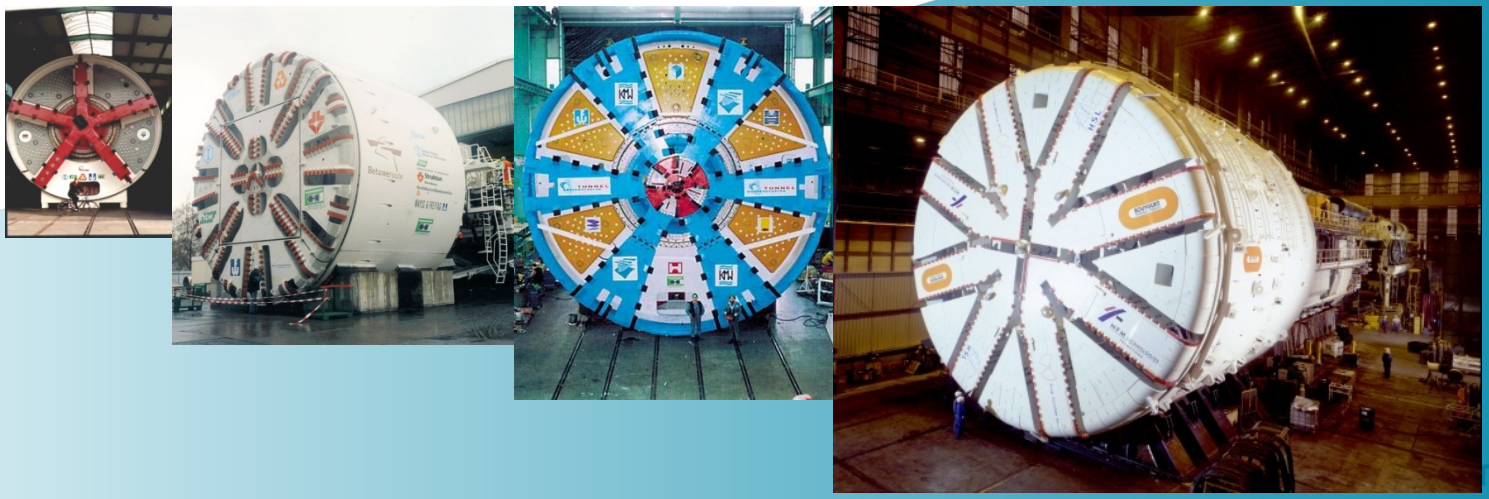
Royal HaskoningDHV
Enhancing Society Together

TEC Tunnel Engineering Consultants

Boortunnels (TBM)

Retrospectief met enkele toekomstige projecten

ir. Predrag Jovanovic, RO
februari 2020



TEC v.o.f. – Opgericht in 1989

Royal HaskoningDHV
Enhancing Society Together

Witteveen Bos

Organisatie

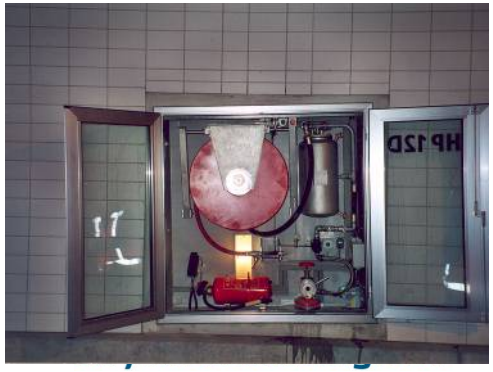
TEC kantoor

Gekwalificeerd personeel van moederbedrijven

- **Potentieel** **8,000**
  - **Royal HaskoningDHV** 7,000
  - **Witteveen+Bos** 1,000

  Ondersteuning beschikbaar op verschillende andere vakgebieden

QA/ISO certificaat



Tunnel gerelateerde expertise

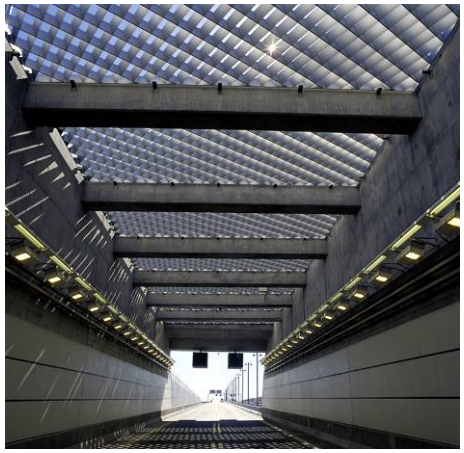
- **Civiel ontwerp en engineering gerelateerd aan**
  - Afgezonken tunnels
  - Geboorde tunnels in slappe grond
  - Cut & Cover tunnels
  - Speciale tunnel technieken
- **Elektromechanische installaties**
  - Ventilatie, pompen, verlichting,
  - stroomvoorziening
  - verkeerscontrole
  - dynamische verkeerssystemen
  - bediening
- **Veiligheidsaspecten**
  - (Weg) Veiligheidsanalyse
  - Operationele procedures
  - Scenario analyse
- **Integraal ontwerp in complexe (stedelijke) omgeving**
- **Weg en rail alignement ontwerp**

Royal HaskoningDHV

Services

Uitgebreid pakket aan services:

- **Beleidsformulering**
- **Master planning**
- **Haalbaarheidsstudies**
- **Voorontwerp, gedetailleerd ontwerp en aanbestedingsdocumenten**
- **Assistentie tijdens aanbestedingen**
- **Toezicht op het werk**
- **Bediening en onderhoud**
- **Opleiding**
- **Contract- en projectmanagement**
- **Risicomanagement & value engineering**
- **Onderhoudsplannen**



Geboorde tunnels

Nederland

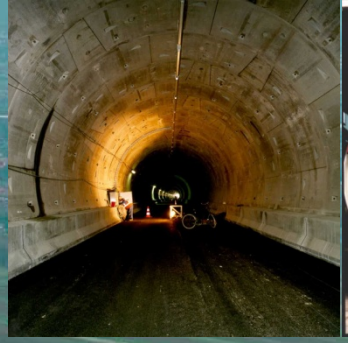
- Noord Zuid Metro Lijn Amsterdam
- HSL Groene Hart Tunnel
- 2e Heinenoordtunnel
- Westerscheldetunnel
- Betuweroute Pannerdensch kanaal
- Betuweroute Sophiatunnel
- Tunnel Noordelijke Randweg Den Haag
- Sluiskil tunnel
- R'dams Baan Tunnel, Den Haag
- Rijnland route Tunnel, Leiden

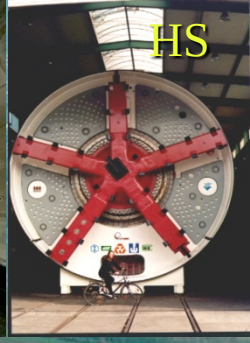
Internationaal

- Metro Lissabon, Portugal
- Genoa Harbor Crossing Italië
- Dublin Metro, Ierland
- Shenzhong crossing China
- Fehmernbelt Link, Denemarken
- Tuen Mun Chek Lap Kok, HK
- Laintang tunnel, HK
- New Centennial Water Source Project, Filipijnen
- Vervanging van bestaande water sifons, New York, US
- Su-Ai tunnel, Shantou, China

Betrokkenheid bij de introductie van geboorde tunnels in Nederland (onderzoeksprogramma's) - jaren negentig van de vorige eeuw

De Tweede Heinenoord Tunnel

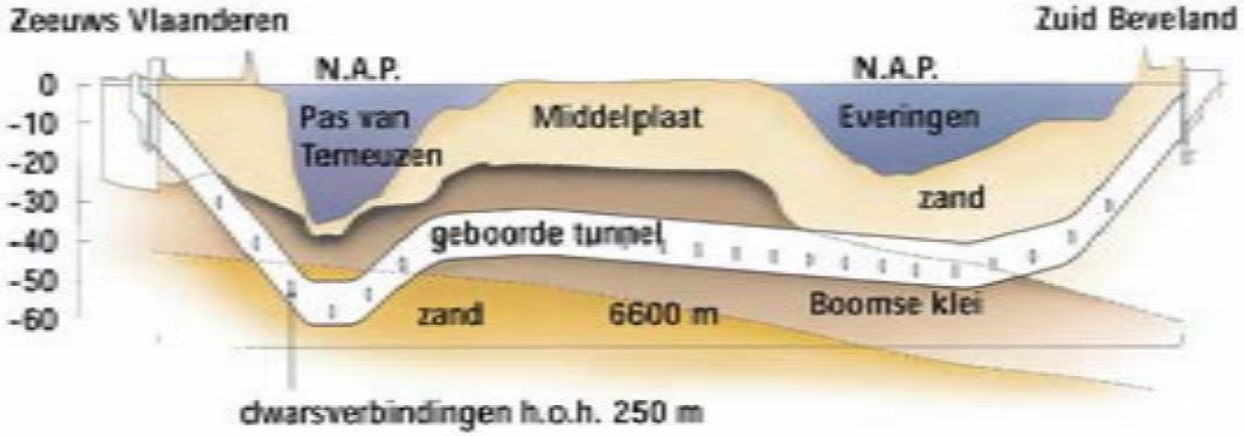




Het eerste pilot project 1995
Uitgebreid monitoringsprogramma

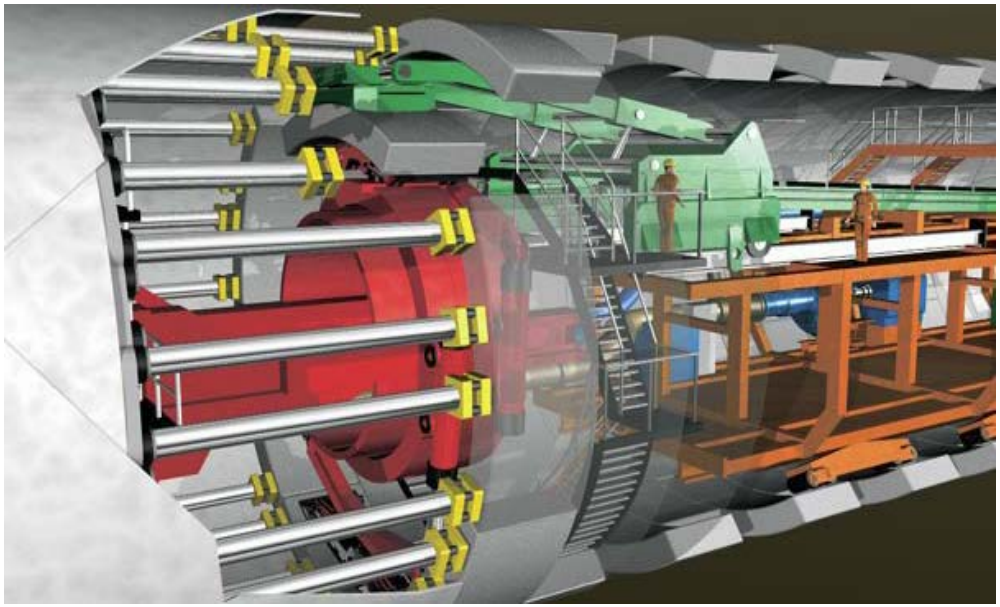
Westerschelde tunnel – 1999

Diepst -60m



De bijzondere uitdaging voor de bouw van de Westerscheldetunnel is de zachte klei

Sophiaspoortunnel - 2000
Continuum boorprocess



Tunnel Pannerdensch Kanaal – 2001

Boren onder bestaande dijk

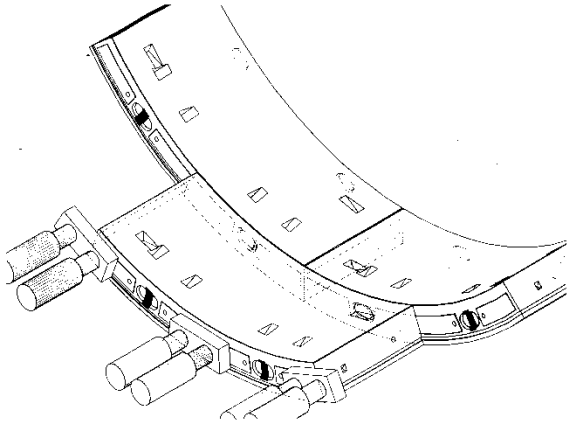
Royal HaskoningDHV

Groene Hart Tunnel
Hoge Snelheidslijn

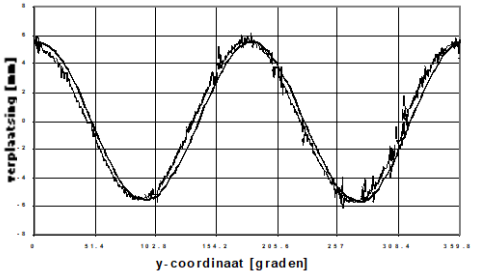
Northern tunnel entrance
Escape shaft Achthoven
Escape shaft N11
Escape shaft Bent
Tunnel entrance 710m
Southern tunnel entrance
Shield driven tunnel 7160m
Tunnel entrance 750m

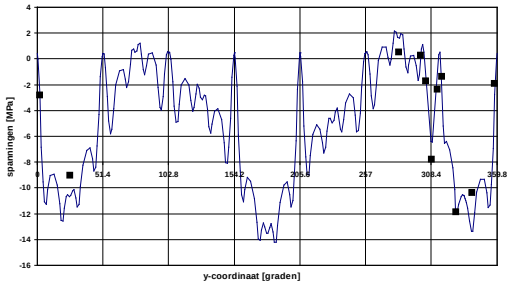
's Werelds grootste TBM in 2003, D = 14,9 m

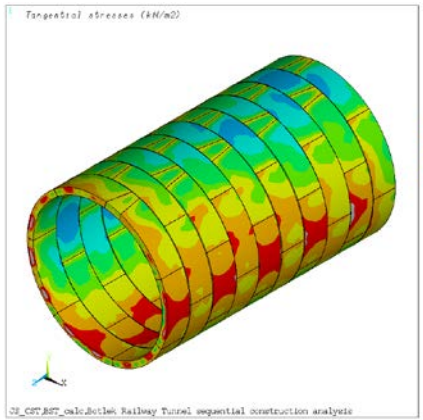
Geen schade
Vlakke voegen
Configuratie vijzels
Grootste diameter

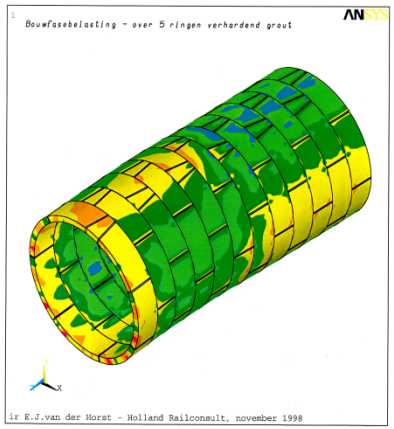


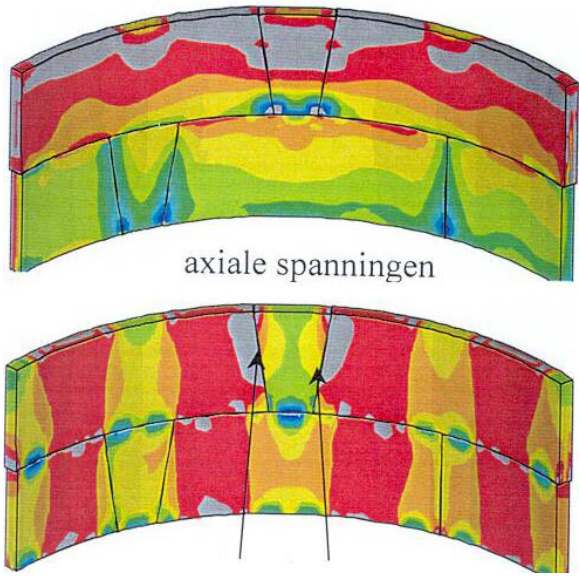
Royal HaskoningDHV


verplaatsing [mm]
y-coordinaat [graden]


spanningen [MPa]
y-coordinaat [graden]


Tangential stresses (kN/m2)
J2_CST_EST_calc.Botlek Railway Tunnel sequential construction analysis


Bouwfasebelasting - over 5 ringen verhardend grout
ANSYS
ir E.J.van der Horst - Holland Railconsult, november 1998


axiale spanningen

Randstadrail Rotterdam

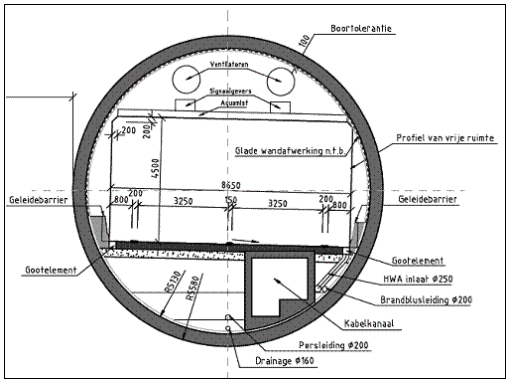
Royal HaskoningDHV

Hubertus tunnel Den Haag - 2008

Boren onder de stad

Royal HaskoningDHV

Sluiskil Tunnel – TBM tunnel



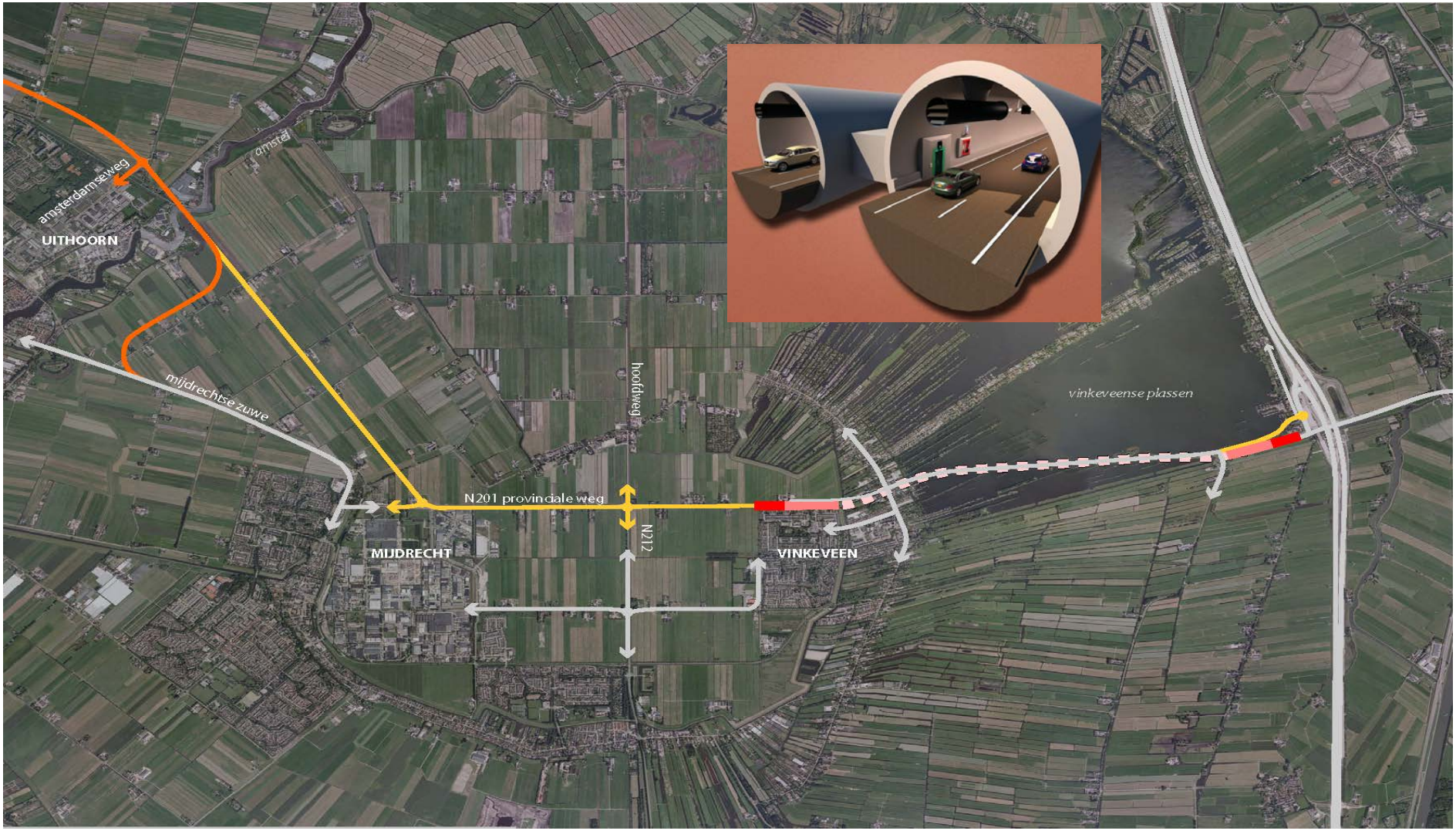
Metro Amsterdam

Conclusies

- TBM tunnels in Nederland in slappe grond zijn, sinds 1995, de realiteit
- Het is mogelijk om zakingen te controleren in steden
- Life Cycle Costs kunnen aanzienlijk verminderd worden als de Risk Management Control wordt toegepast vanaf het begin van het project
- Goedgekeurde ontwerpfilosofie geverifieerd in de praktijk en laboratoria is de basis (voorspelling, observatie, evaluatie, actie, mitigatie)
- Passende mitigatie is essentieel voor de totale kosten (ontwerp, procedure, verificatie, validatie)
- Gezamenlijk inspanningen (publiek en privaat) hebben Nederland wereldwijd naar de polepositie gebracht wat betreft de kennis over de boortunnels in zachte bodems
- De totale kosten van de TBM-tunnels liggen dicht bij de kosten van de gelijkwaardige bruggen

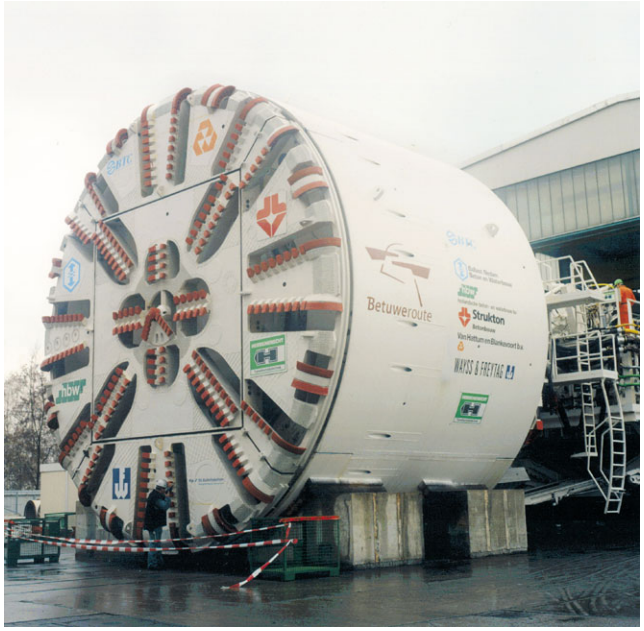
Toekomstige projecten

Uitbreiding N201 Vinkeveen, wegtunnel - TBM



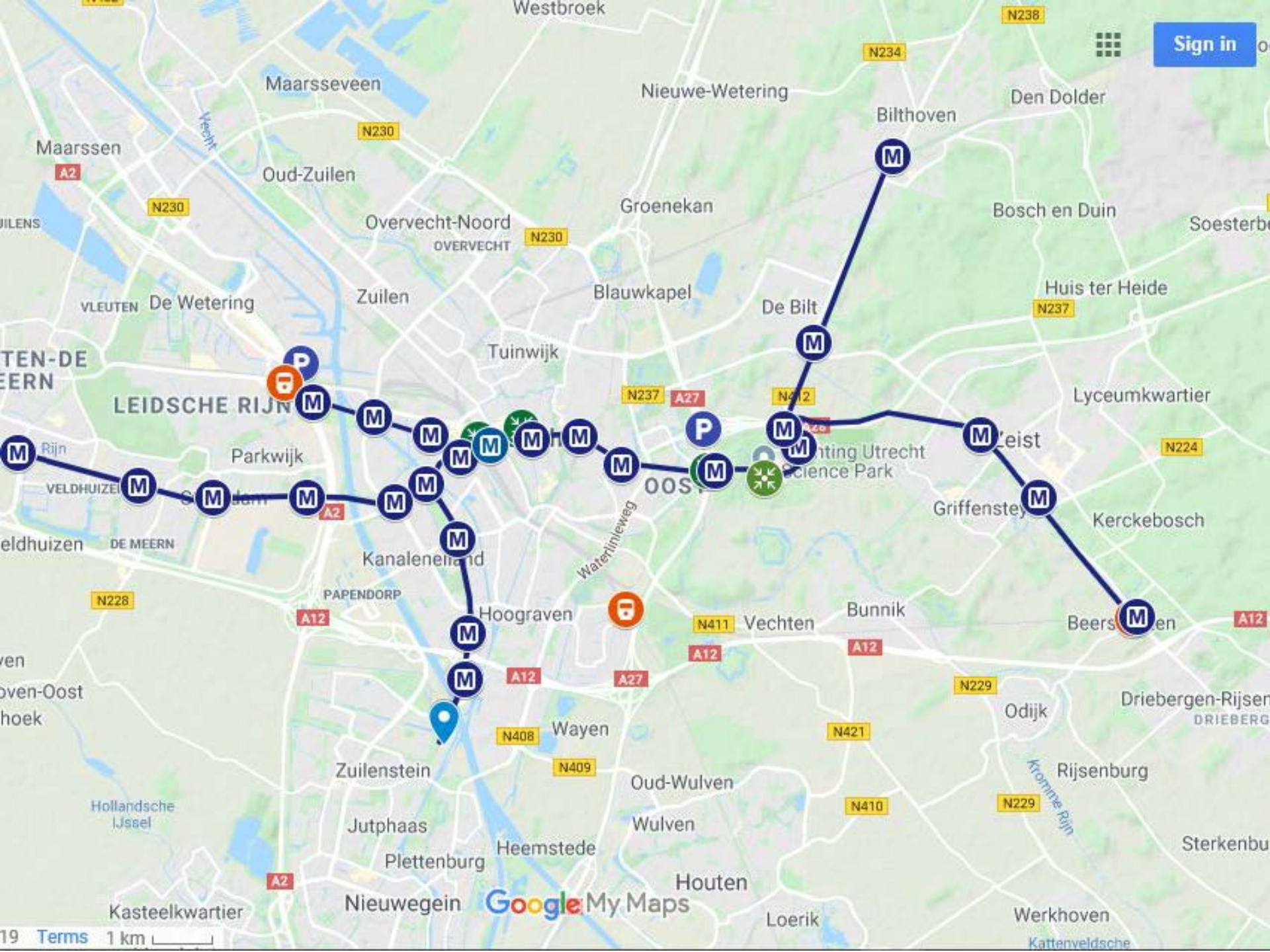
Royal HaskoningDHV

Vracht Lijn TBM tunnel, Dordrecht



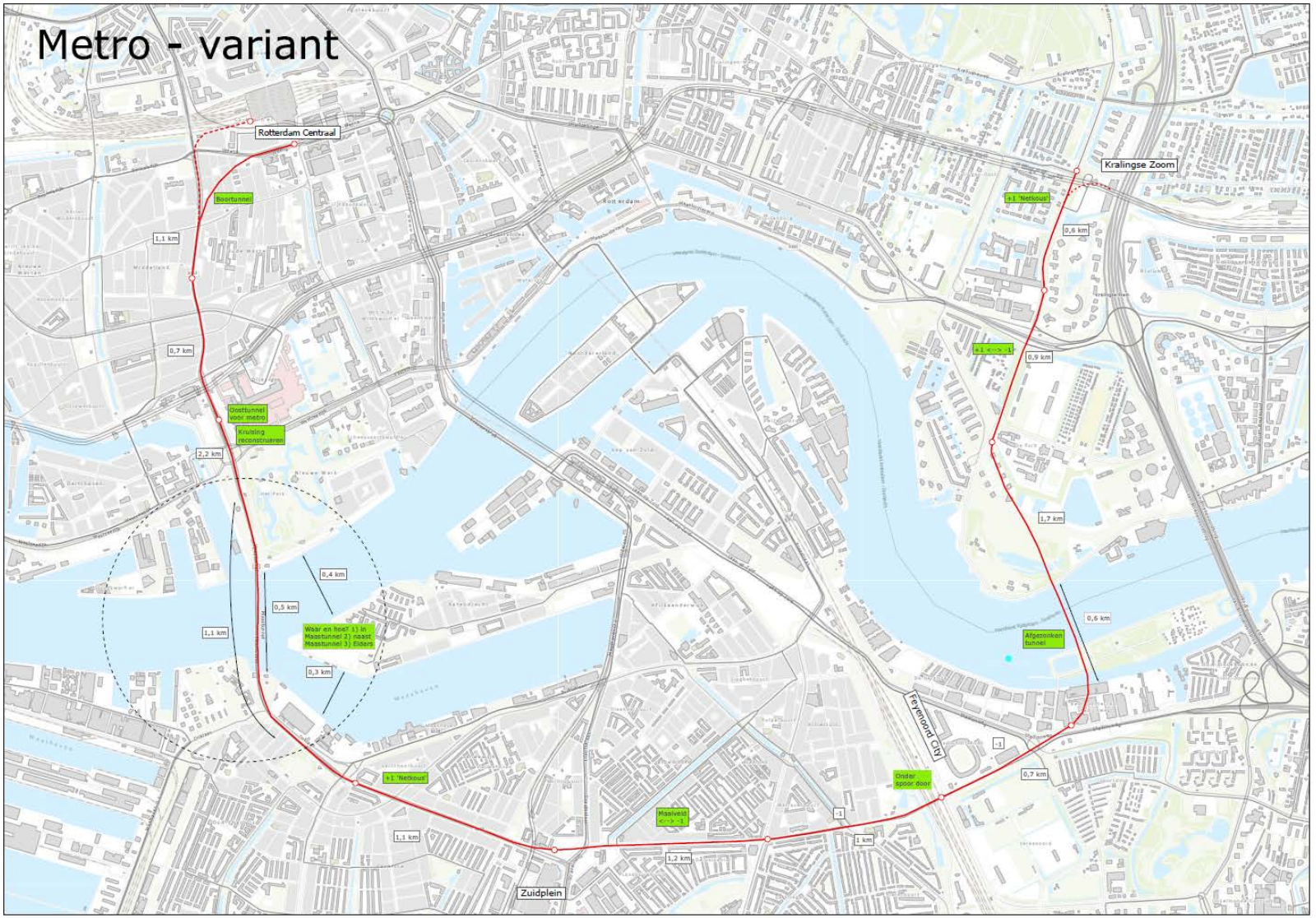
Metro Utrecht

Tracé variant rood


Westbroek
Sign in
Maarsseveen
Nieuwe-Wetering
Den Dolder
Bilthoven
Maarssen
Oud-Zuilen
Groenekan
Bosch en Duin
Overvecht-Noord
OVERVECHT
Zuilen
Blauwkapel
De Bilt
Huis ter Heide
VLEUTEN
De Wetering
Tuinwijk
LEIDSCHE RIJN
Lyceumkwartier
Parkwijk
Science Park
Griffenstey
Kerckebosch
DE MEERN
Kanaleneiland
Waterlinieweg
PAPENDORP
Hoograven
Vechten
Bunnik
Odijk
Driebergen-Rijsen
Wayen
Zuilenstein
Oud-Wulven
Rijsenburg
Hollandsche IJssel
Jutphaas
Wulven
Heemstede
Plettenburg
Houten
Nieuwegein
Kasteelkwartier
Loerik
Werkhoven
Google My Maps
Terms
1 km

Ge Dubbelman/Hollandse Hoogte 2011

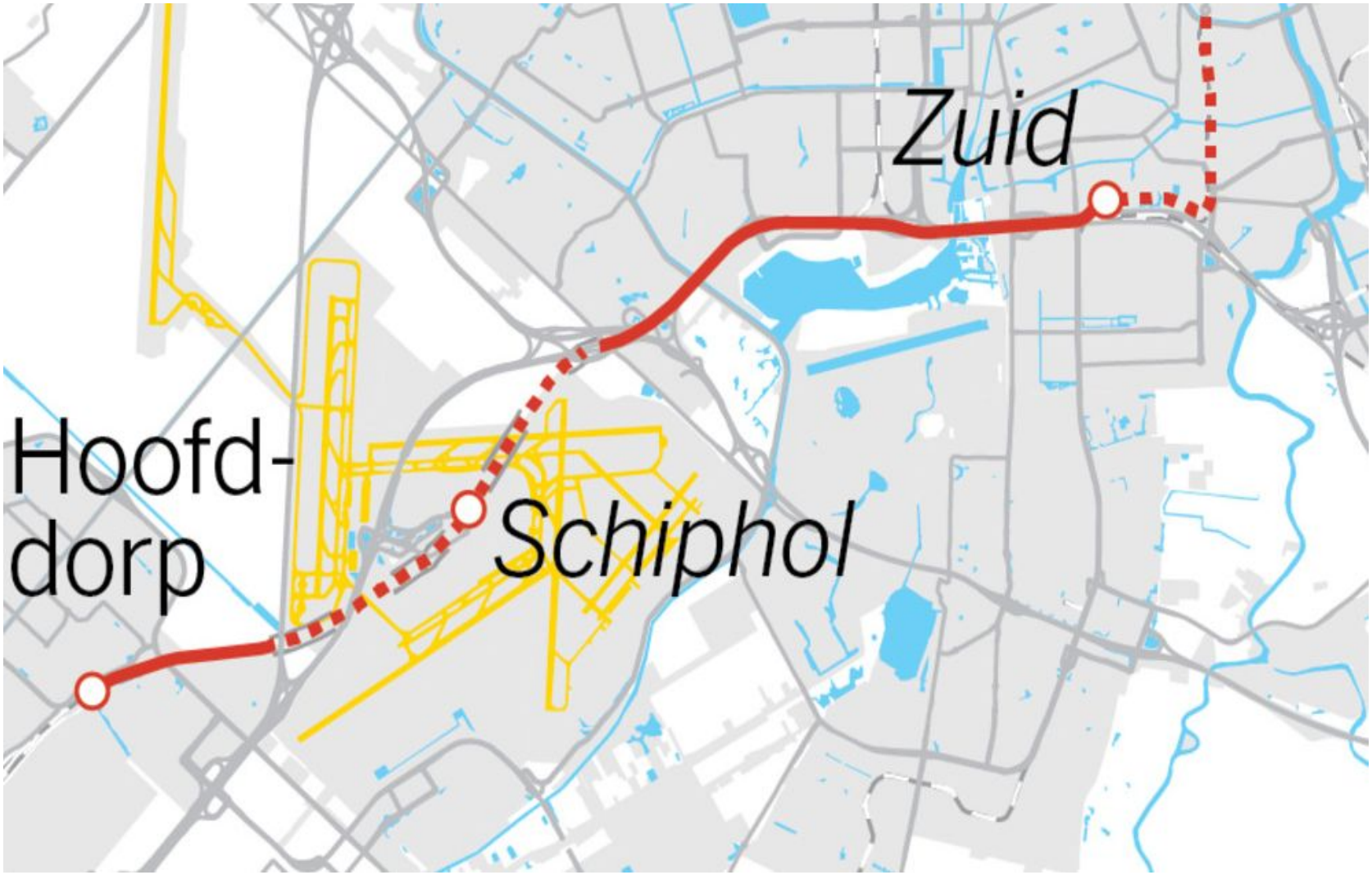
Metro Rotterdam



Royal HaskoningDHV

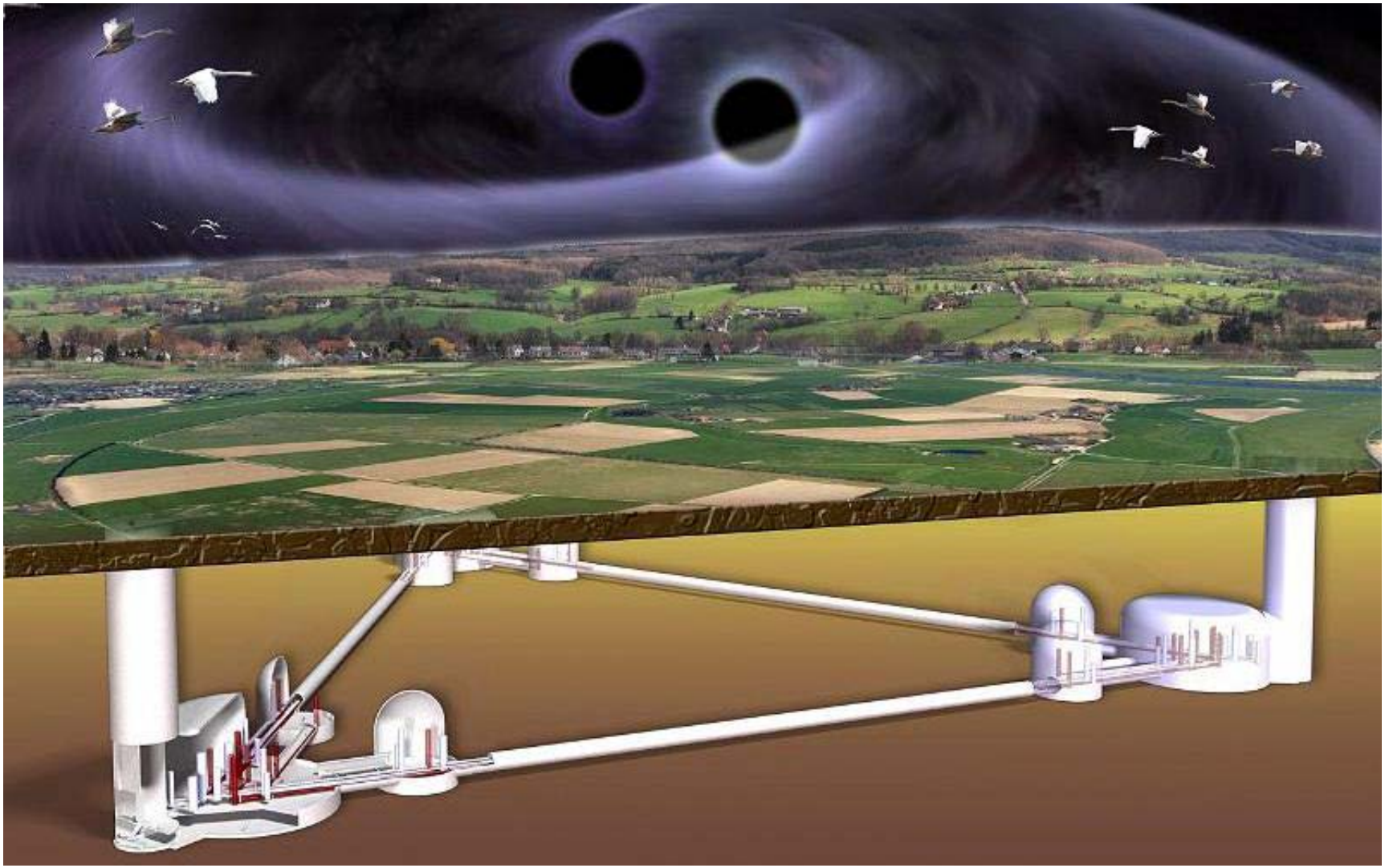
Royal HaskoningDHV

Metro Amsterdam



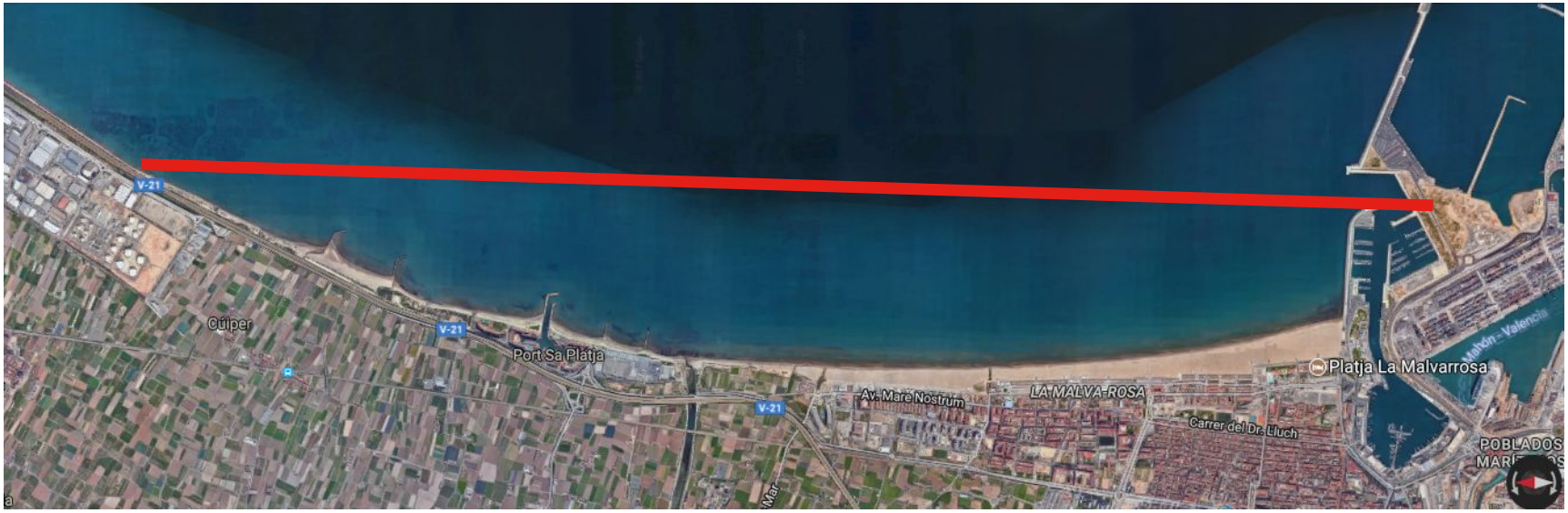
Royal HaskoningDHV

Einstein telescoop – 30 Km, D=8,4m, -250m

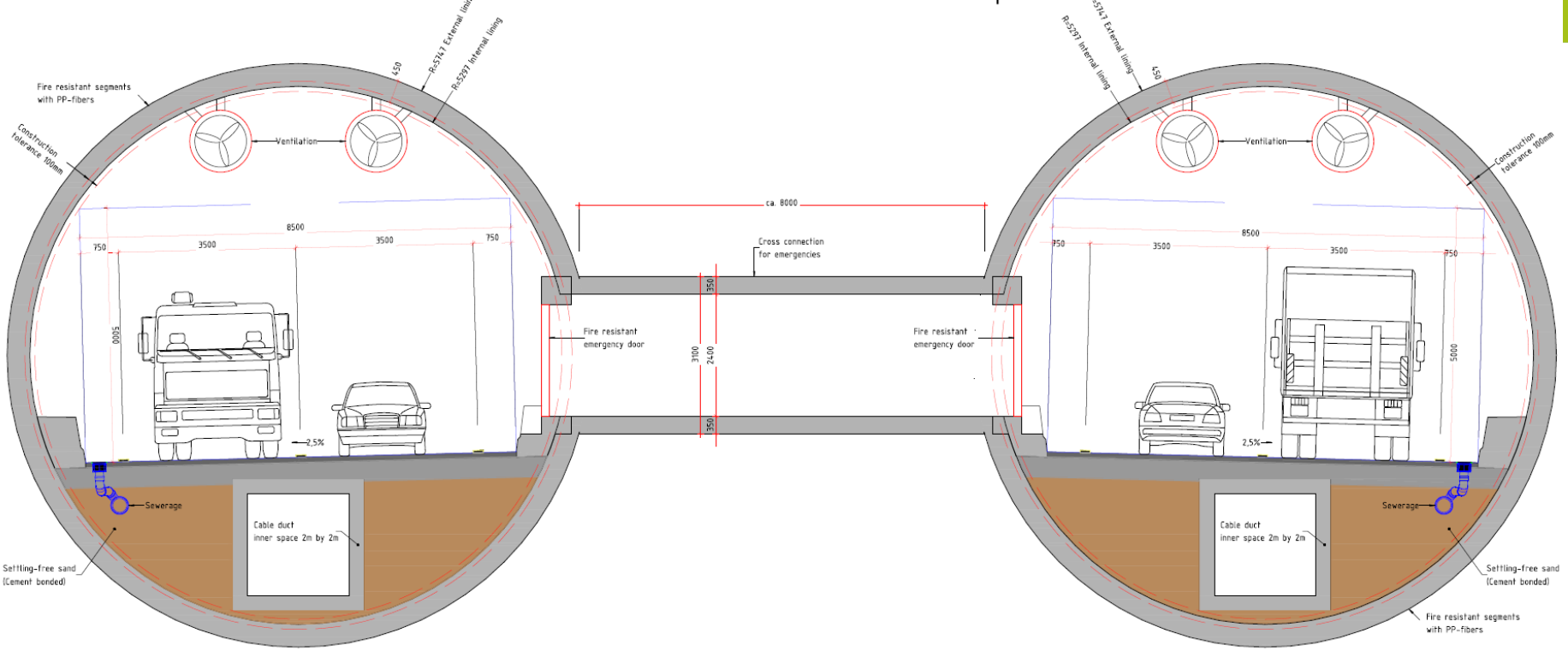


Royal HaskoningDHV

Valencia Haven wegtunnels met optie voor de spoorwegtunnels - TBM en afgezonken tunnelopties, 10 km

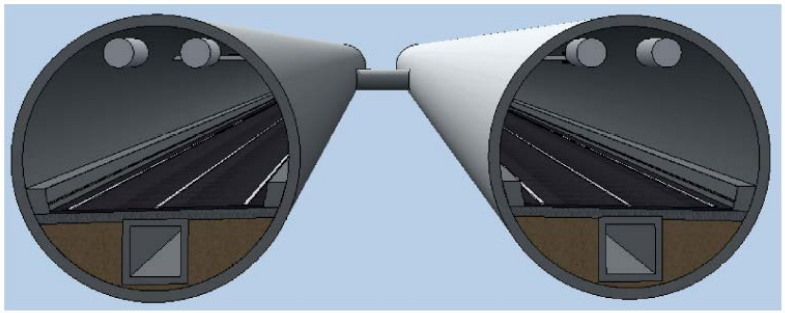


Royal HaskoningDHV



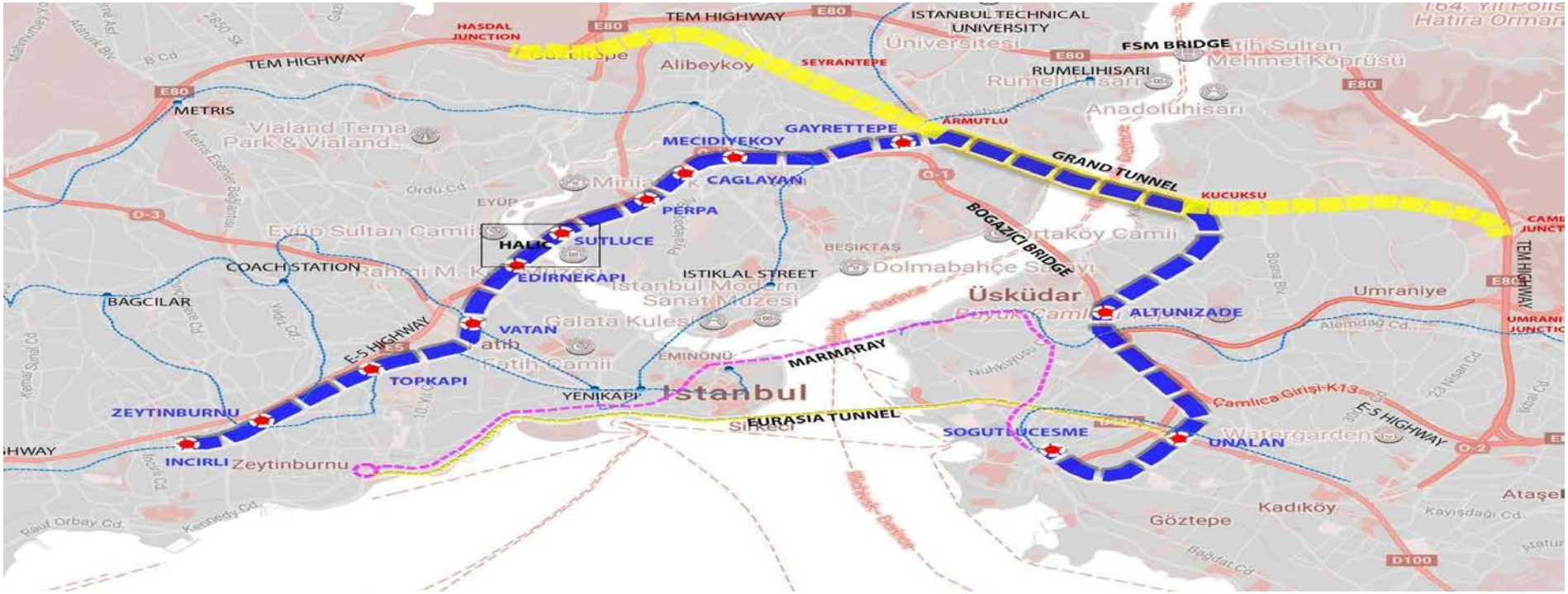
Cross section bored tunnel at cross connection

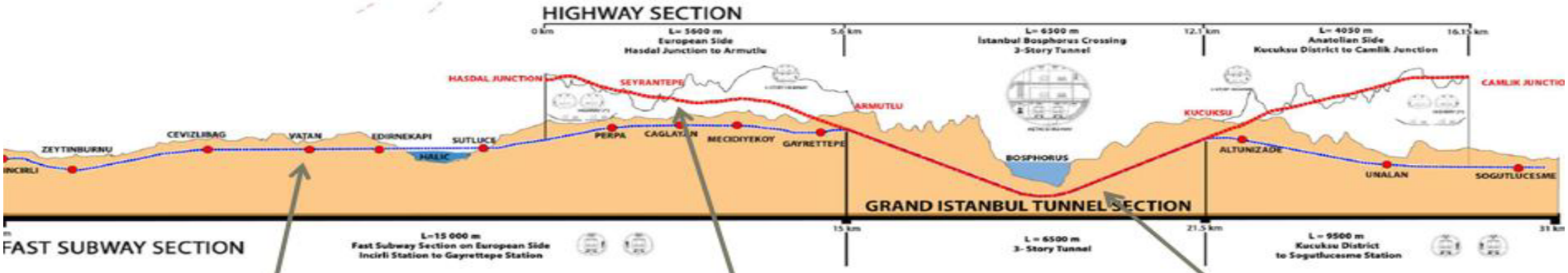
Scale 1:50



Royal HaskoningDHV

Grand Istanbul tunnel project





Söğütlüçeşme-İncirli Metro Line

31km - length
14 - stations
120km/hr - design speed

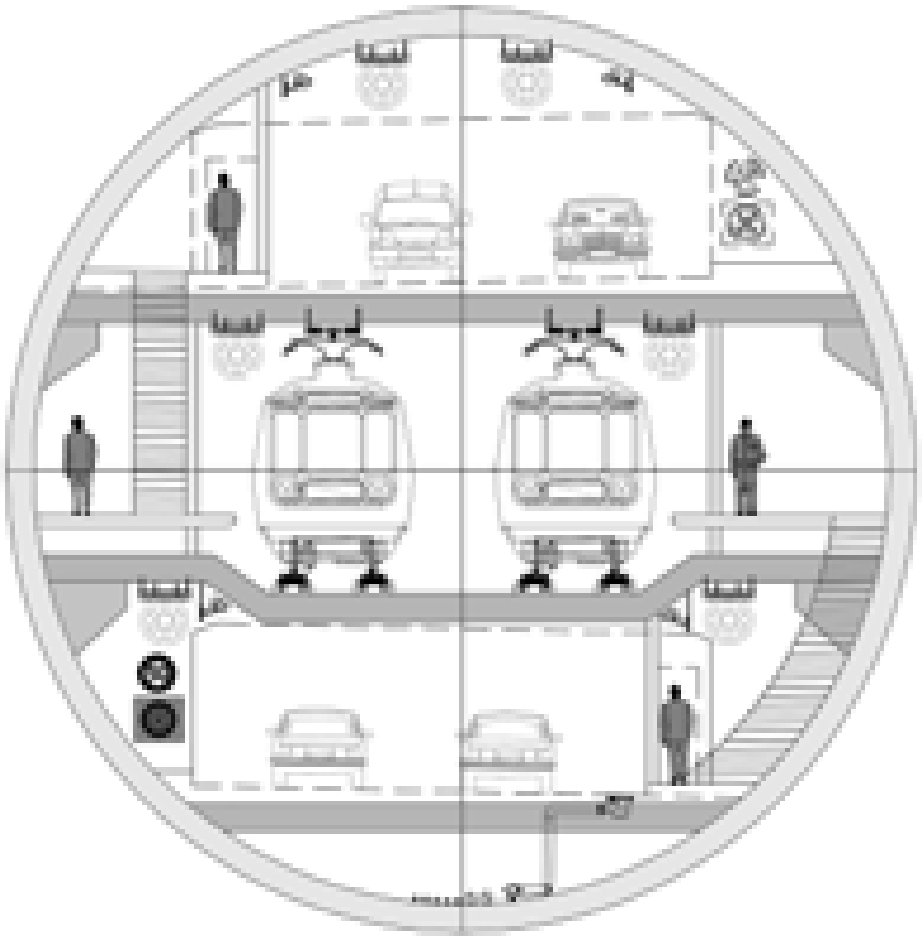
Çamlık-Hasdal Highway

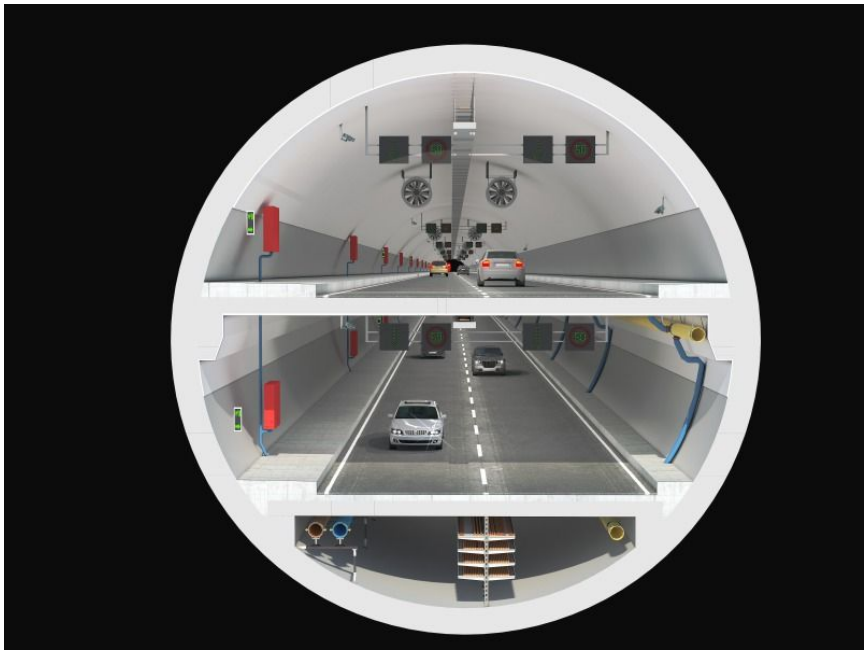
16km - length
70km/hr - Design speed

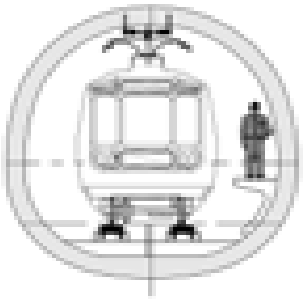
Three-Story Grand Istanbul Tunnel

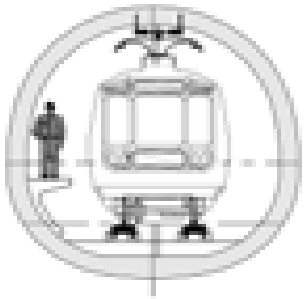
6,5 km - length
16,8m - diameter
110m - below sea level

Dwarsdoorsneden









Royal HaskoningDHV

Johannesburg – Uitbreiding Gautrain 140Km

Royal HaskoningDHV

Tunnels in België (selectie):

- Brussel – Metro-Noord (ca. 4,7 km Ø 9,80 m)
- Antwerpen – 2e Havenontsluiting (ca. 16 km Ø 7,30 m met 4 TBMs)
- Brussel – uitbreiding Noord-Zuidverbinding (4 extra spoorwegen onder bestaande tunnel, elk 10 km lang
- Antwerpen – A102 (wegtunnel van Antwerpen Noord naar Wommelgem; ca. Ø 8,25 m onder Albertkanaal).

Directe bouwkosten van TBM-tunnels

Project: Metro Rotterdam
Version estimate: 0.1 - Status: concept - Prepared by: p.jovanovic

Prijspeil raming: 01-01-20
Datum raming: 20-01-20

Description post	Hoeveelheid	Eenheid	Prijs	Totaal euro
Investment estimate:				
assumptions				€ -
				€ -
Monitoring system € 100, - / m1				€ -
TTI 15% of DCC				€ -
Tracé lenght 2 tubes 6,7m 5.000m	10.000	m1		€ -
5 stations		m1		€ -
		m1		€ -
launch and reception shaft 18 + 18 Meter	36	m1		€ -
tunnel drilled approximately 5 m diameter external monotube	9.964	m1		€ -
				€ -
Launch and reception shaft				€ -
Monitoring system	36	m1	€ 1.000,00	€ 36.000
civil and architectural (including technical buildings)	2	post	€ 10.000.000,00	€ 20.000.000
				€ -
Bored tunnel				€ -
Monitoring system	9.964	m1	€ 100,00	€ 996.400
TBM tunnel drilling machine, buy, assembly, disassembly and resale value	2	post	€ 12.000.000,00	€ 24.000.000
separation plant	1	post	€ 2.000.000,00	€ 2.000.000
tunnel lining including logistics to the TPM	9.964	m1	€ 18.000,00	€ 179.352.000
production 2x6,7 m x 3.14 x 0.3 m x 1m € 500, - / m3 = € 6,310, - / m1				€ -
pipelines for grout , water and air 3 x 400 = € 1200, - / m1				
transport 15 tons a € 100, - = € 1,500, - / m1				€ -
Control TBM € 1650, -				€ -
Operations supply, electricity and axilaries 2370				
tracks € 3000, - / m1	9.964	m1	€ 3.000,00	€ 29.892.000
				€ -
segment factory plant	1	pst	€ 4.000.000,00	€ 4.000.000
stations	3	pst	€ 20.000.000,00	€ 60.000.000
				€ -
Cleared Direct construction costs				**€ 320.276.400**
TTI	15,00%		€ 320.276.400	€ 48.041.460
Further detailing construction costs	7,83%	-	€ 320.276.400	€ 25.077.642
Direct construction costs				**€ 393.395.502**
Separate construction costs	2,00%	-	€ 393.395.502	€ 7.867.910
General site Construction costs	1,00%	-	€ 393.395.502	€ 3.933.955
Execution costs	10,00%	-	€ 393.395.502	€ 39.339.550
General costs	7,00%	-	€ 444.536.917	€ 31.117.584
	5,00%	-	€ 475.654.502	€ 23.782.725
Not directly estimated construction costs	*26,96%*	*t.o.v. directe bouwkosten*		**€ 106.041.725**
Estimated construction costs				**€ 499.437.227**
Other additional costs N.N.B.	10,00%	-	€ 499.437.227	€ 49.943.723
Costs of Risks	*10,00%*	*t.o.v. voorziene bouwkosten*		**€ 49.943.723**
Total estimated construction costs				**€ 549.380.949**
Expropriation & Property costs				
Property charges tunnel	1	ehd	€ -	€ -
Acquisition costs	1	ehd	€ -	€ -
	-	ehd	€ -	€ -
Expropriation & Property costs bored tunnel				**€ -**
Engineering Costs				
Tunnel Engineering costs,% of construction costs	3,00%	-	€ 549.380.949	€ 16.481.428
		-		€ -
Engineering costs bored tunnel				**€ 16.481.428**
taxes and fees licenses % of the construction costs	1,70%	-	€ 549.380.949	€ 9.339.476
insurance costs,% of construction costs	1,00%	-	€ 549.380.949	€ 5.493.809
Other ancillary costs NNB	3,00%	-	€ 549.380.949	€ 16.481.428
K & L others	1	post	€ -	€ -
		-		€ -
Other additional costs bored tunnel				**€ 31.314.714**
Not named object transcending risk investment	10,00%	-	€ 597.177.092	€ 59.717.709
Investment bored tunnel			excl. Btw	**€ 656.894.801**

Kostenvergelijking investeringen metro - tram

Kijkend naar Europese projecten en exclusief uitschieters, liggen de totale directe kosten per route per m (inclusief stations) voornamelijk tussen 50.000 en 100.000 euro

Ondergronds:
Metro Amsterdam geboorde tunnel – 100,000 euro/m
Metro Rotterdam (SSK) – 65,000 euro/m
Metro Madrid – 38,000 euro/m

Bowengronds
Tram Groningen – 28.000 euro/m
Tram Utrecht – 65,000 euro/m