

Aide Memoire for Select Committee

1. Programme (see Scheduling note)

	A	C	D	E	G
Organisation	HS2 Ltd	HS2 Ltd	HS2 Ltd	REPA	REPA
Tunnel length (km)	13.3	17.4	17.4	17.4	17.4
Tunnelling rate (m/week)	80	80	80	90	120
Ends for fit-out	South	South	Both ends	South	South
Duration (years)	8.25	9.50*	8.00	8.00	5.50

*Exceeds programmed period for Chiltern Tunnel (8.25yrs)

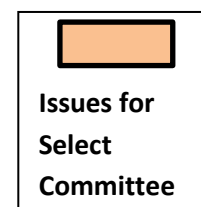
2. Environment and related issues (from HS2 Ltd 'sift')

	HS2 Ltd Sift Assessment of REPA	REPA Assessment
Construction feasibility impact on existing infrastructure	Major improvement vs. current scheme	Agreed
Safety	Worse during ops vs current scheme	Disagree
Environment Overall	Major improvement vs. current scheme	Agreed
1. Landscape and town scape	Major improvement vs. current scheme	Agreed, but discuss
2. Cultural Heritage	Minor improvement vs. current scheme	Agreed
3. Biodiversity	Major improvement vs. current scheme	Agreed
4. Sound and Vibration Construction	Major improvement vs. current scheme	Agreed
5. Sound and Vibration Operation	Minor improvement vs. current scheme	Disagree
6. Community Integrity	Major improvement vs. current scheme	Agreed
7. Transport accessibility /severance	Minor improvement vs. current scheme	Disagree
8. Health and Wellbeing	Not Assessed	Relevant factor
9. Socio economic factors	Not Assessed	Relevant factor
10. Agricultural, soil and land use	Major improvement vs. current scheme	Agreed
Property Blight	Not considered by HS2 Ltd at all	Relevant factor

3. Costs (see Cost differences note)

Item	Net Costs in £m	HS2 Ltd July 15	HS2 Ltd* published rates	REPA 11 June 2015 Report	REPA 19 July Amended	Difference
Land & Property (£m)		-32.7		-11.4	-11.4	21.3
Tunnels (£m)		134.5		71.5	55.5	-79.0
Bored Tunnels		181.8	170.2	139.4	102.7	-79.1
Green Tunnel		-57.1		-67.9	-57.1	0.0
Portals		-10.4			-10.4	0.0
Shafts		14.2		0.0	14.2	0.0
Disposal costs		6.1		0.0	6.1	0.0
Civil Engineering (£m)		-57.0		-68.6	-83.4	-26.4
Cuttings		-33.3	-79.4	-53.8	-53.8	-20.5
Landscape/Planting/Noise		-7.3		0.0	-7.3	0.0
Bridges		-10.5		-7.8	-7.9	2.6
Highways		-7.2		-2.0	-7.2	0.0
Utilities Culverts		-7.3		-5.0	-7.3	0.0
Extended preliminaries		8.5		0.0	0.0	-8.5
Railway systems (£m)		21.7		0.0	21.7	0.0
Indirect costs (£m)		18.0		0.0	-1.1	-19.1
ECP/VE (£m)		-8.1		0.0	0.5	8.6
Net TOTAL £m		76.4		-8.5	-18.1	-94.6

* from Tunnel Guide (for tunnelling), and 2012 Appendix A (for cuttings)



19 July 2015

www.repahs2.org.uk

G

Benchmarking: tunnels

Data Obtained

G.1 Survey participants have returned a number of cost questionnaires for projects that include tunnels, and where possible the data relating specifically to the tunnelling elements of the project have been extracted.

G.2 In addition, the British Tunnelling Society has carried out a benchmarking exercise involving some 14 tunnels in the UK and 21 tunnels in other EU countries¹. The tunnels are from the rail, highway, water and power sectors, and from Norway, Spain, Netherlands, Austria, Portugal, Germany, Switzerland, France, Greece and Luxembourg.

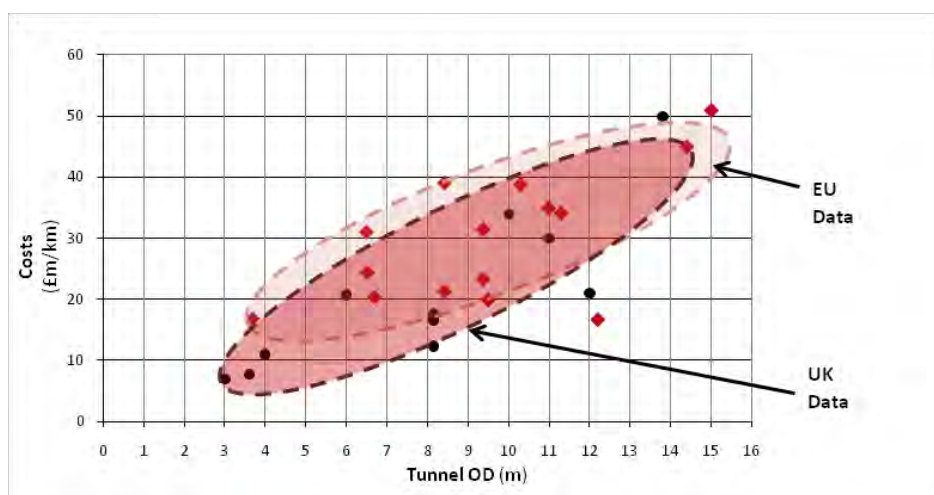
G.3 Tunnelling costs were also obtained from other sources for this study.

Data Analysis

G.4 The data points represent the outturn cost of each tunnelling contract, including portals and shafts, divided by the total length of the tunnel drives.

G.5 Chart G.1 below shows the all-in rate for tunnelling plotted against the tunnel diameter for all the available data points, together with envelopes that encompass the data points of different origins.

Chart G.1: The effects of tunnel outside diameter on unit costs



Source: Infrastructure UK Cost Questionnaires and British Tunnelling Society

¹ Note that not all projects are represented on the below charts due to difficulties obtaining all the requisite data.

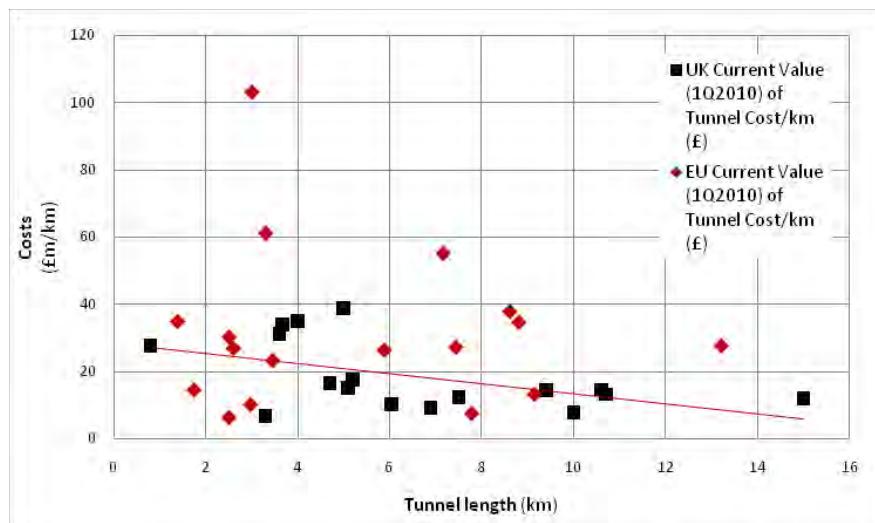
G.6 The light pink envelope encompasses all the European tunnels (red diamonds) with the exception of one outlier. The darker envelope encompasses all the UK tunnels (black circles), again with the exception of one outlier.

G.7 There is a similar scatter of results from the 15 European projects compared with the 12 results from the UK only. There is, however, insufficient data to enable other country-related trends to be established as the 15 EU projects are well-spread amongst the member states.

G.8 There are a number of reasons why a range of results exist, including ground conditions, tunnelling method, lining type. The all-in rate for tunnelling also depends on tunnel length, and this is explored further below.

G.9 Variation of tunnel costs with length of tunnels. The BTS study explored the influence of tunnel length on its cost, and the figure below is taken from their report. Whilst there is a large scatter in the results, a slight trend of reducing unit costs with length of tunnel can be seen.

Chart G.2: The effect of tunnel length on unit costs



Source: Infrastructure UK Cost Questionnaires and British Tunnelling Society.

G.10 It is noted elsewhere in this report that benchmarking of rail projects that involve significant amounts of tunnelling has shown a significantly higher cost in the UK than other European countries. This is explored further in the main body of the report.

Key Findings

G.11 The average unit rate for tunnels of 3m diameter or greater is principally dependent on its diameter. Lesser factors influencing cost include overall length, ground conditions, tunnelling method and lining type.

G.12 The average unit rates for tunnelling construction contracts in the UK are not significantly different to those in Europe.

REPA tunnel options - cost comparison vs HS2 Proposed Scheme: REVISED 17 July 2015

	REPA OPTION C1 (to Liberty Lane)	REPA OPTION C3 (to Liberty Lane)	REPA OPTION C4 (to Liberty Lane)	REPA OPTION C5 (to Leather Lane)	HS2 OPTION C6 (to Green tunnel north portal)	COMMENTARY	
1.00	LAND AND PROPERTY	-32.70	-31.90	-31.90	-32.70	-19.60	Excludes any allowance for re-sale of returned or unused land/property
2.00	TUNNELS	115.47	316.82	205.92	134.54	67.78	
	Bored Tunnels	163.34	370.69	252.81	181.76	116.70	
	Fire Fighting Cavern						
	Green Tunnels	-57.14	-57.14	-57.14	-57.14	-57.14	Removal of S Heath green tunnel
	Portals	-10.38	-10.57	-5.89	-10.38	-10.34	
	Portals at "Gap"	0.00	0.00	0.00	0.00	0.00	
	Shafts	14.19	13.84	16.13	14.19	14.74	One additional shaft required
	Additional disposal costs	5.45	0.00	0.00	6.11	3.82	Options 1, 5 and 6 require additional disposal at southern
3.00	CIVIL ENGINEERING	-48.21	-57.48	-56.20	-57.01	-45.46	
	CUTTINGS	-28.65	-28.65	-28.65	-33.33	-24.30	
	Cuttings	-28.65	-28.65	-28.65	-33.33	-24.30	
	EMBANKMENTS	0.00	0.00	0.00	0.00	0.00	
	EARTHWORKS	-2.96	-2.99	-1.86	-3.03	-2.48	
	Landscaping	-2.96	-2.99	-1.86	-3.03	-2.48	
	ENVIRONMENTAL MITIGATION WORKS	-3.89	-3.91	-3.19	-4.26	-3.16	
	Planting	-3.38	-3.41	-2.90	-3.72	-2.88	
	Noise Barriers	-0.50	-0.50	-0.29	-0.54	-0.28	
	RETAINING WALLS						
	BRIDGES	-7.06	-7.11	-7.16	-10.47	-6.61	
	Overbridge	-4.47	-4.52	-4.57	-7.88	-4.02	
	Underbridge	-2.59	-2.59	-2.59	-2.59	-2.59	
	VIADUCTS						
	HIGHWAYS	-7.18	-7.28	-8.01	-7.18	-7.20	
	OTHER	-6.78	-7.54	-7.33	-7.27	-7.60	
	Culverts	-0.51	-0.51	-0.51	-0.51	-0.51	
	Utilities Diversions	-6.37	-7.13	-6.70	-6.86	-7.03	
	Utilities Connections	0.10	0.10	-0.12	0.10	-0.06	
	EXTENDED PRELIMINARIES	8.31	0.00	0.00	8.53	5.89	Options 1 & 5 assume 12month longer tunnel programme; Option 6 assumes 9month longer tunnel programme; Options 3 & 4 assume no programme delay
5.00	DEPOT AND SIDINGS	0.00	0.00	0.00	0.00	0.00	
6.00	RAILWAY SYSTEMS	21.70	21.70	21.70	21.70	18.40	
8.00	INDIRECT COSTS	16.16	51.06	31.15	18.03	7.40	
		72.42	300.20	170.67	84.56	28.52	
	Less ECP/VE	-6.95	-28.82	-16.38	-8.12	-2.74	
	Net total	65.47	271.38	154.29	76.44	25.78	
	E/o for north portal TBM power supply connection	0.00	0.00	7.00	0.00	0.00	
	Adjusted Net total	65.47	271.38	161.29	76.44	25.78	

OPTION NOTES

1

- Option C1 would extend the existing bored tunnel from Mantles Wood to a new north portal near Liberty Lane
- Option C3 assumes two simple TBMs to construct the bored tunnel from new north portal southwards to Mantles Wood
- Option C4 assumes two TBMs to construct the bored tunnel from new north portal southwards to the Little Missenden shaft
- Option C5 would extend the existing bored tunnel from Mantles Wood to a new north portal near Leather Lane
- Option C6 would extend the existing bored tunnel from Mantles Wood to the Proposed Scheme green tunnel north portal location

COST NOTES

- 1 Costs are point estimates, based at second quarter 2011 levels and therefore exclude contingency and escalation
- 2 Land and property costs are figures provided by CBRE. Property costs exclude costs associated with compensation schemes.
- 3 Construction costs are based on PSC figures as reviewed by the HS2 costs team
- 4 Railway systems costs are figures provided by Parsons Brinkerhoff and include allowance for tunnel cooling
- 5 Indirect costs figures have been provided by the HS2 costs team
- 6 Savings from the Efficiency Challenge Programme and Value Engineering have been provided by the HS2 costs team



CONSTRUCTION (OPTION C5)

Buckinghamshire
Chiltern District

KING'S LANE

Footpath TLE/2
Accommodation
Overbridge

Bowood Lane
Overbridge
Satellite Compound

Bowood Lane
Overbridge

KING'S LANE

Leather Lane
Diversion

Footpath TLE/2
Temporarily Stopped Up

Cottage Farm
Accommodation
Overbridge

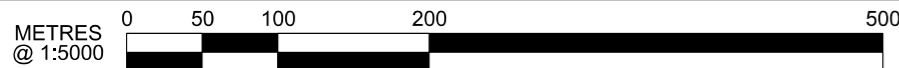
Chiltern Tunnel
North Portal
Satellite Compound

Chiltern Tunnel
North Portal
(Rail Systems)
Satellite Compound

Footpath WEN/37
Temporarily Stopped Up

Buckinghamshire
Aylesbury Vale District

Existing Leather Lane
Temporarily closed and diverted
on to Temporary Access Road



For Continuation Refer to Drawing C222-ATK-EV-DPL-020-550913-PET000000

For Continuation Refer to Drawing C222-ATK-EV-DLP-020-550907-PET000000

P00.1					

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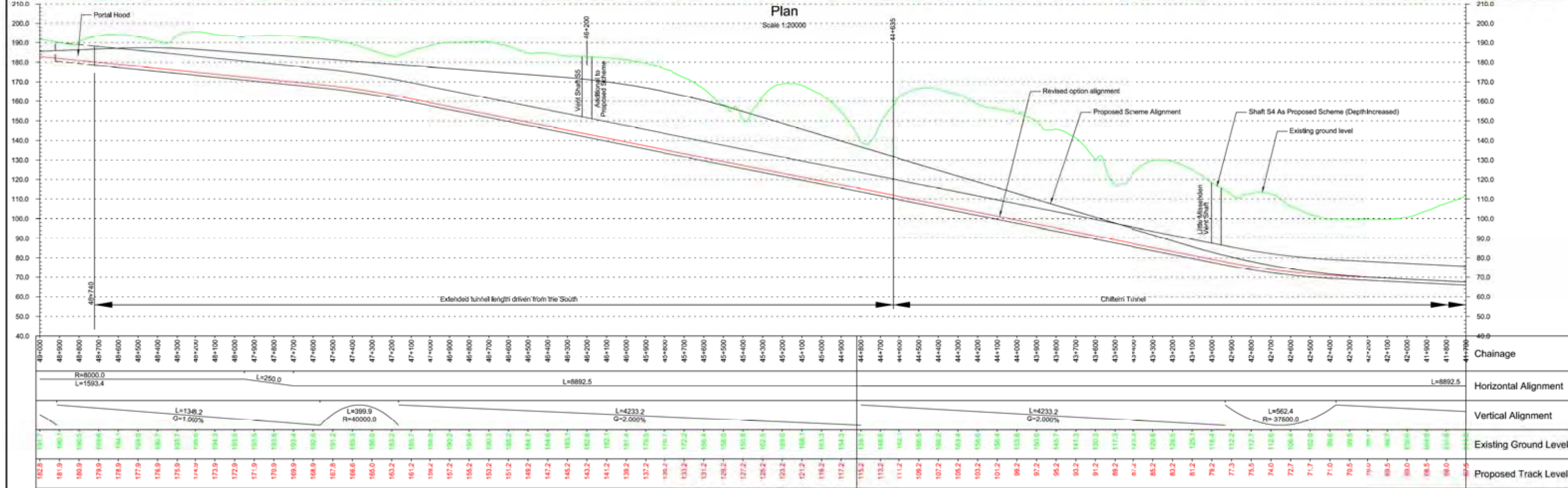
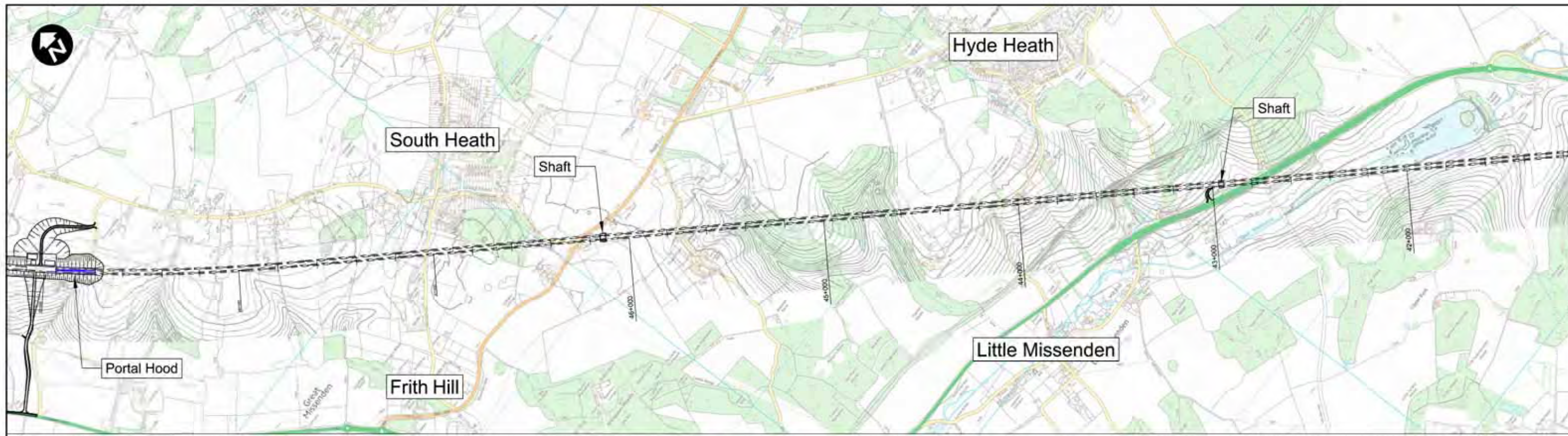
Legends/Notes:

- Satellite construction compound
- Main construction compound
- Tunnel portal
- Rail alignment formation
- Tunnels external extent
- Rail alignment
- Engineering earthworks
- Landscape earthworks
- Land potentially required during construction
- Temporary site access route / haul route
- Construction traffic route
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Temporary PRoW
- Temporary material stockpile

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Creator/Originator
Atkins

Zone	Country South		Project/Contract	Country South Design	
Design Stage	DESIGN-FOR-PETITION		Discipline/Function	Environmental	
Drawing Title	Construction Phase		Drawn	Checked	Approved
	Extended Chiltern Tunnel		Date	Scale	Size
	Option C5		24/09/2014	AS SHOWN	A1
	Drawing No. C222-ATK-EV-DPL-020-550910-PET000000				Rev. P00.1



Profile
Scale H 1:20000 V 1:2000

P00.1	FIRST DRAWN				

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- Legends/Notes:**
- The Chiltern Tunnel will consist of a twin bored tunnel constructed from both the North and South ends.
 - The maximum line speed within the tunnel shall be 320km/h.
 - A 550m² safe area for emergency vehicles is required at the tunnel portals.
 - In the event of an emergency, passengers will be evacuated via a rescue train from a place of relative safety (in the adjacent cell or portal area).
 - A 200m long portal hood structure has been allowed for at each end of the tunnel to mitigate micro-pressure wave burst.
 - Internal bored tunnel diameter of 8.8m.
 - External bored tunnel diameter of 9.6m.

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Zone	Country South	
Design Stage	DESIGN-FOR-PETITION	
Drawn Title	Community Forum Request	
	Chiltern Tunnel Extension to 48+740	
	Option C5	

Project/Contract	Country South Design		
Discipline/Function	Tunnels		
Drawn	TB	Checked	Approved
Date	01/07/2015	Scale	AS SHOWN
		Size	A3
Drawing No.	C22-ATK-TN-DPL-020-000323-PET000000		Rev.
			P00.1

Tunnel Boring Machines – UK tunnel average drive rates for slurry TBMs in Upper Chalk – Recent projects

Project	Start/Finish Dates	Length	Average per week	Source
Lee Tunnel TBM O.D. 8.6m 1 shaft traversed	Feb 02–Jan 04	6,900 m	83m/week	Presentation to Engineering Group of the Geological Society and BTS 29/01/2014
Crossrail Thames Crossings TBM O.D. 6.9m No shafts traversed	Sophia: Jan 13–May 14 Mary: May 13–May 14	3,000 m	Sophia: 76m/week Mary: 91.2m/week	TunnelTalk 11/06/2015 web archive
CTRL Thames Crossings TBM O.D. 7.85m No shafts traversed	July 02-Mar 03 Apr 03-Sept 03	2,550 m	74m/week 96m/week	T&T International Sept 2003 RLE/Hochtief Murphy Joint Venture paper

Appendix A: Infrastructure rate comparison

Base cost only excludes contractor costs, design, testing and commissioning, client costs, risk and Optimism Bias

Item	Unit	Rate (£) Previous	Rate (£) Current	Notes
Permanent Way				
Single track	£ / route m	£860	£1,431	Average rate
2 track	£ / route m	£1,370	£2,273	Average rate
4 track	£ / route m	£2,440	£1,686	Average rate
Overhead Line Equipment				
Single track	£ / route m	£390	£377	Typical rate
2 track	£ / route m	£780	£544	Typical rate
4 track	£ / route m	£1,530	£1,084	Typical rate
Signalling and comms				
Train control - route	£ / route km	£320,000	£320,000	Rate as previously
Train control - point end	£ / point end	£510,000	£510,000	Rate as previously
Earthworks				
Embankment	£ / cubic metre	£21.50	£11.02	Averaged across 4 different heights
Cutting	£ / cubic metre	£17.85	£27.91	Averaged across 4 different depths
Structures				
Single span bridge (12.6m wide)	£ / square metre	£1,900	£2,346	Rail over Road Bridge 2 track 0 - 10 metres high
2 span bridge (12.6m wide)	£ / square metre	£1,400		
3 span bridge (12.6m wide)	£ / square metre	£1,300		
Elevated section (12.6m wide)	£ / square metre	£900	£1,072	Viaduct 2 track 0 - 10 metres high
Retaining Wall	£ / square metre	£370	£632	Average rate across 3 height bands
Tunnels				
Single bore 9.8m internal diameter	£ / tunnel route metre	£45,050	£66,300	Single bore 12m internal diameter Range dependent on length
Twin bore 7.25m internal diameter	£ / tunnel route metre	£61,625	£32,400 to £51,600	
Road				
Rural	£ / square metre	£120	£138	Averaged across different road widths
Urban	£ / square metre	£200	£230	Averaged across different road widths
Major	£ / square metre	£210	£207	Averaged across different road widths

REPA Engineering Report: Appendix 7: Tunnel drivage rates

the TBM was removed from the tunnel and installed for the second drive with the new back up. The same tunnelling crews were used for the second drive so there was little or no learning curve.

Cross Rail

- 2.4 Crossrail provides the most recent tunnelling rates ie since 2010, albeit they are relatively short tunnels]
- 2.5 The average rate for the two longest drivages was 122.3m/week. While the rates of progress for all the tunnels are high for relatively short drivages, some of these rates are depressed by periods in which progress was suspended. The true average rates are therefore higher.

Table A6.5 –Crossrail tunnel boring rates

Tunnel	Length (m)	Fastest week (m)	Average speed (m/week)
Royal Oak – Farringdon (Ada)	6,849	257	92.5
Limmo Peninsula – Farringdon (Elizabeth)	8,268	259	122.5
Pudding Mill Lane – Stepney Green (Ellie 1)	2,765	259	187.9
Limmo Peninsula – Victoria Dock Portal (Ellie 2)	830	248	151
Pudding Mill Lane – Stepney Green (Jessica 1)	2,724	188.8	155.9
Limmo Peninsula – Victoria Dock Portal (Jessica 2)	837	194	90
Plumstead Portal – North Woolwich (Mary)	2,980	160	91.2
Royal Oak Portal – Farringdon (Phyllis)	6,861	249	91.5
Plumstead Portal – North Woolwich (Sophia)	2,990	146	76
Limmo Peninsula – Farringdon (Victoria)	8,270	260	122.1

Thames Tunnel between Beckton and Abbey Mills

- 2.6 The Thames Water sewer tunnel between Beckton and Abbey Mills is in chalk. The tunnelling has recently been completed with a slurry TBM, with a lining with an external diameter of 8.8m and an internal diameter of about 8.1m. As the 6.9km long tunnel was driven from a shaft, the TBM back up was not installed in the tunnel until 432m of the drive had been completed. Over the 423m, which included the learning curve, the average rate of progress was 17m per week. Once the back-up was installed, the average rate of progress to the end of the drive (the marginal rate) was 107m per week, with an overall average of 85m per week. The slurry treatment plant included filter presses to remove the smaller material from the slurry.

Stuttgart 21

- 2.7 The Stuttgart 21 project is a new high speed link between Stuttgart and Ulm and includes a separate new line to Stuttgart Airport. The scheme is 57 km long of which 30km is in bored tunnel. The twin Filder tunnels on the route to the Airport are 9.5km long. The tunnel is being driven from a very restricted site next to a motorway. The segments are being cast 250km from the site and are initially taken by train to a local loading bay where they are transferred to lorries to be taken to site. The rings are 2m wide and have a thickness of 450 or 600mm depending upon the ground conditions. The ground conditions vary from clay, sandstone to chalk, with zones of gypsum.
- 2.8 The TBM will work initially in closed mode for the first 4km of drive with the excavated material removed by conveyor, after which it will be removed and taken back to the portal for the start



The Mitigation and Integration of HS2 within the Chilterns AONB

July 2015