length
- 17 underground stations
- 4 crossover facilities
- 3 construction- and ventilation shafts
- Automated Control- and Maintenance Centre (CMC)
- Civil Works Contract value approx. 1,6 billion Euro
- Transportation Services Contract value approx. 700 million Euro (incl. 5 years maintenance)





Cityringen – Passenger Prognosis

- 75 mill. passengers per year
- 240.000 passengers in the system per weekday
- Copenhagen Central Kh: 41.000 / weekday (boarding)
- Kongens Nytorv Kgn: 36.000 / weekday (boarding)

Existing Metro - Passenger

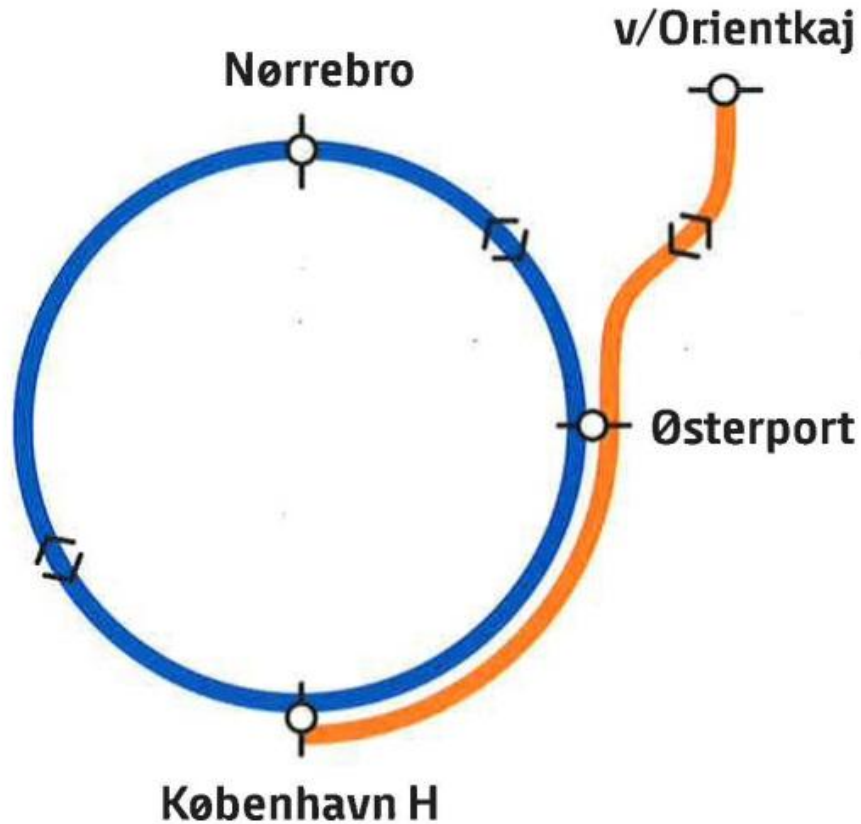
- 50 mill. passengers per year

Total Metro – Passenger

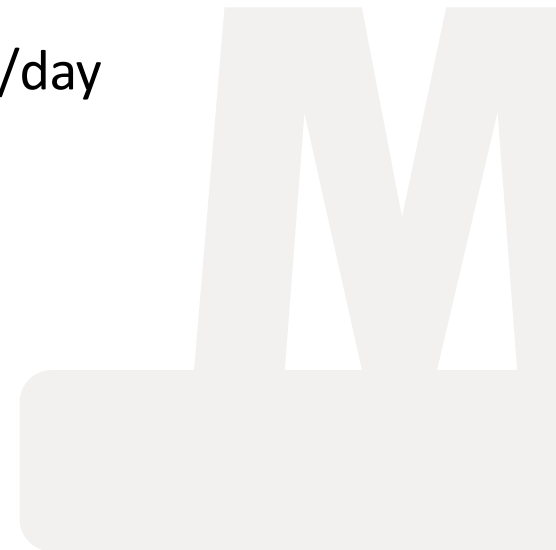
- 125 mill. passengers per year (from 2019)



Planned Operation



- 24/7 Operation
- Combined circle and pendulum operation
- 150/200 sec headway in rush hour
- 240,000 pass./day





Cityringen - Current Status

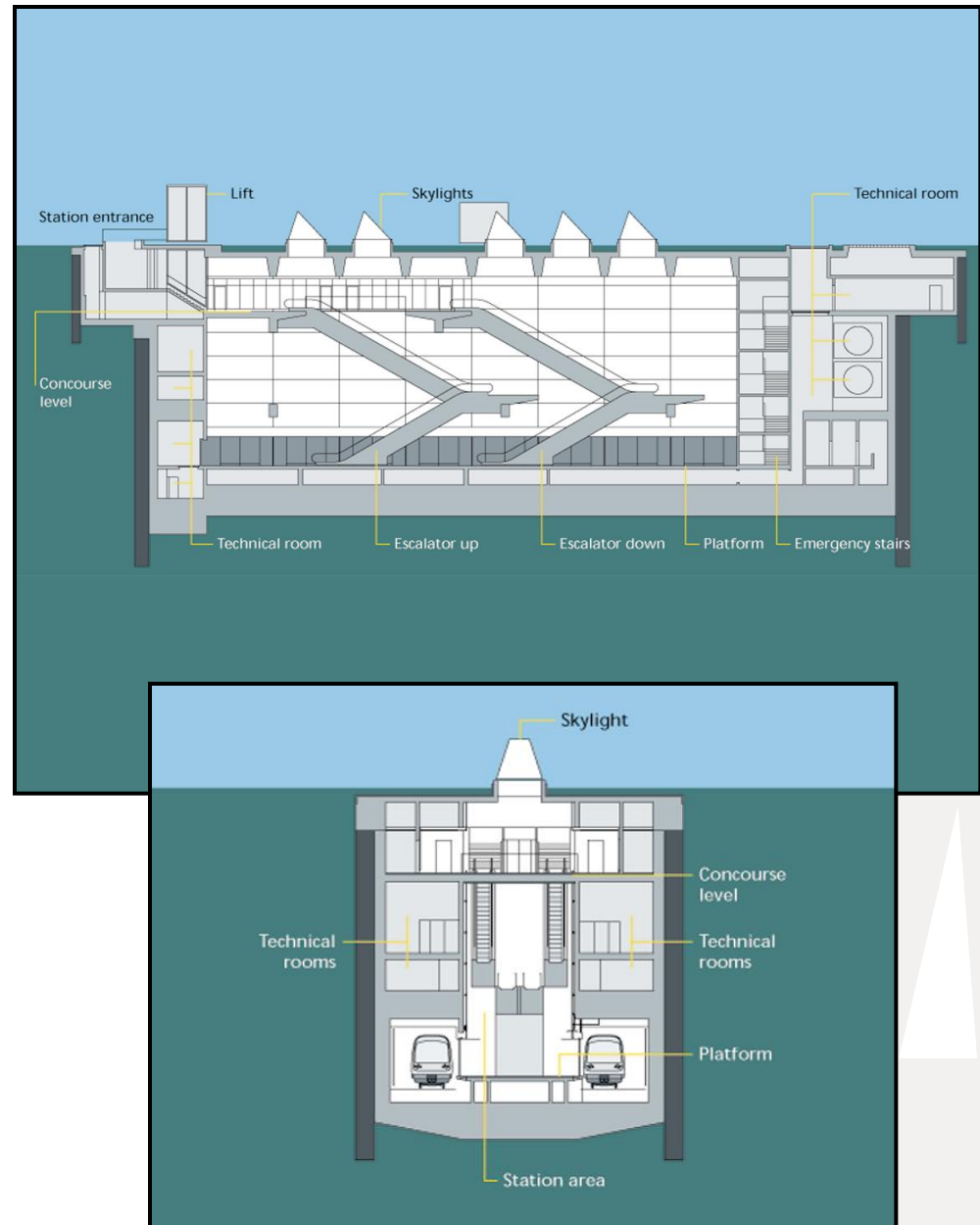
- Contract Award January 2011
- Design and Construct Contracts
- Civil Works Contract with Copenhagen Metro Team
- Joint Venture of Salini, Seli, Tecnimont of Italy
- Transportation System Contract including 5 years Operation and Maintenance with Ansaldo of Italy'
- Works start 2011, completion 2019





Underground Stations

- Daylight to platform level
- Minimalistic design
- Open space
passengers can feel safe
- Island platform
- Platform screen doors
- Water tight structures



M Short Station Designs fit into small spaces



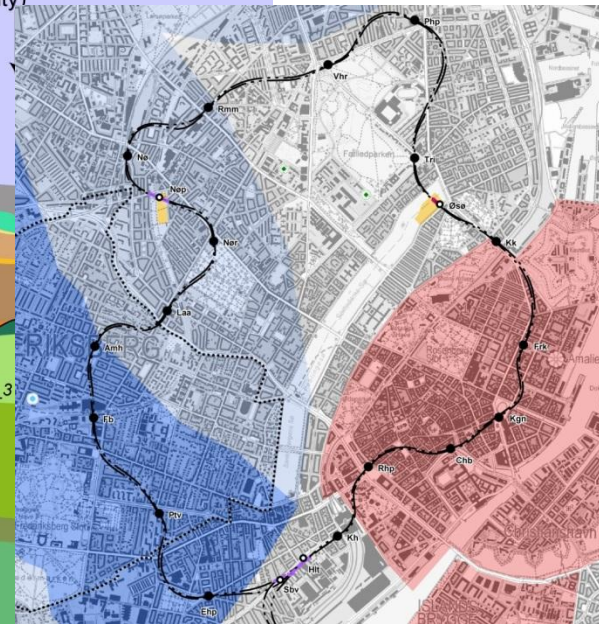
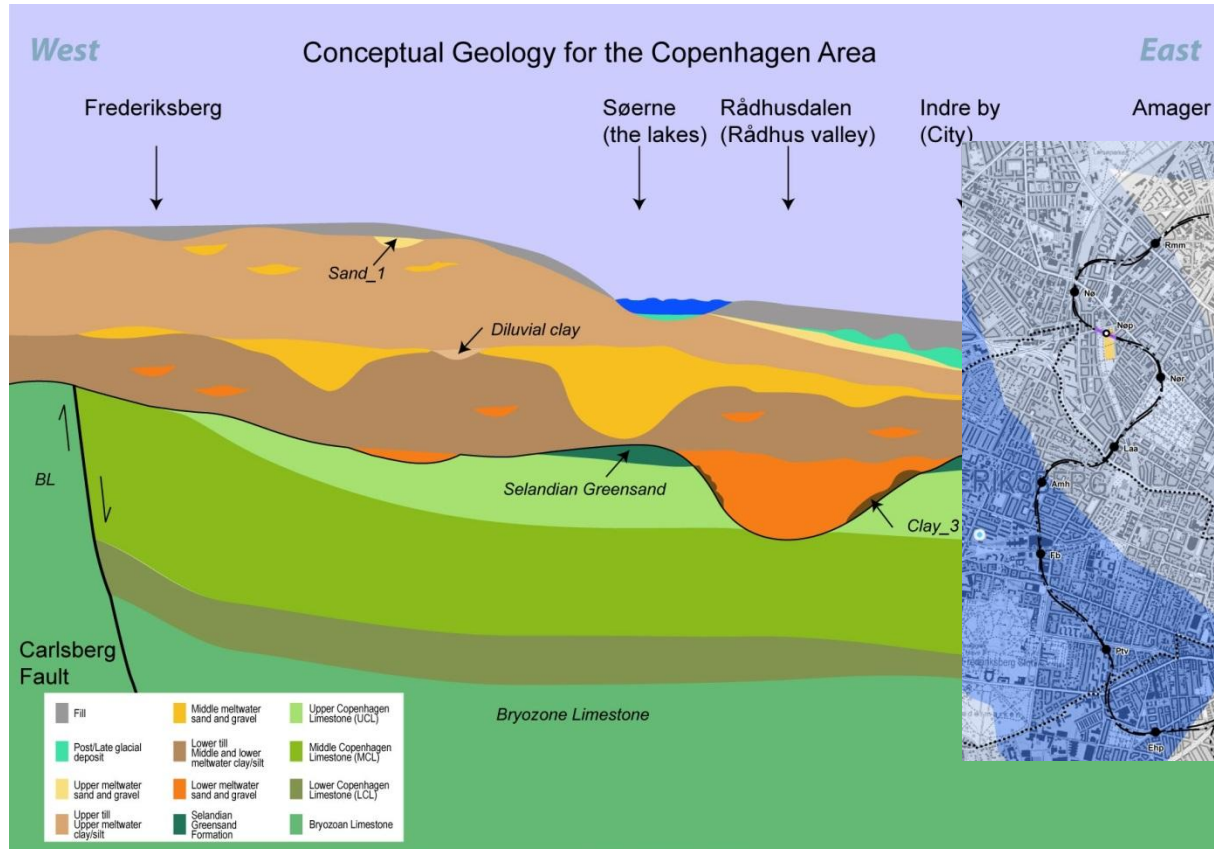


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- **Environmental Challenges and Risk Mitigation Solutions**
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Geology





Construction Focus Areas

Secant Piling



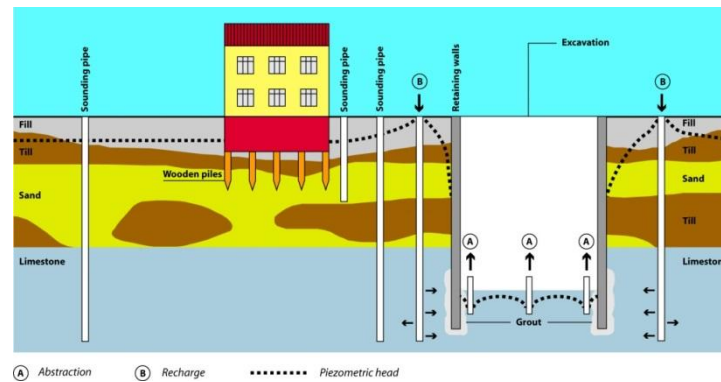
Tunnelling



Diaphragm Walling

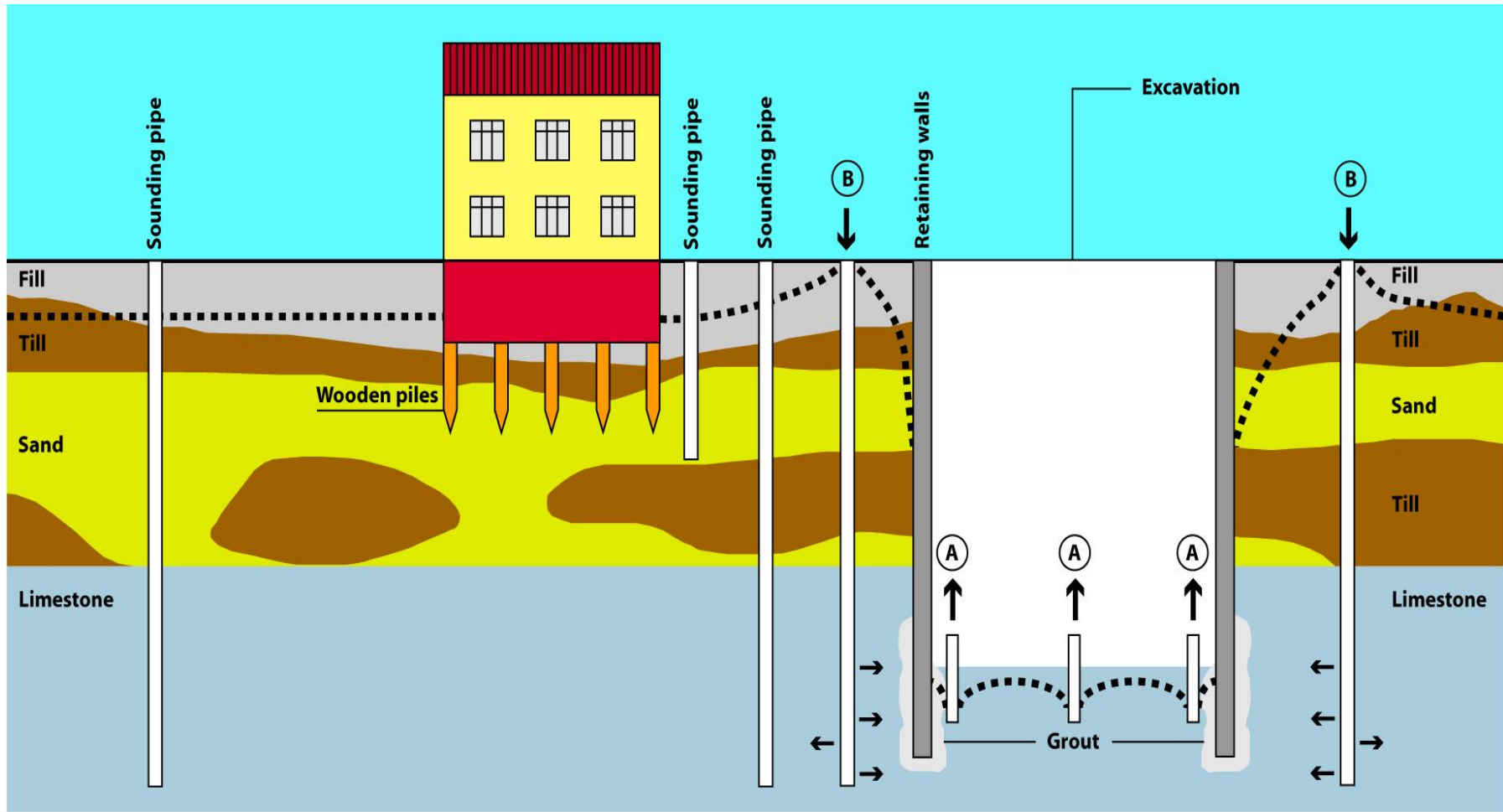


Groundwater Control





Groundwater Control for open excavations

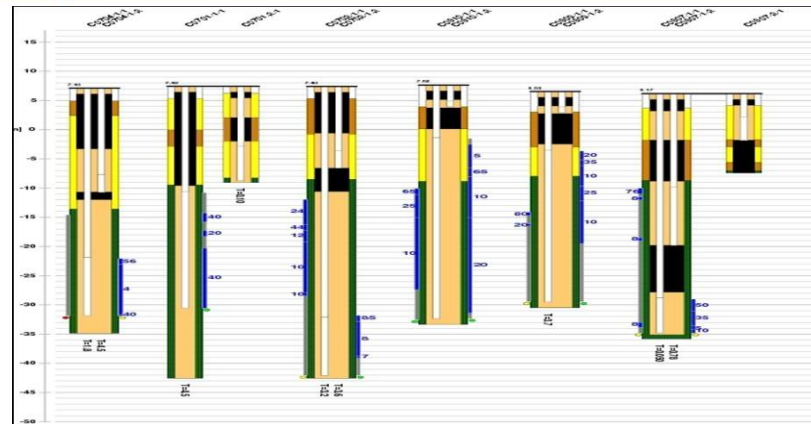


(A) Abstraction

(B) Recharge

..... Piezometric head

Groundwater flow in limestone



MWater treatment before recharge

Treatment of abstracted groundwater before recharge:

- Necessary to avoid clogging of recharge wells
- Aeration and sand filtering removes iron and manganese
- When suspended limestone: Sedimentation, using flocculants if necessary
- If contaminants: Carbon filter



Water treatment, sedimentation





Water treatment, sand filters





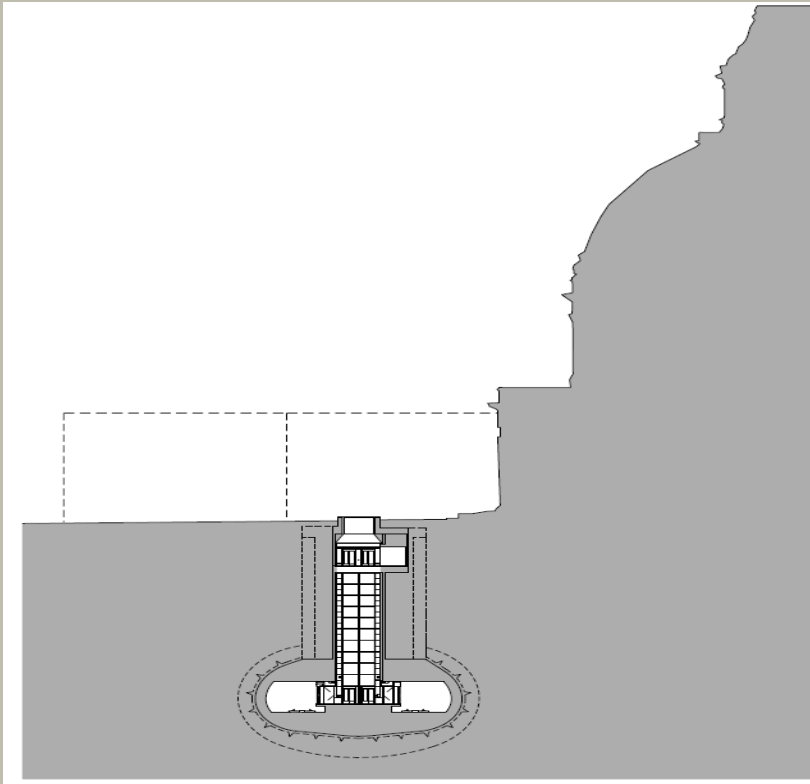
Marmorkirken Special Station Risk Mitigation Measures



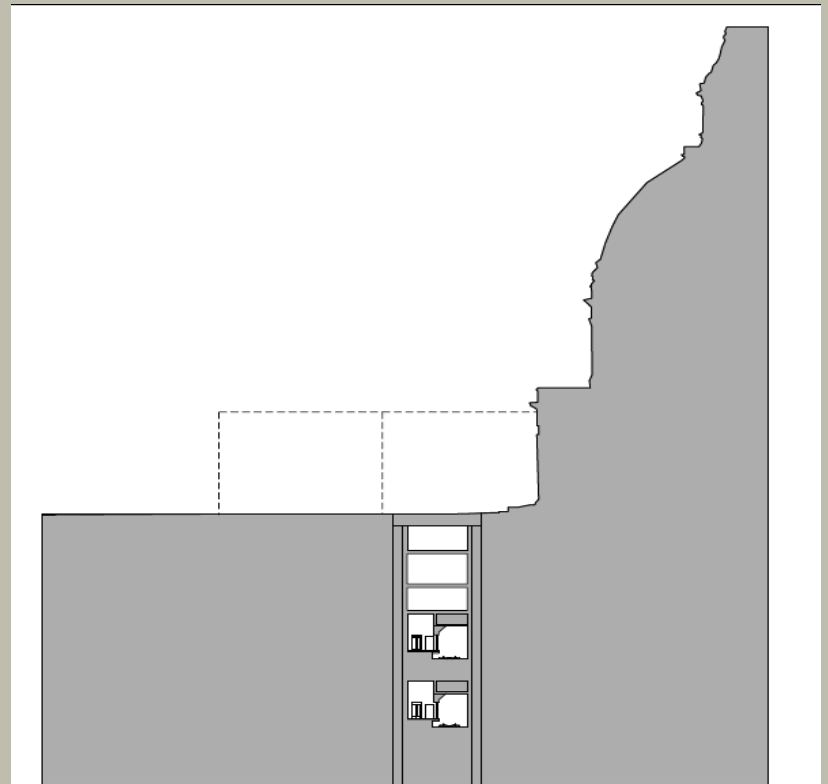


Marmorkirken

In Tender Document

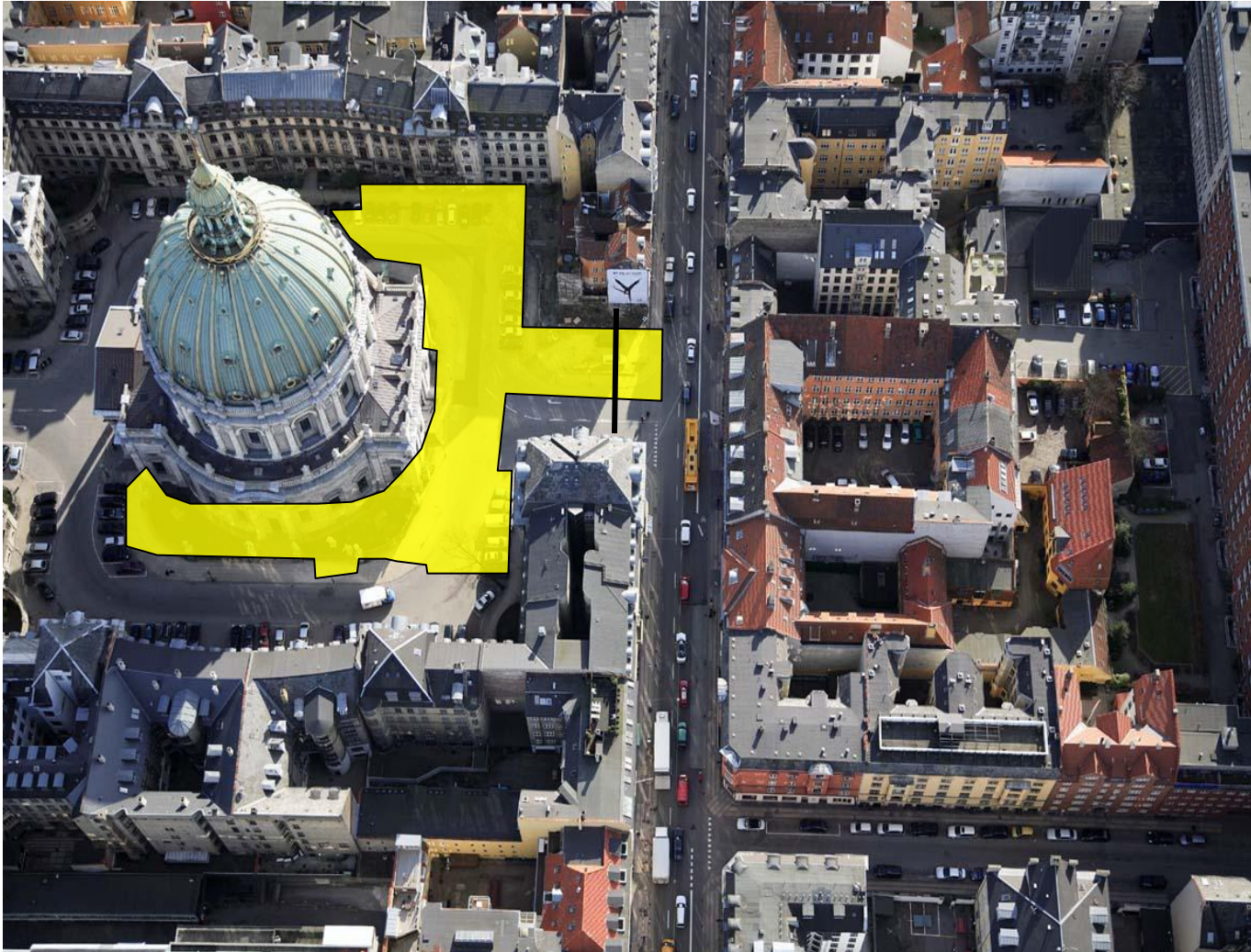


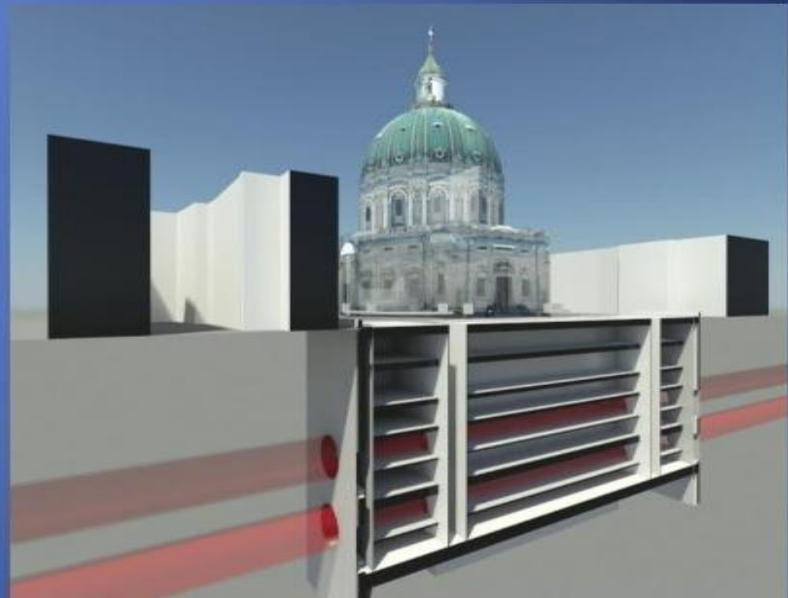
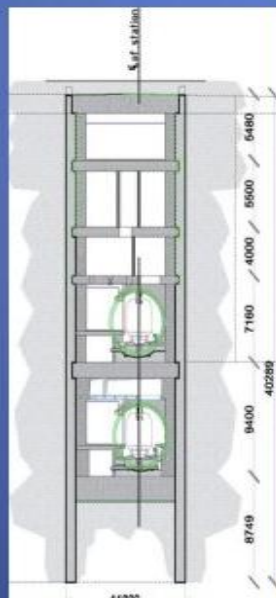
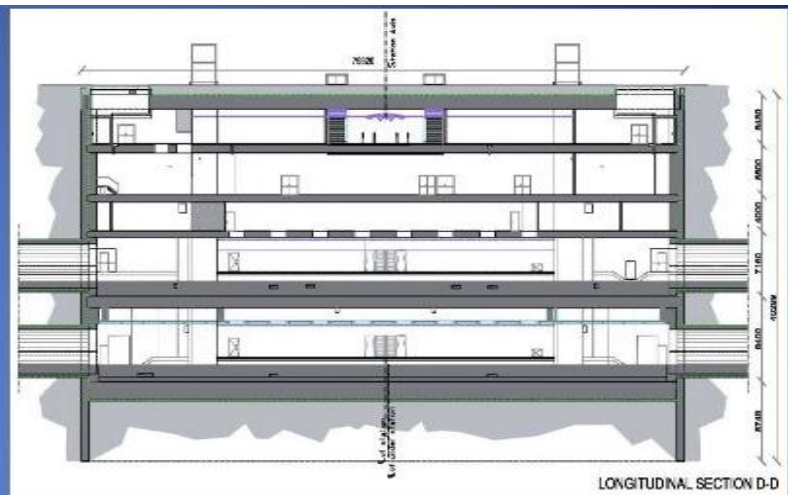
After risk engineering





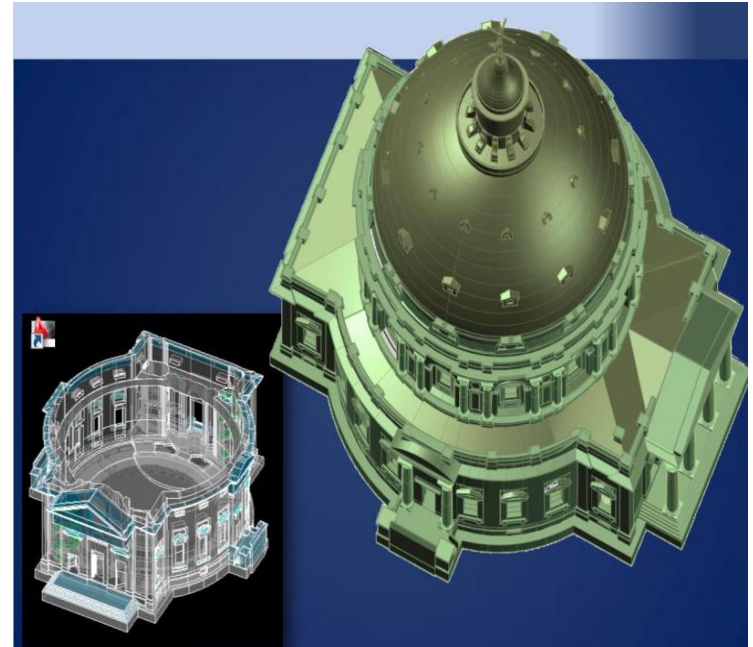
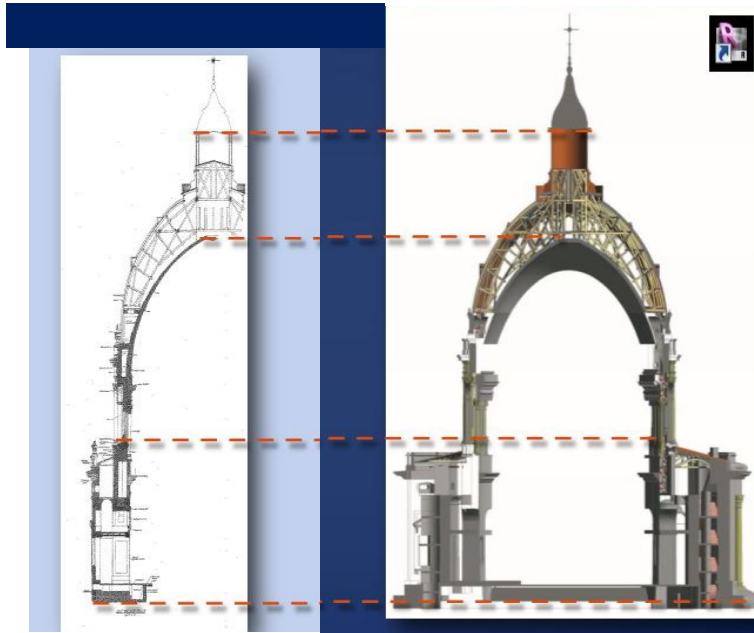
Marmorkirken Special Station







Marmorkirken – 3D Model



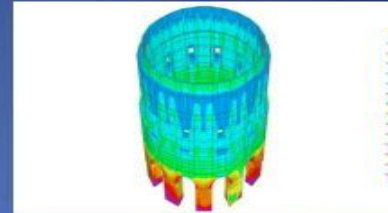
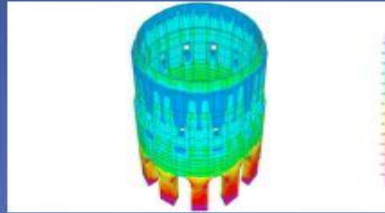


STRUCTURAL RESULTS

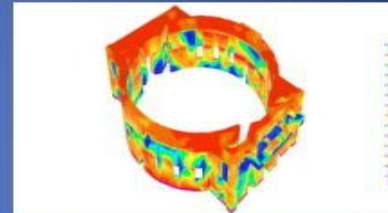
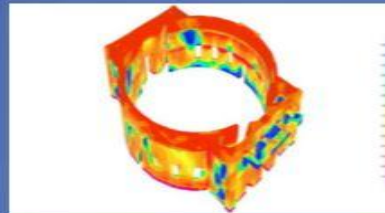
BEFORE STATION CONSTRUCTION

AFTER STATION CONSTRUCTION

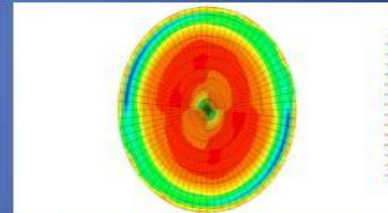
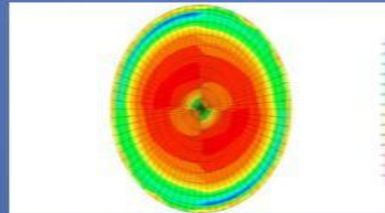
- INNER STRUCTURE



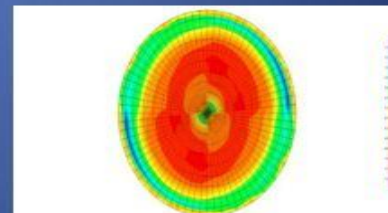
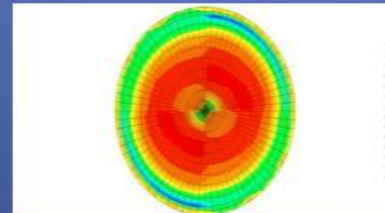
- OUTER STRUCTURE



- DOME TOP

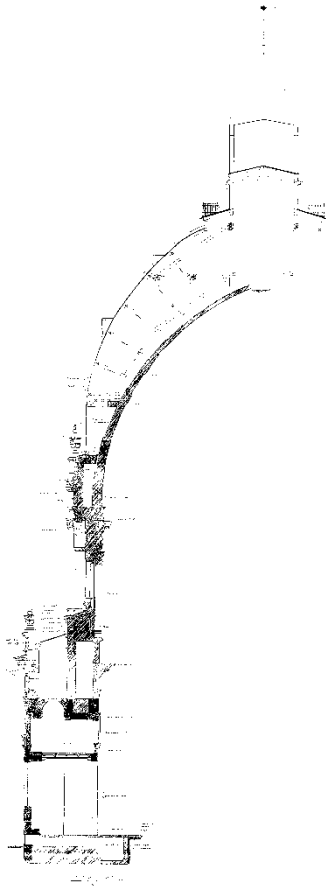


- DOME BOTTOM





Marmorkirken – Registration and Collection of Data







Marmorkirken Station Finished Design





Cityringen TBMs

4 Earth Pressure Balance (EPB)

Machines

5.78m Diameter cutterhead

110m Long

~700t

Max boring speed 80mm/min

Average approx 40mm/min



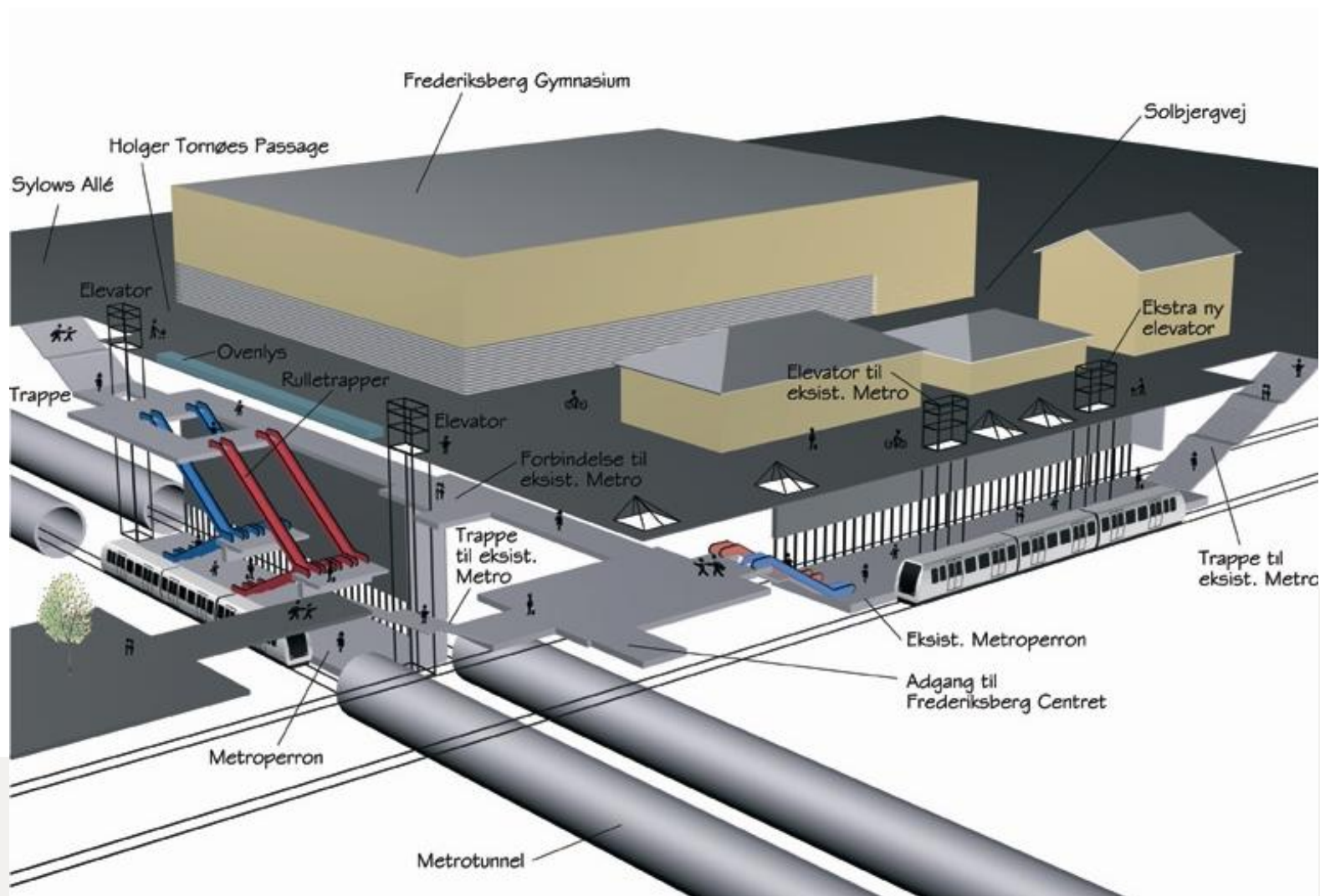


TBM Passage through station



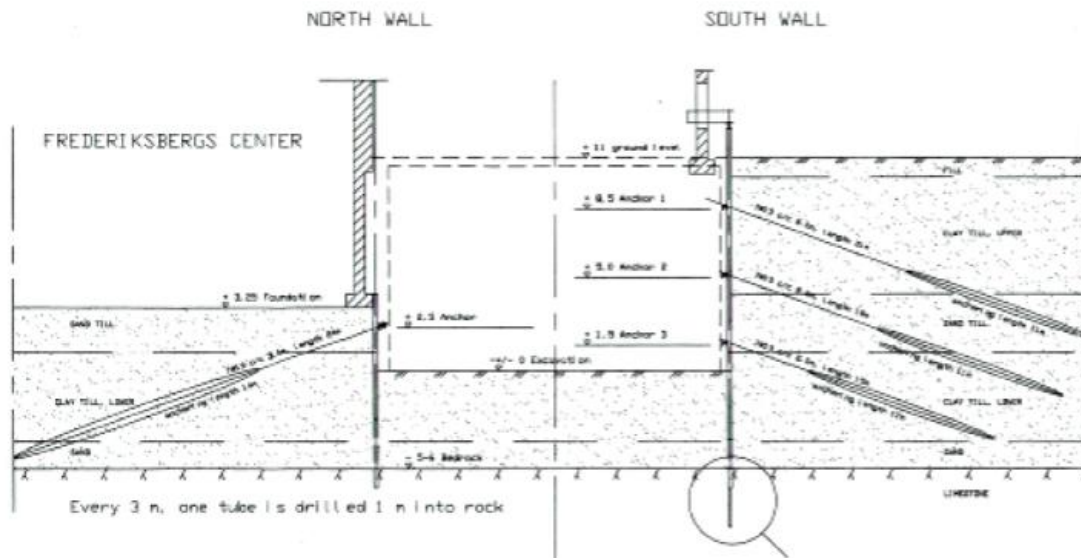


Frederiksberg station





Frederiksberg station AS-BUILT detail for previous station works



SPECIFICATIONS

BBK 94 and BSK 94 (BKR94), SWEDEN.
EC7, eurocode

MATERIAL

SEE DRAWING NO K500-20 and -21

INCLINATION OF ANCHORS:

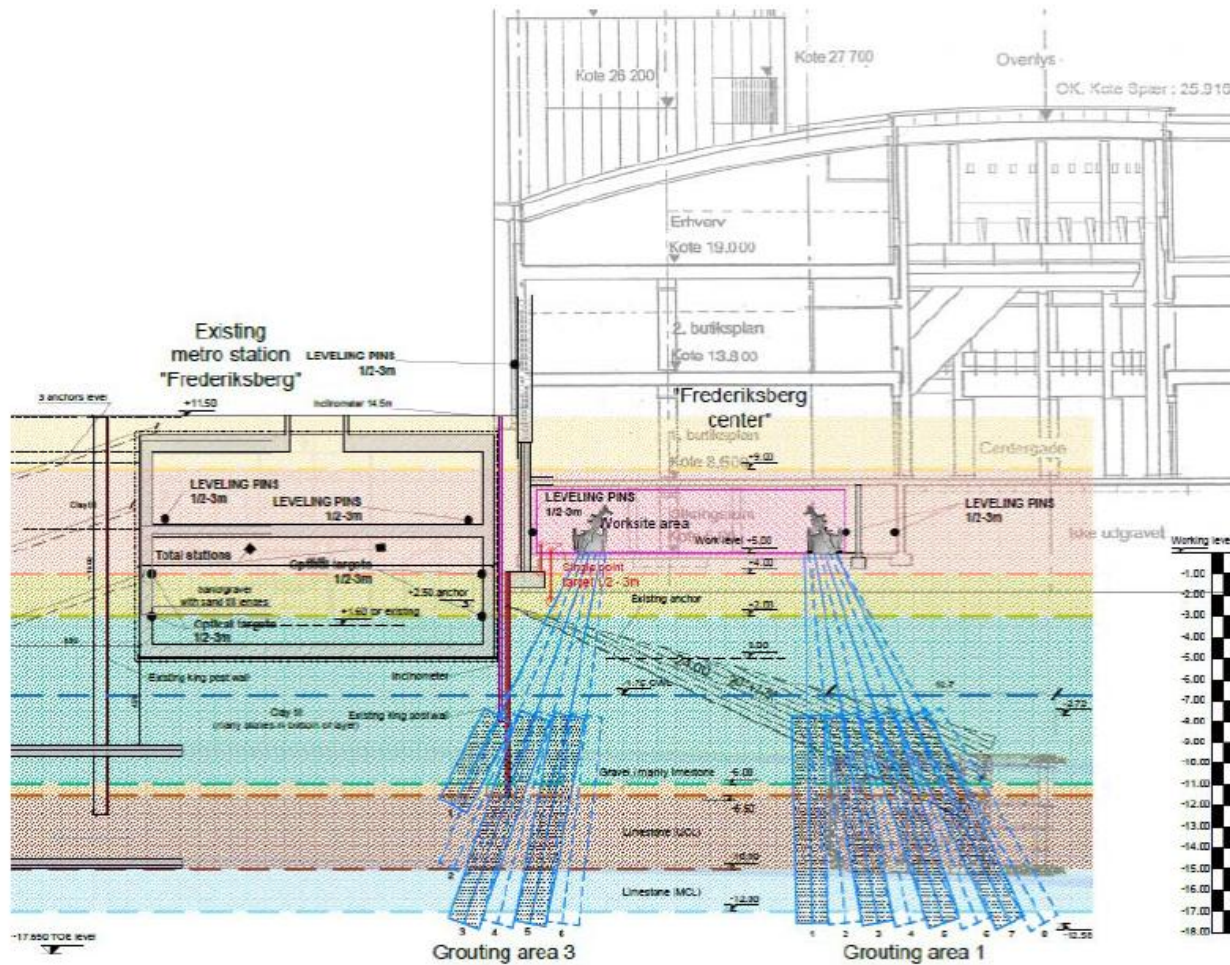


<SECTION 3.115+3.035, NORTH: 30°

THE LENGTH OF THE
ANCHORS WILL BE DECIDED
BY ACTIVE DESIGN.



Frederiksberg station – Long section for TBM Approach







Frederiksberg station – King Posts







Shallow tunnelling under Magasin



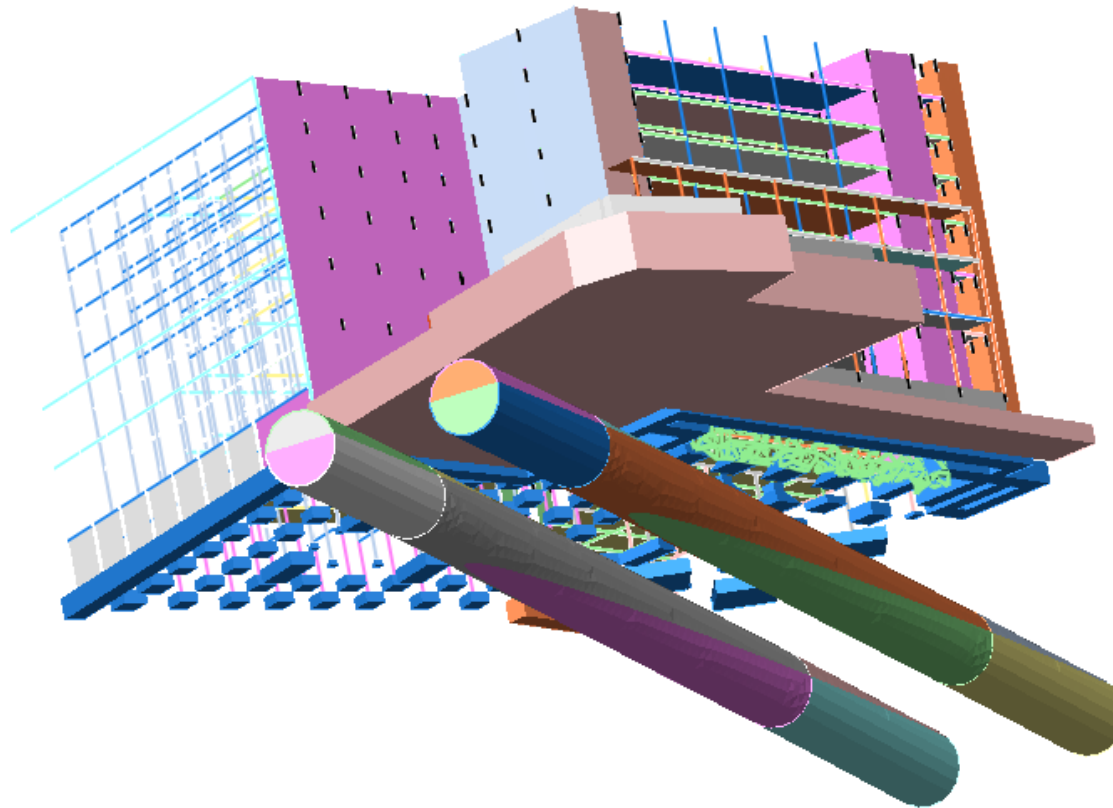




FEM model: 3D Geometrical model

Tunnels alignment - bottom view

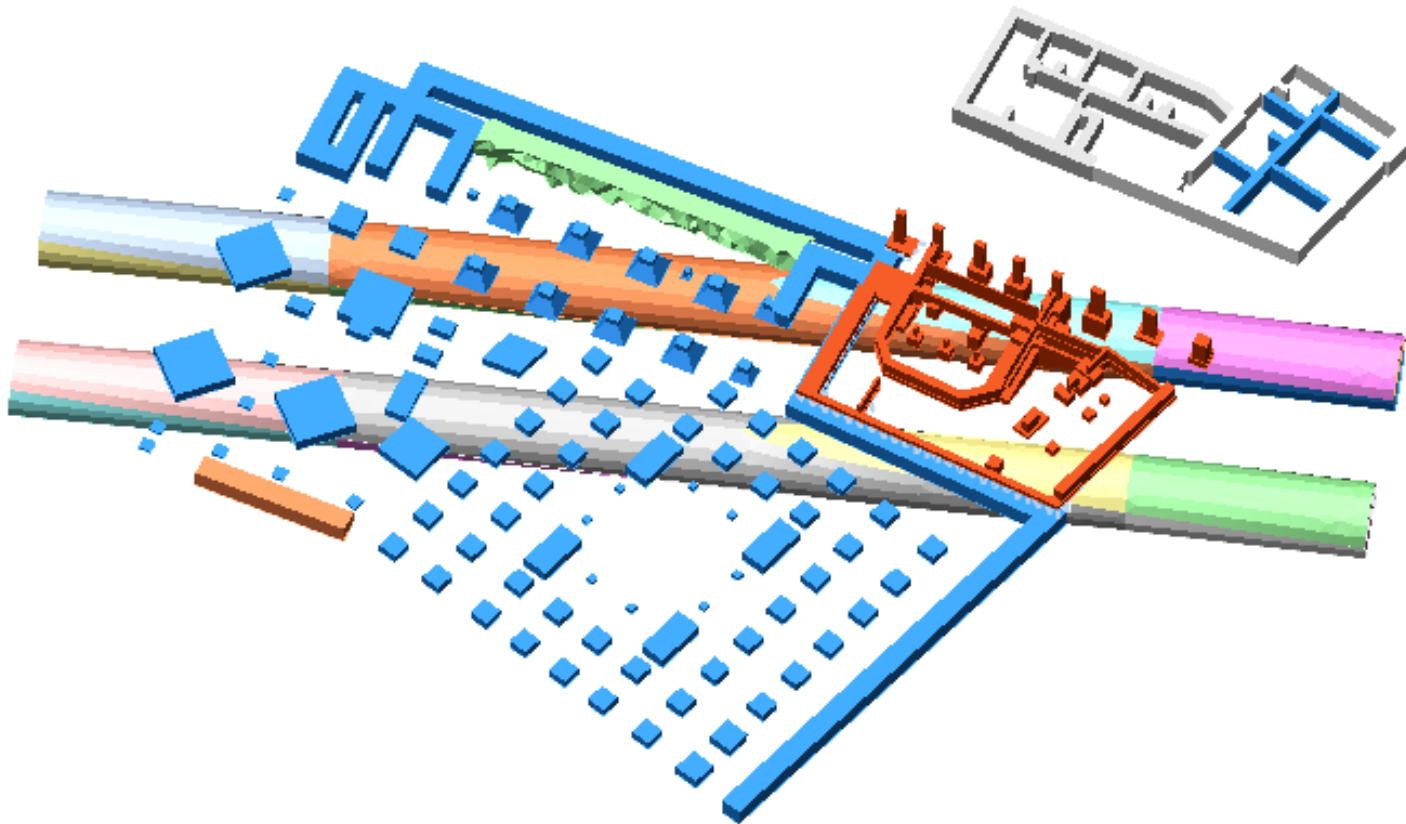
0.000 7.704 15.408 23.112 30.816





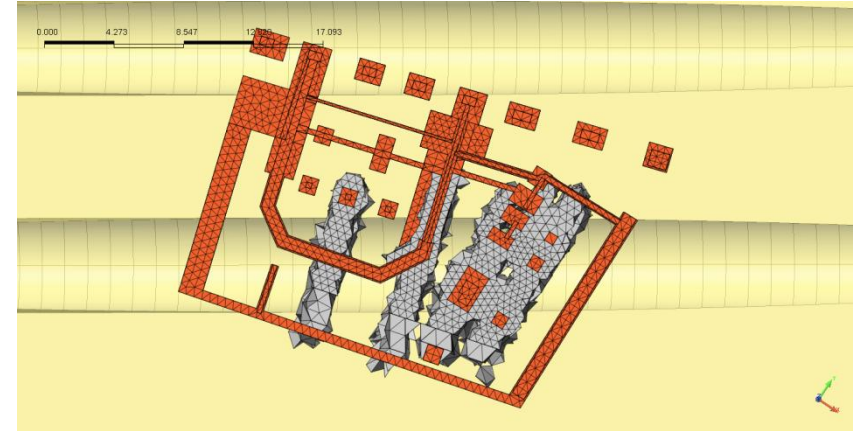
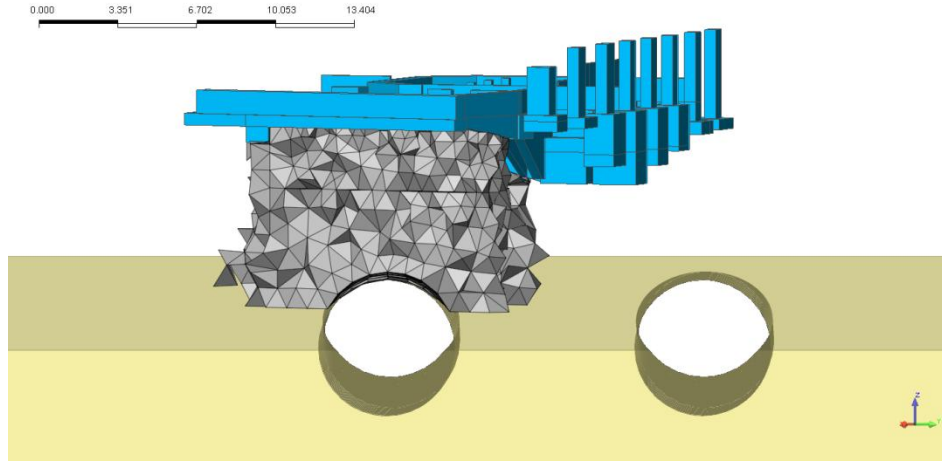
FEM model: 3D Geometrical model

Foundation plan

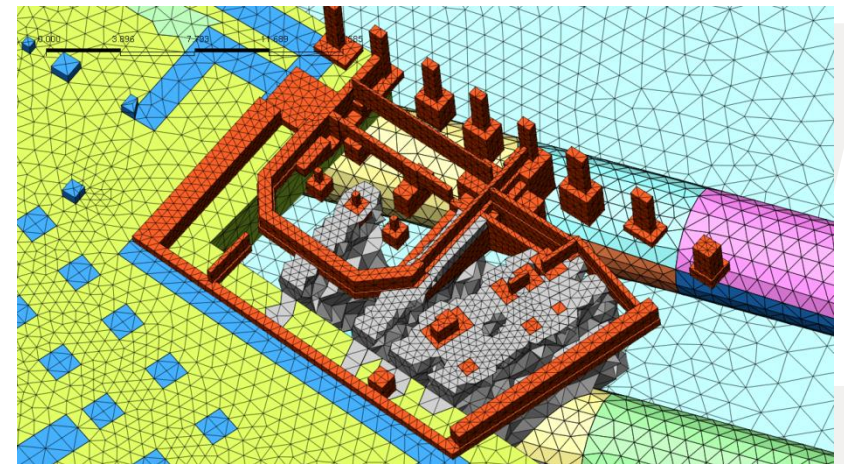
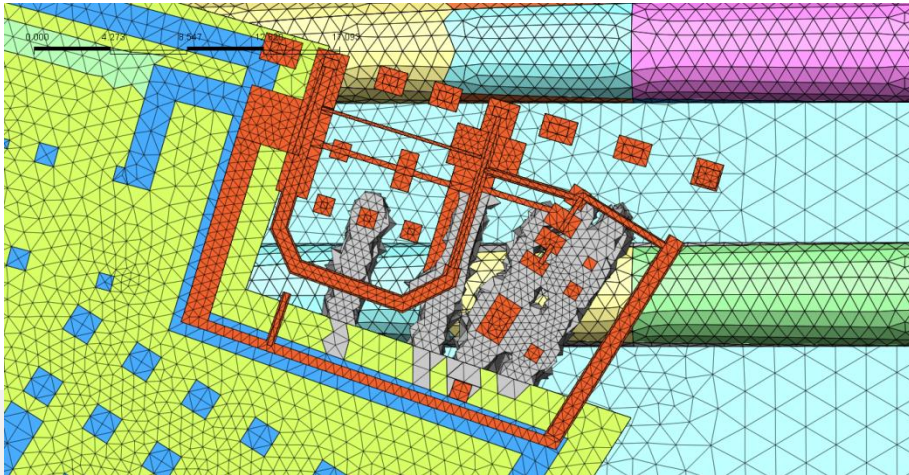




Grouting Model – Jet grouting

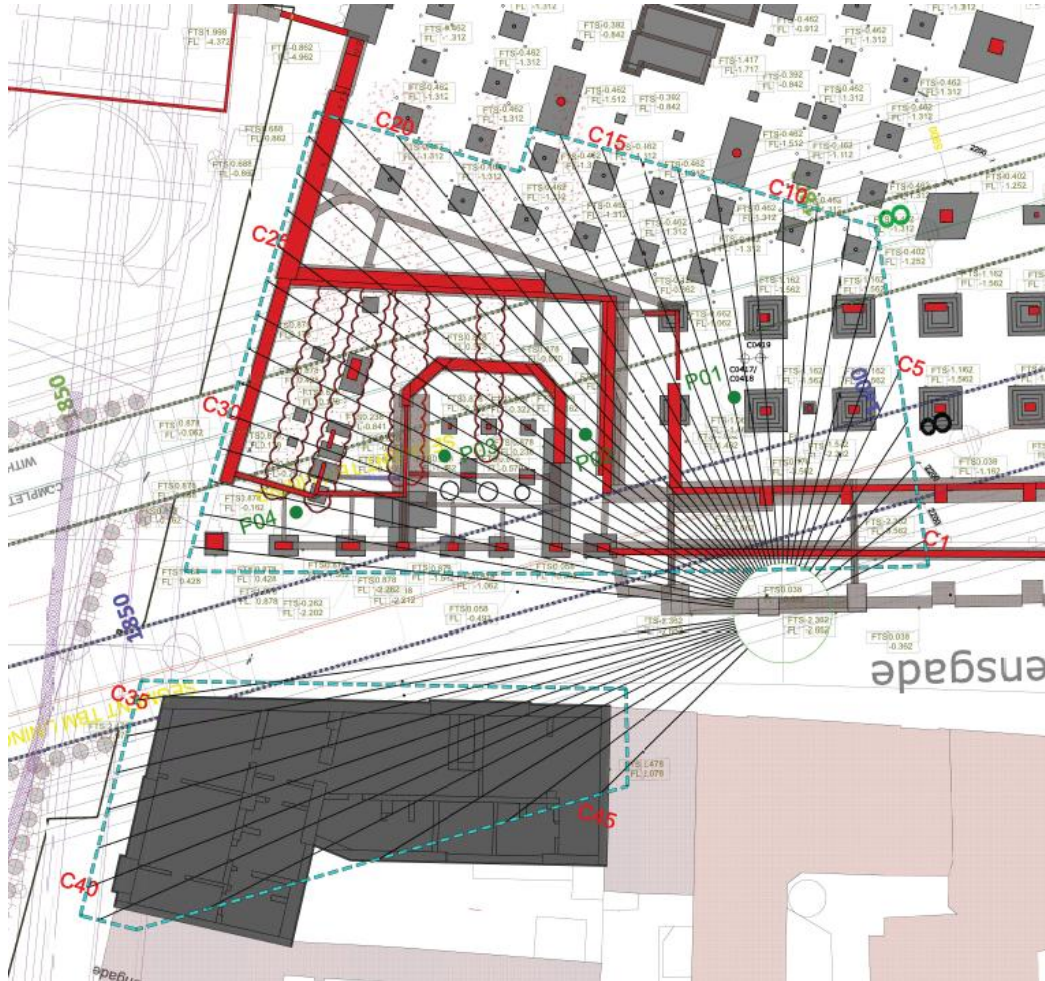


Creation of arch structures over the tunnels





Mitigation measures through compensation grouting



Position of the compensation shaft and of the injection pipes



- History of the Metro in Copenhagen
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Mechanical and Electrical Installations

Tunnel ventilation



Escalators



Electrical installations



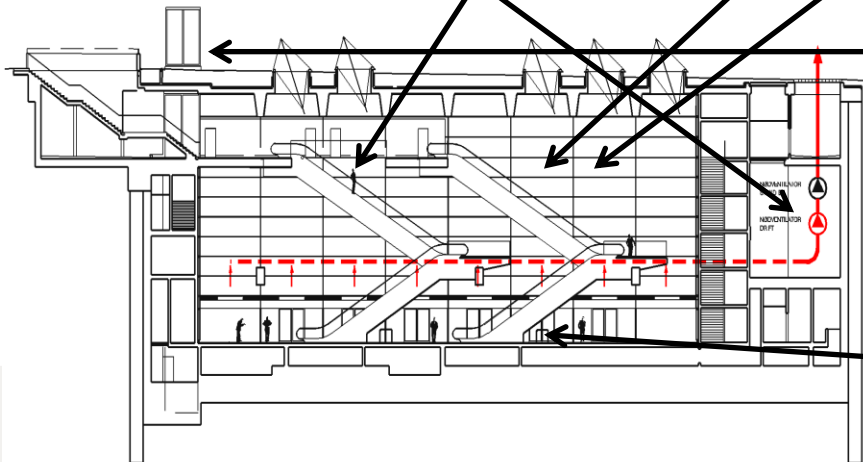
Ventilation and cooling



Lifts

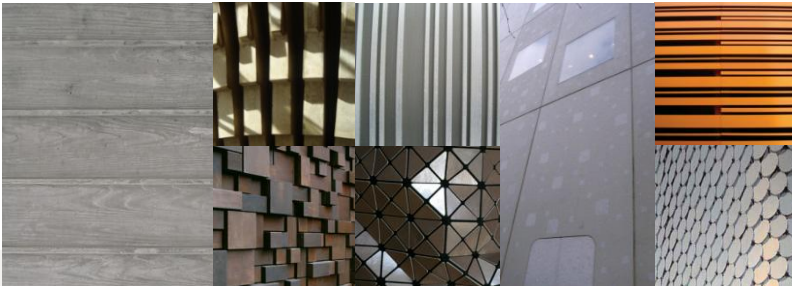
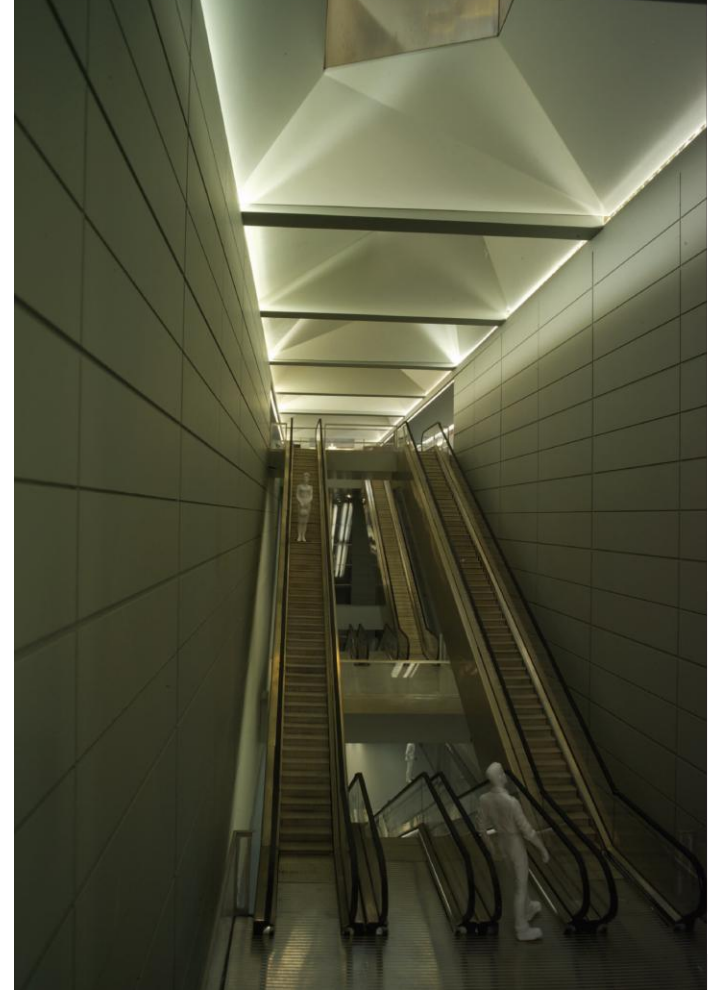


Fire fighting installations



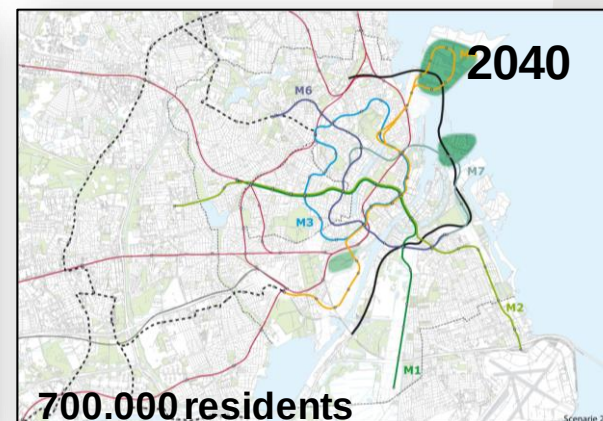
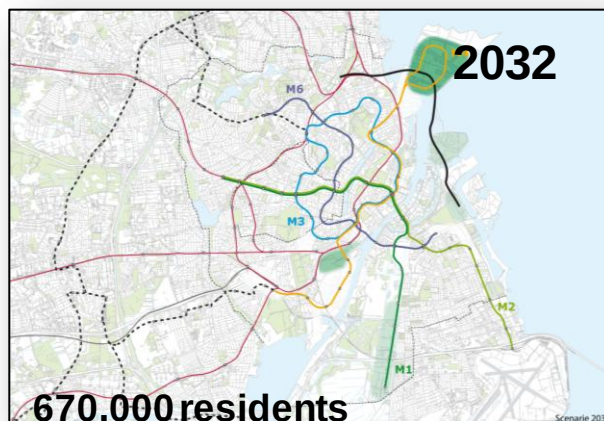
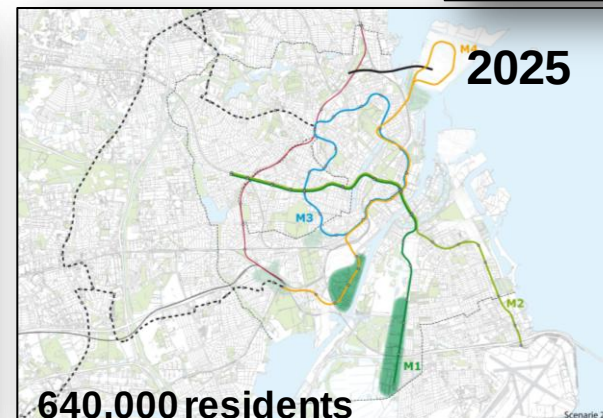
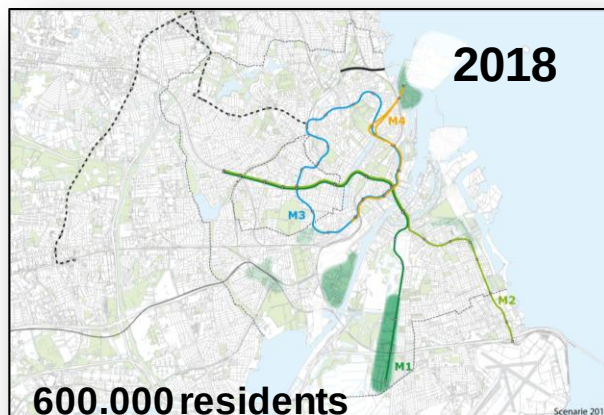


Architectural Finishes





Future Plans





Thank you for your attention

For further information

www.m.dk

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