

Supplementary Materials

The following Tables gather the calculations of the three case studies analyzed in the manuscript.

Burata tunnel

Table S1. Material cost to support the tunnel. Original project estimation.

	Length Lf- Lo (m)	RMR	mst (t/m)	mc (t/m)	Mass of steel (t)	Mass of concrete (t)	Total cost (€)
Granite	3,600	60	0.28	21.1	997	75,960	8,201,700
Residual soil	400	30	3.15	57.5	1,260	22,992	4,159,320
Total	4,000						12,361,020

Table S2. Material cost to support the tunnel. Actual conditions estimation.

	Length Lf- Lo (m)	RMR	mst (t/m)	mc (t/m)	Mass of steel (t)	Mass of concrete (t)	Total cost (€)
Granite	2,800	60	0.28	21.1	776	59,080	6,379,100
Residual soil	1,200	30	3.15	57.5	3,780	68,976	12,477,960
Total	4,000						18,857,060

Table S3. Total fixed cost, original project conditions.

	Length Lf- Lo (m)	Section (m ²)	RMR	ab (m/round)	nb (round/day)	T (days)	Total cost (€)
Granite	3,600	90	60	4	2	450	5,400,000
Residual soil	400	90	30	1	2	200	2,400,000
Total	4,000					650	7,800,000

Table S4. Total fixed cost, actual project.

	Length Lf- Lo (m)	Section (m ²)	RMR	ab (m/round)	nb (round/day)	T (days)	Total cost (€)
Granite	2,800	90	60	4	2	350	4,200,000
Residual soil	1,200	90	30	1	2	600	7,200,000
Total	4,000					950	11,400,000

Table S5. Support treatments, original project conditions.

	Length Lf- Lo (m)	Micropile unit cost (€/m)	Micropile length (m)	Number of umbrellas	Number of micropiles	Total cost (€)
Granite	3,600	90	0	0	0	0
Residual soil	400	90	9	80	7760	6,285,600
Total	4,000	90	9	80	7760	6,285,600

Table S6. Support treatments, actual project conditions.

	Length Lf- L₀ (m)	Micropile unit cost (€/m)	Micropile length (m)	Number of umbrellas	Number of micropiles	Total cost (€)
Granite	2,800	90	0	0	0	0
Residual soil	1,200	90	9	240	23,280	18,856,800
Total	4,000	90	9	240	23,280	18,856,800

Table S7. Water drainage of the original and actual project conditions.

	Total volume (m³)	Energy cost (€)	Water treatment cost (€)	Total cost (€)
Original conditions	4,656,325	327,946	1,276,891	1,604,837
Actual conditions	8,180,831	455,298	2,290,633	2,745,931

Pajares' variant Lot 3 tunnel

Table S8. Cost comparison of the lining segments.

	Lining segment type 1	Lining segment type 2	Total cost (€)
Unit cost (€/m)	4,943.63	6,769.28	
Conditions according to original project (m)	850	0	4,202,085
Conditions according to actual project (m)	300	550	5,206,193
Uncertainty cost			1,004,108

Table S9. TBM performance and rock mass conditions.

	Performance (m/day)	Original conditions	Actual conditions
Good rock mass	15	850	300
Poor rock mass	6	0	550
Excavation period (days)		57	111

Table S10. TBM original and actual cost.

	Excavation period (days)	Fixed cost (€)	Total cost (€)
Original conditions	57	30,000	1,710,000
Actual conditions	111	30,000	3,330,000
Uncertainty	54	-	1,620,000

Table S11. Entrapment cost.

	Excavation period (days)	Fixed cost (€)	Total uncertainty cost (€)
Potential entrapment	30	30,000	900,000

Table S12. Methane emissions.

Tunnel section m(m2)	78,5
TBM advance (m/day)	6
rock density (t/m3)	2,2
Production (t/day)	1036
Methane emission rate (m3/t)	11
stretch affected (m)	850
Methane emission (m3/day)	1,562,000
CO2 - CH4 ratio	25
Co2 emitted (tCO2)	25,000
Emissions cost rate (€/tCO2)	14
Total uncertainty cost (€)	+350,000

Table S13. Cutter tools consumption.

	Original project	Actual project	Uncertainty
Cutter tool unit cost (€)	2,500	2,500	
Low abrasiveness rock mass	0	550	
High abrasiveness rock mass	850	300	
High abrasiveness cutter consumption (units/m)	0.7	0.7	
Low abrasiveness cutter consumption (units/m)	0.4	0.4	
Cutters consumed (units)	595	232	
Total cost (€)	580,000	1,487,500	-907,500

Bolaños tunnel

Table S14. Cost related to the geochemical composition of the rock mass excavated.

	Original project	Actual project	Uncertainty
Special landfill construction cost (€)	0	100,000	
Material treatment cost (€/m3)	0	5	
Length assumed with special treatment (m)	0	1,000	
Total cost (€)	0	600,000	+600,000

Table S15. TBM performance in an unstable stretch.

	Original conditions	Actual conditions	Uncertainty
Length (m)	106	106	
Performance (m/day)	25	4	
Excavation time (days)	4	26	
Fixed cost (€/day)	30000	30000	
Total cost (€)	120000	780000	+660000

Table S16. Entrapment cost.

	Excavation period (days)	Fixed cost (€)	Total uncertainty cost (€)
Potential entrapment	30	30,000	+900,000

Table S17. Cost related to special treatments.

Length (m)	1000
Original resin unit consumption (kg/m)	150
Actual resin unit consumption (kg/m)	550
Resin treatment unit cost (€/t)	8400
Original cost (€)	1260000
Actual cost (€)	4620000
Uncertainty cost (€)	+3360000