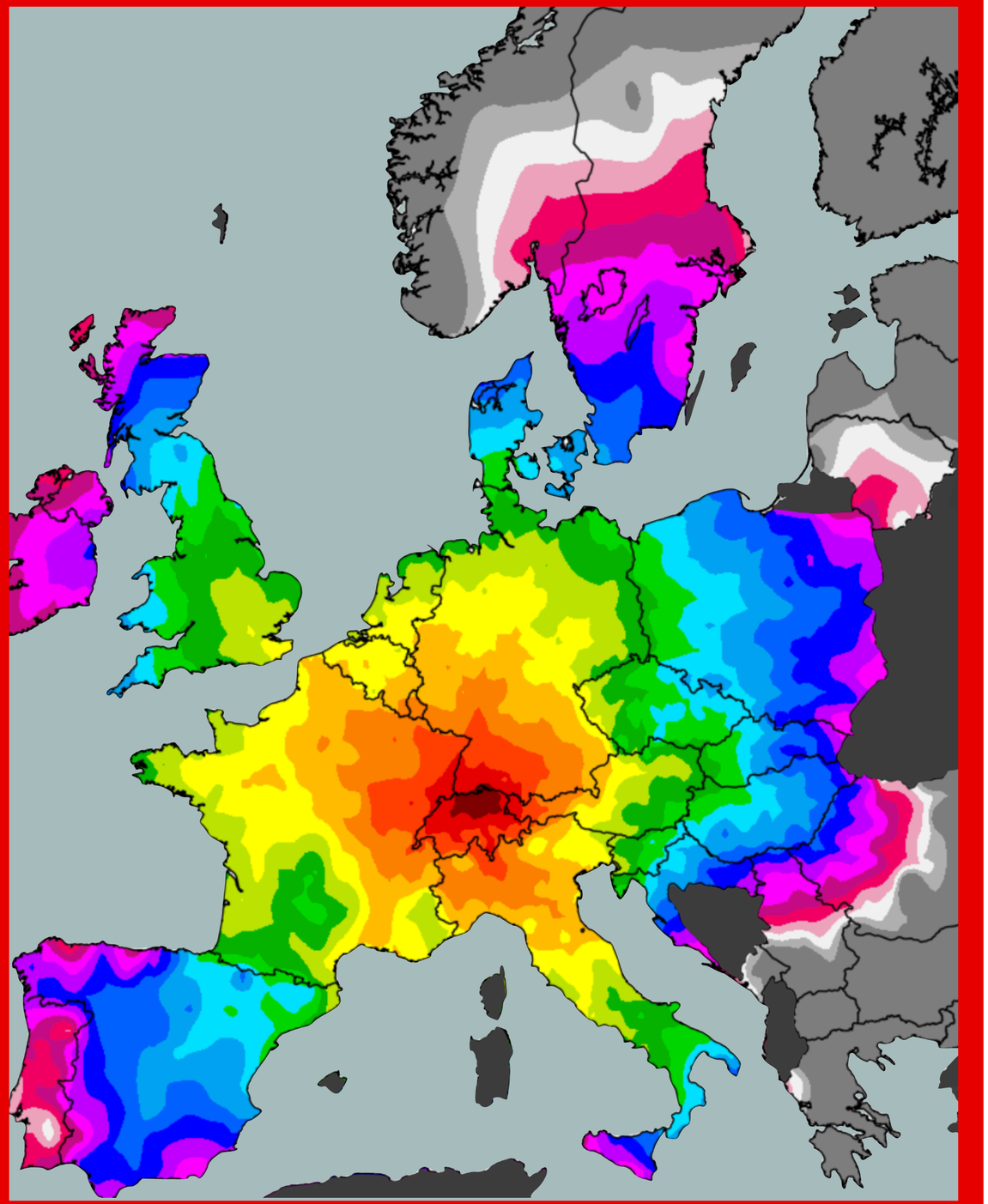


IVT Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

ETH
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Swiss Federal Institute of Technology Zurich

Time Reduction Potential through a Continental-Scale Schedule Optimisation of Long-Distance International Passenger Rail Corridors in Europe

Bachelor Thesis

Matthias Benjamín Andrews García

Headed and supervised by:

Prof. Dr. Francesco Corman, Dr. Bernardo Martin Iradi, Thomas Spanninger

Adaptiert für
Fachtagung “Internationaler Bahnverkehr: Nachfrage TOPP! – Angebot FLOPP?”
25.10.2024

Inhalt

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E P M R A C

Long-Distance
European Rail Travel

Promotional Map for the Simplon Orient Express



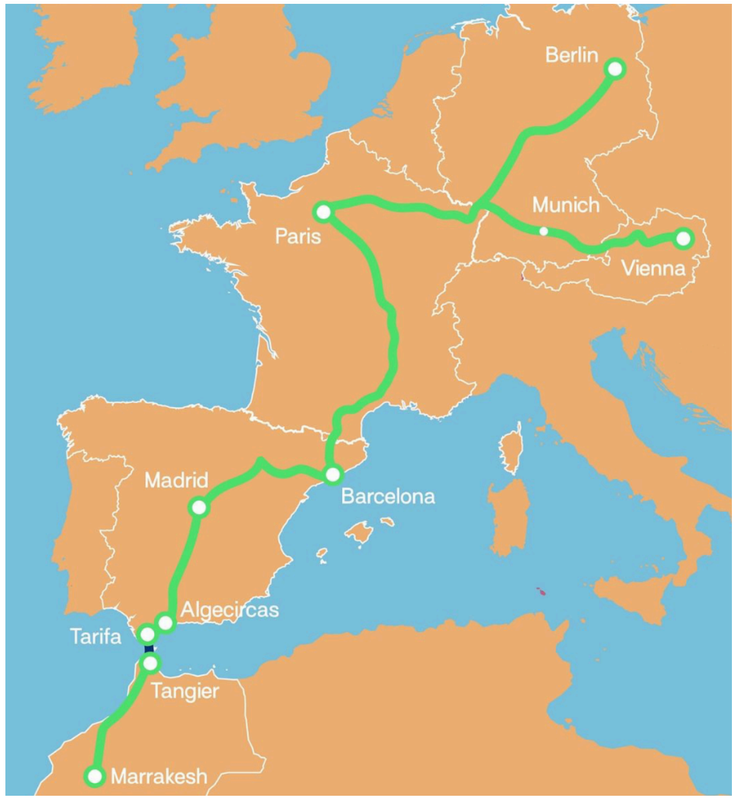
Source: Walther Spinner (1947)

Interrail Validity Map



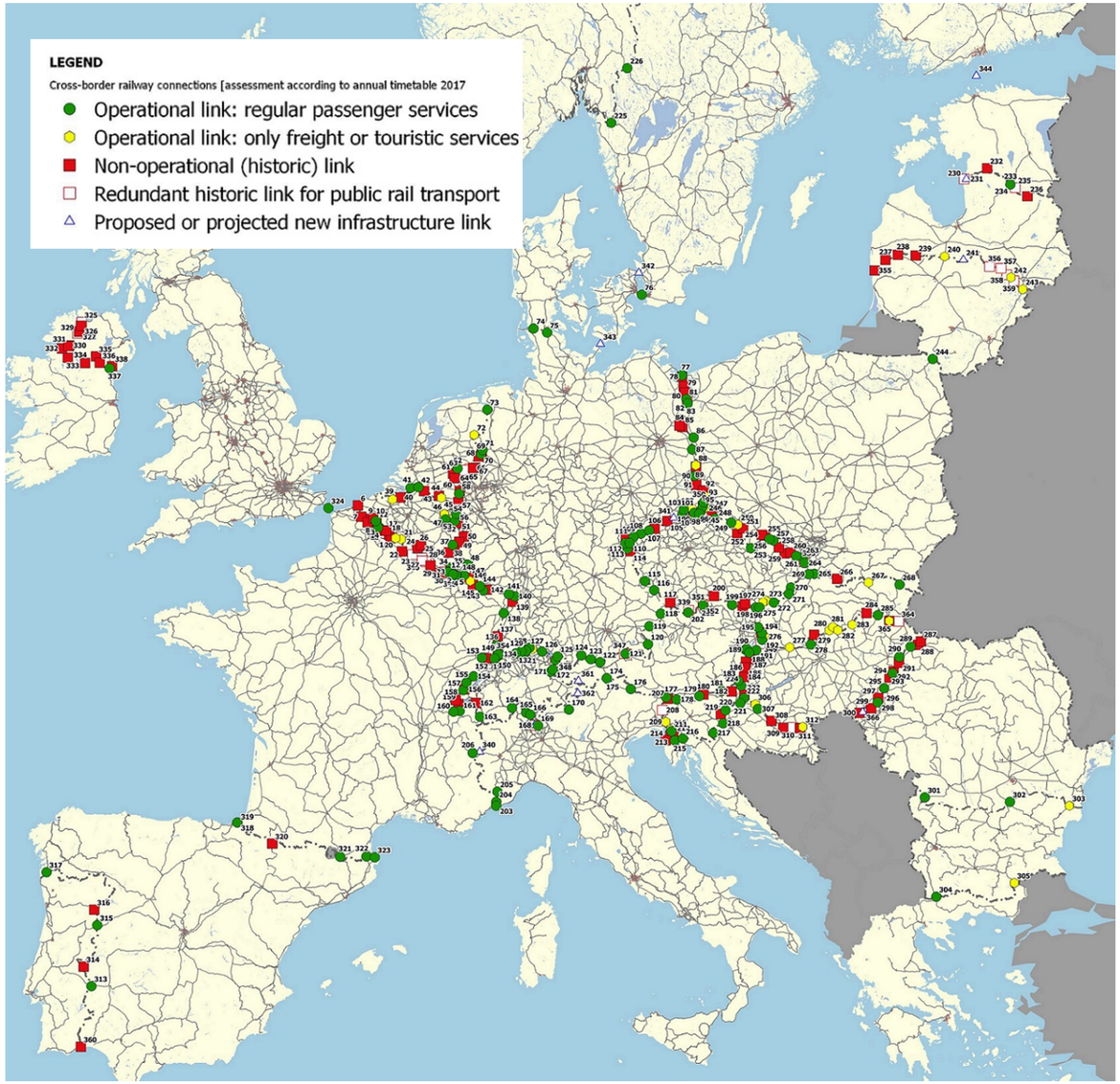
Source: Interrail (2024)

Promotional Map for a Long-Distance Rail Route



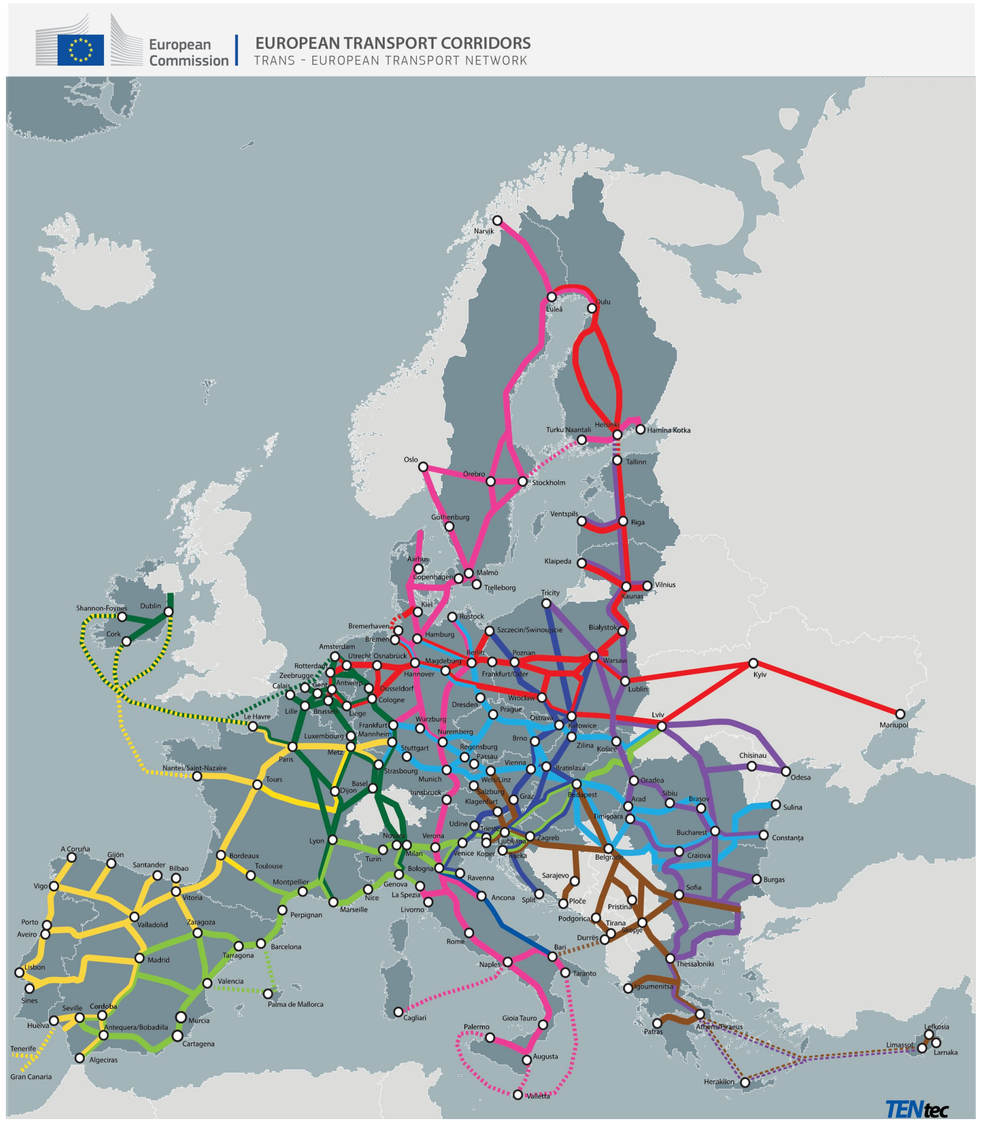
Source: Traivelling (2024)

Overview of European cross-border rail connections



Source: European Commission (2018)

TEN-T Core Network Corridors Schematic Map



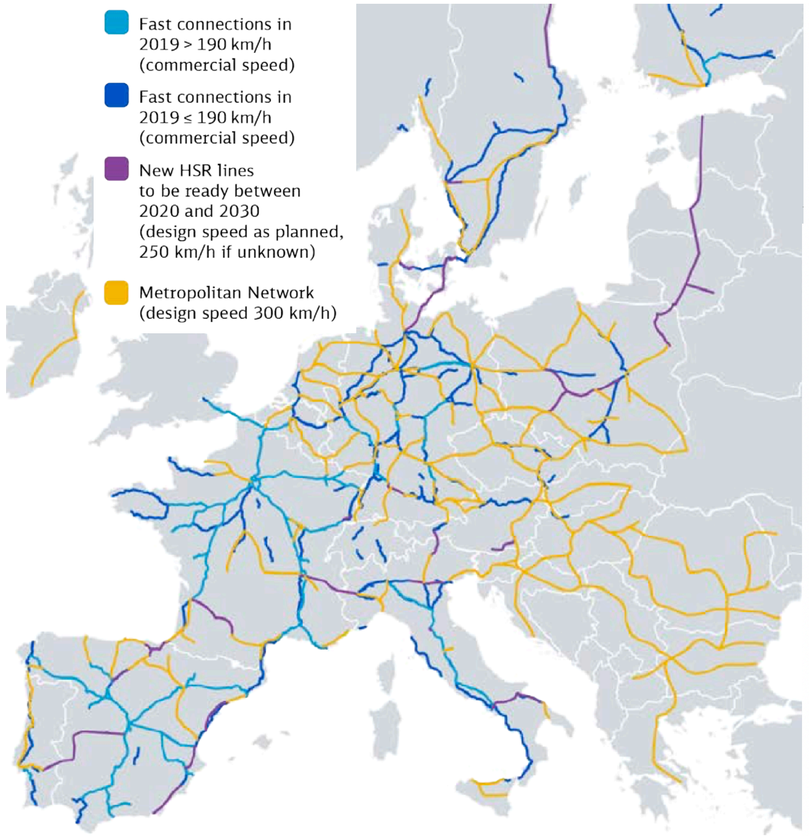
Source: European Commission (2023)

E P M R A C

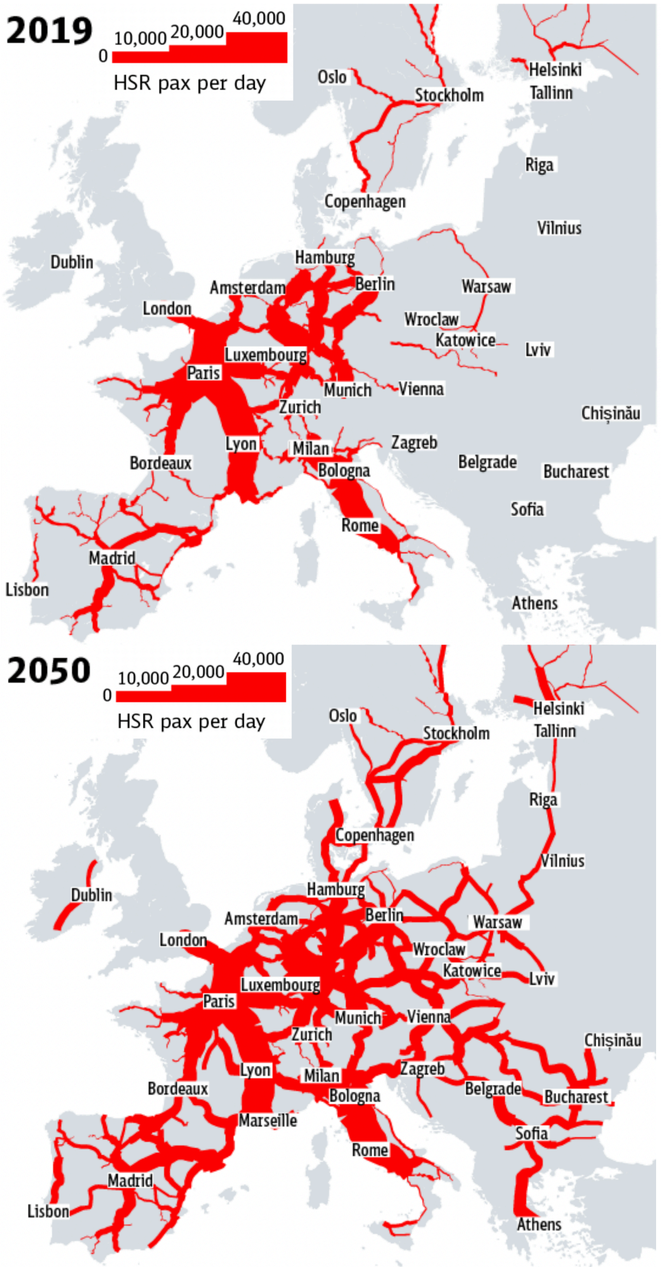
High Speed Network

Infrastructure Proposals

Vision 2050: European Metropolitan Network

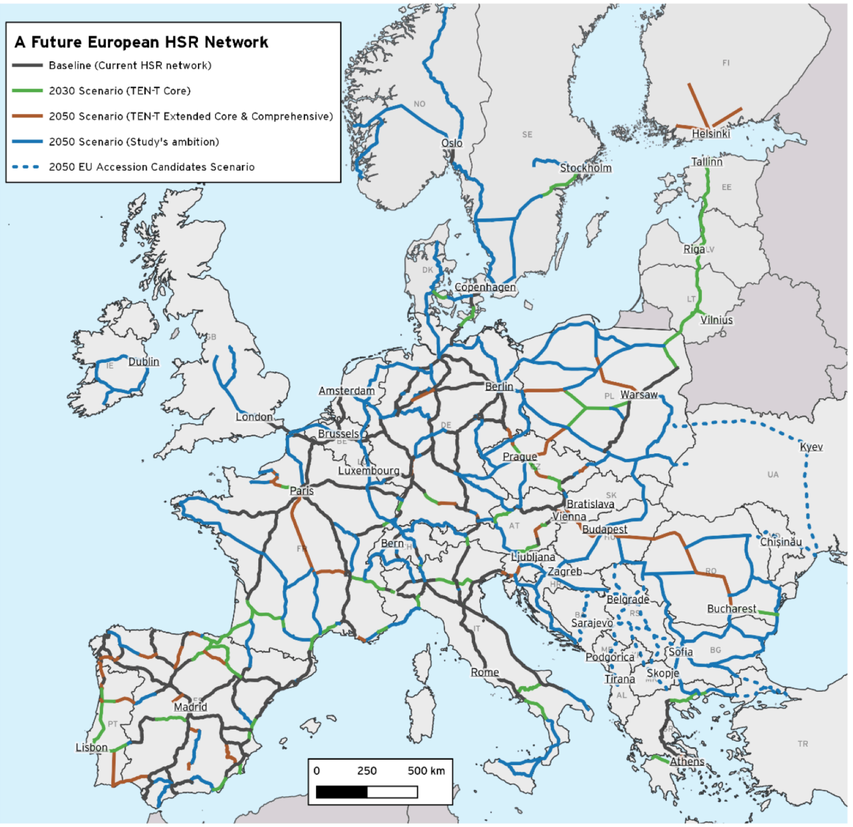


Past vs expected 2050 HSR passenger volumes



Source: PTV Group (2019), in collaboration with DB, ČD, NS, ÖBB, PKP, RENFE, SBB, SNCB, SNCF, Trenitalia

Vision 2050: European Metropolitan Network

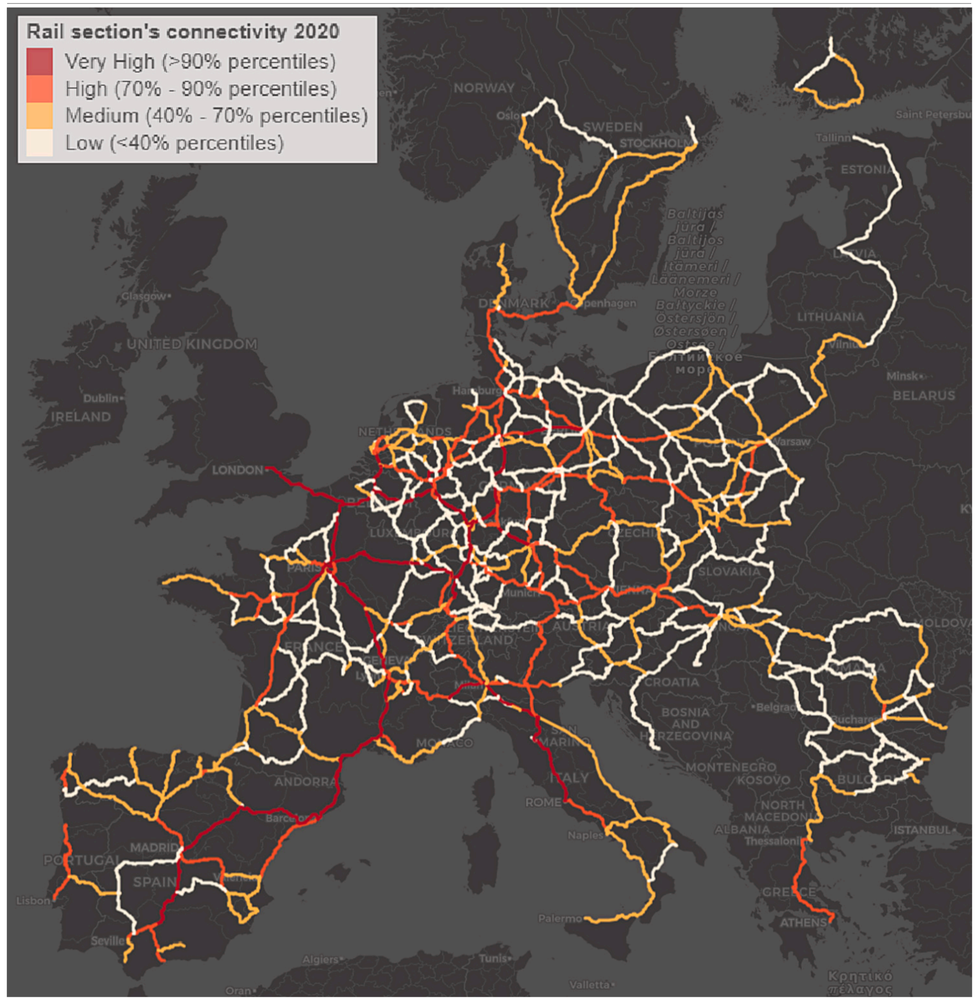


Source: Community of European Railway and Infrastructure Companies (2023)

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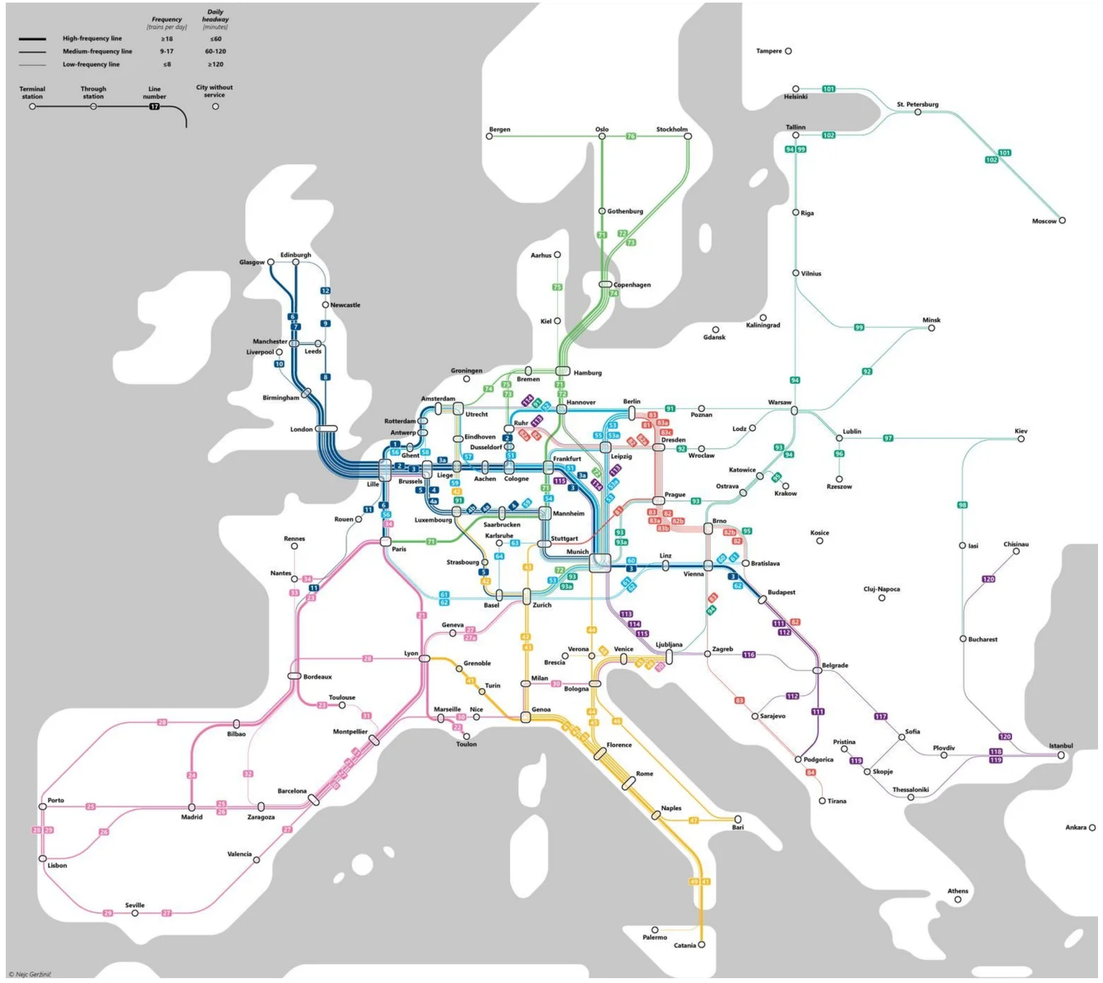
High Speed Network
Connectivity Improvement

Connectivity of rail network corridors in Europe



Source: Meyer et al. (2023)

Proposed European high-speed rail network plan



Source: Grolle et al. (2024)

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E P M R A C

Speeds

Top vs Average

Fastest timetabled average speeds between global station pairs

Train	From	To	Distance *km*	Time *min*	Speed *km/h*
250-350 km/h					
1. China (350 km/h)					
G17/G39	Beijing Nan	Nanjing Nan	1 021·9	193	317·7
G8/G19/G7/G3/G11/G4	Nanjing Nan	Jinan Xi[1]	616·0	117	315·9
G22	Nanjing Nan	Bejing Nan	1 021·9	196	312·8
G1	Jinan Xi	Nanjing	616·0	120	308·0
2. Italy (300 km/h)					
Italo 9955	Milano Rogoredo	Reggio Emilia AV	145·3	32	272·4
Several Italo	Roma Tiburtina	Milano Rogoredo	560·3	158	212·8
Several Frecciarossa	Roma Tiburtina	Milano Rogoredo	560·3	160	210·1
Italo 9907	Roma Termini	Napoli Centrale	222·4	66	202·2
3. France (320 km/h)					
TGV 5479/5441/5422	Champagne-Ardenne TGV	Lorraine TGV[1]	167·6	37	271·8
Ouigo 7851	Lyon St-Exupéry	Aix-en-Provence	289·4	64	271·3
TGV 8505/8500	Paris Montparnasse	Bordeaux St-Jean[1]	537·0	128	251·7
TGV 9561	Paris Est	Strasbourg	439·6	105	251·2
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Several trains	Omiya	Sendai[1]	294·1	66	267·4
Several trains	Morioka	Sendai[1]	171·1	39	263·2
N52	Kokura	Hiroshima	192·0	44	261·8
N1	Shin Yokohama	Nagoya	316·5	76	249·9
5. Spain (310 km/h)					
AVE 3062	Zaragoza Delicias	Guadalajara-Yebes	242·3	56	259·6
Several trains	Madrid Atocha	Barcelona Sants[1]	621·0	150	248·4
AVE 5149/5340	Requena/Utiel	Cuenca F'do Zóbel[1]	132·4	33	240·6
AVE 5141	Valencia Joaquin Sorolla	Madrid Atocha	391·0	98	239·4
6. Taiwan (300 km/h)					
Several trains	Zuoying	Taichung	179·5	42	256·4
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7. Germany (300 km/h)					
ICE 772/10	Frankfurt Flughafen	Siegburg/Bonn	143·3	36	238·8
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KTX 503	Gwangmyeong	Chonan Asan	74·0	20	222·0
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Source: Railway Gazette International (2019)

High-speed lines of Europe, coloured by top speed



Source: Wikimedia (2024)

Speeds

Top vs Average

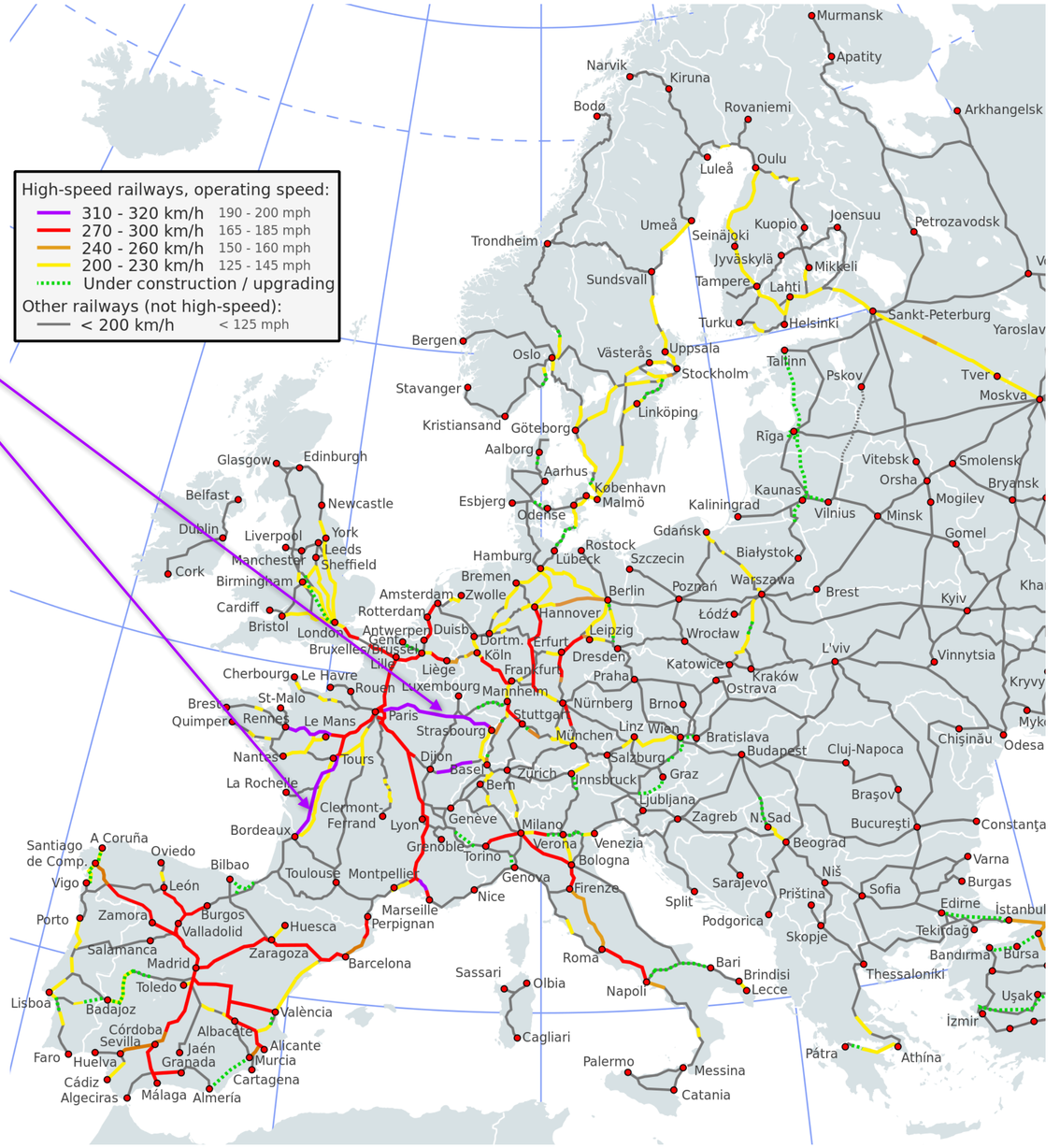
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Speeds

Top vs Average

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Speeds

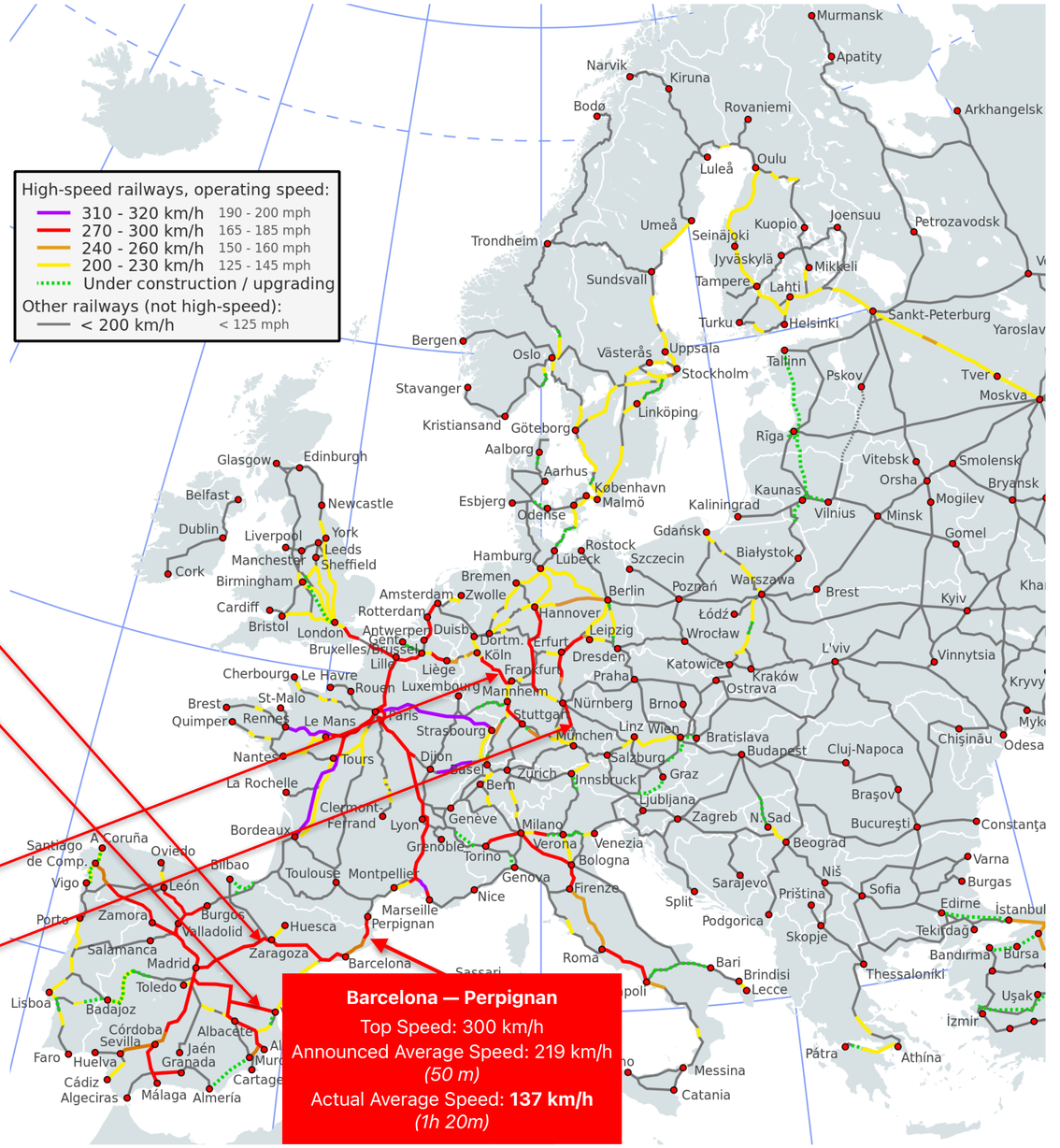
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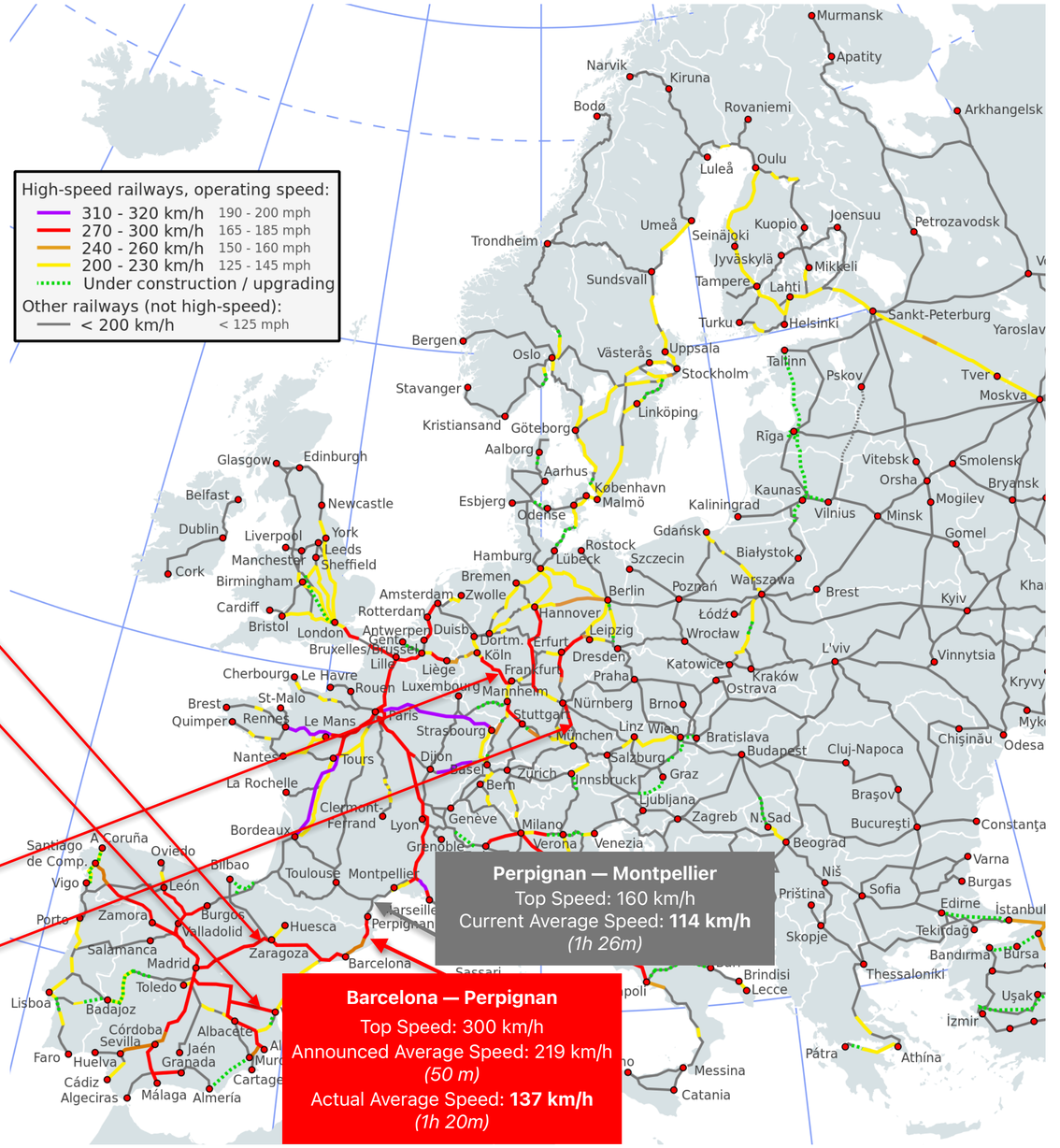
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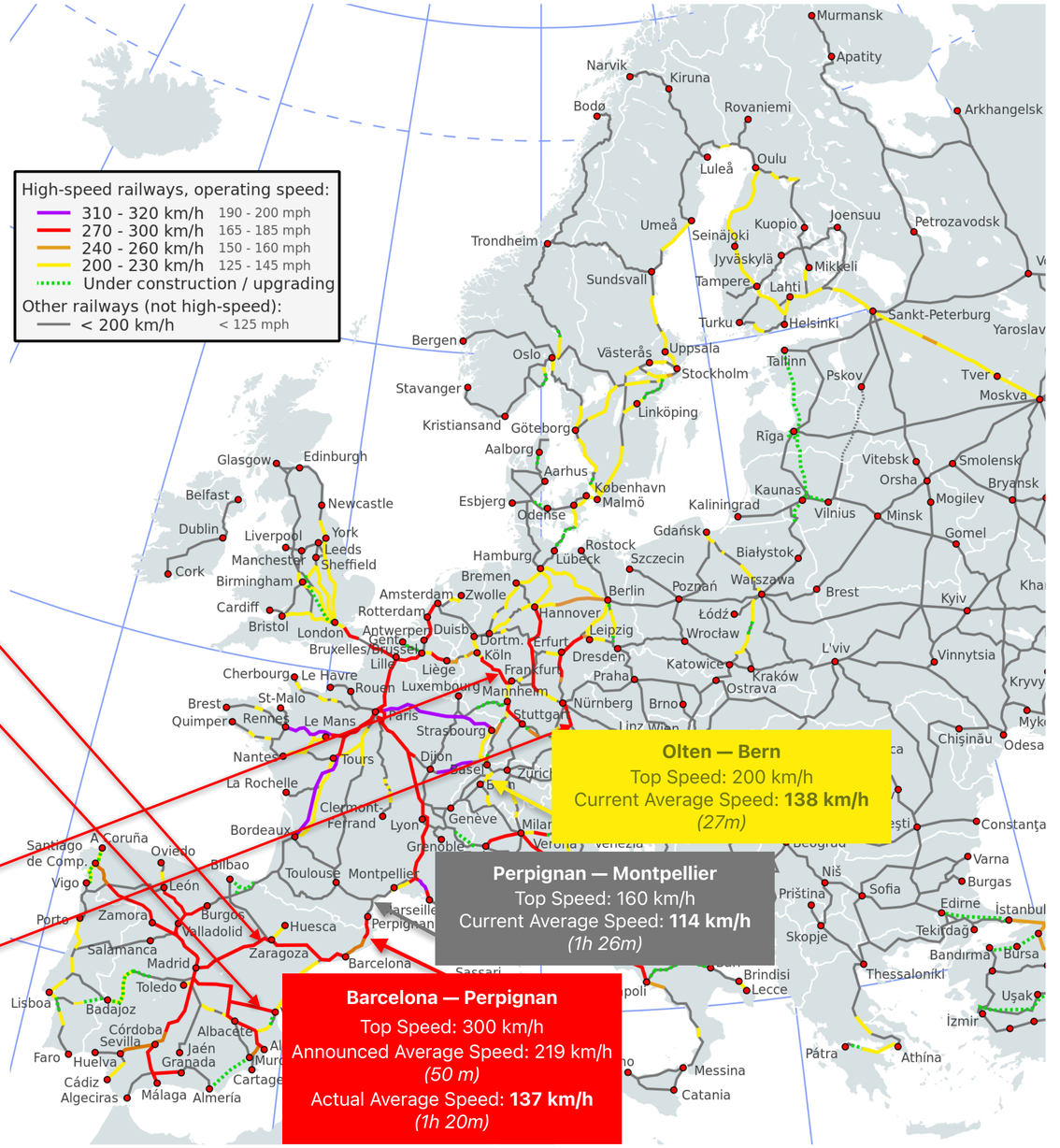
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G1	Jinan Xi	Nanjing	616·0	120	308·0
2. Italy (300 km/h)					
Italo 9955	Milano Rogoredo	Reggio Emilia AV	145·3	32	272·4
Several Italo	Roma Tiburtina	Milano Rogoredo	560·3	158	212·8
Several Frecciarossa	Roma Tiburtina	Milano Rogoredo	560·3	160	210·1
Italo 9907	Roma Termini	Napoli Centrale	222·4	66	202·2
3. France (320 km/h)					
TGV 5479/5441/5422	Champagne-Ardenne TGV	Lorraine TGV[1]	167·6	37	271·8
Ouigo 7851	Lyon St-Exupéry	Aix-en-Provence	289·4	64	271·3
TGV 8505/8500	Paris Montparnasse	Bordeaux St-Jean[1]	537·0	128	251·7
TGV 9561	Paris Est	Strasbourg	439·6	105	251·2
4. Japan (320 km/h)					
Several trains	Omiya	Sendai[1]	294·1	66	267·4
Several trains	Morioka	Sendai[1]	171·1	39	263·2
N52	Kokura	Hiroshima	192·0	44	261·8
N1	Shin Yokohama	Nagoya	316·5	76	249·9
5. Spain (310 km/h)					
AVE 3062	Zaragoza Delicias	Guadalajara-Yebes	242·3	56	259·6
Several trains	Madrid Atocha	Barcelona Sants[1]	621·0	150	248·4
AVE 5149/5340	Requena/Utiel	Cuenca F'do Zóbel[1]	132·4	33	240·6
AVE 5141	Valencia Joaquin Sorolla	Madrid Atocha	391·0	98	239·4
6. Taiwan (300 km/h)					
Several trains	Zuoying	Taichung	179·5	42	256·4
Several trains	Taichung	Banqiao	152·6	38	240·9
200-249 km/h					
7. Germany (300 km/h)					
ICE 772/10	Frankfurt Flughafen	Siegburg/Bonn	143·3	36	238·8
ICE 715/214/1223	Siegburg/Bonn	Montabaur[1]	63·1	18	210·3
Several trains	Halle	Erfurt[1]	92·8	27	206·1
ICE 827	Nürnberg	Ingolstadt	90·1	27	200·2
8. Morocco (300 km/h)					
All trains	Kénitra	Tanger[1]	193·9	50	232·7
9. South Korea (305 km/h)					
KTX 503	Gwangmyeong	Chonan Asan	74·0	20	222·0
Several SRT	Gwangju	Iksan	92·7	27	206·0
Several KTX	Dongdaegu	Daejeon	133·3	40	200·0
Several SRT	Dongdaegu	Daejeon	133·3	40	200·0

Source: Railway Gazette International (2019)

High-speed lines of Europe, coloured by top speed



Source: Wikimedia (2024)

Structural Inefficiencies

Current Berlin ↔ Tallinn Rail Timetable (1774.5km)

Station	Travel Time	Dwell Time				Dwell Time	Travel Time	Station
Tallinn			21:06	arrive depart	07:50			Tallinn
	10h 6m						9h 57m	
Riga		17m	11:00	depart arrive	17:47	21h 41m		Riga
	4h 12m		10:43	arrive depart	15:28		4h 37m	
Kaunas		14h 3m	06:31	depart arrive	20:05	17h 33m		Kaunas
	10h 9m		16:28	arrive depart	13:38		7h 43m	
Warszawa		4h 40m	05:19	depart arrive	20:21	1h 44m		Warszawa
	7h 18m		00:39	arrive depart	22:05		10h 54m	
Berlin			17:21	depart arrive	08:59			Berlin
	1d 7h 45m						1d 9h 11m	
TOTAL	2d 2h 45m	19h 0m				1d 16h 58m	3d 2h 9m	TOTAL

Structural Inefficiencies

Current Berlin ↔ Tallinn Rail Timetable (1774.5km)

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	10h 6m						9h 57m	
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	4h 12m		10:43	arrive depart	15:28		4h 37m	
Kaunas		14h 3m	06:31	depart arrive	20:05	17h 33m		Kaunas
	10h 9m		16:28	arrive depart	13:38		7h 43m	
Warszawa		4h 40m	05:19	depart arrive	20:21	1h 44m		Warszawa
	7h 18m		00:39	arrive depart	22:05		10h 54m	
Berlin			17:21	depart arrive	08:59			Berlin
	1d 7h 45m						1d 9h 11m	
TOTAL	2d 2h 45m	19h 0m				1d 16h 58m	3d 2h 9m	TOTAL

Berlin — Tallinn
Total Average Speed:
35.0 km/h

Tallinn — Berlin
Total Average Speed:
23.9 km/h

Structural Inefficiencies

Current Berlin ↔ Tallinn Rail Timetable (1774.5km)

Station	Travel Time	Dwell Time				Dwell Time	Travel Time	Station
Tallinn			21:06	arrive depart	07:50			Tallinn
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	10h 9m		16:28	arrive depart	13:38		7h 43m	
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	7h 18m		00:39	arrive depart	22:05		10h 54m	
Berlin			17:21	depart arrive	08:59			Berlin
	1d 7h 45m						1d 9h 11m	
TOTAL	2d 2h 45m	19h 0m				1d 16h 58m	3d 2h 9m	TOTAL

Berlin — Tallinn
Total Average Speed:
35.0 km/h

Berlin — Tallinn
Average speed excluding dwell time at shown 3 intermediate stops: **55.9** km/h

Tallinn — Berlin
Average speed excluding dwell time at shown 3 intermediate stops: **53.5** km/h

Tallinn — Berlin
Total Average Speed:
23.9 km/h

Structural Inefficiencies

Current Berlin ↔ Tallinn Rail Timetable (1774.5km)

Station	Travel Time	Dwell Time				Dwell Time	Travel Time	Station
Tallinn	10h 6m	17m	21:06		07:50	21h 41m	9h 57m	Tallinn
Riga	4h 12m		11:00		17:47		4h 37m	Riga
			10:43	arrive depart	15:28			
Kaunas	10h 9m	14h 3m	06:31	depart arrive	20:05	17h 33m	7h 43m	Kaunas
			16:28	arrive depart	13:38			
Warszawa	7h 18m	4h 40m	05:19	depart arrive	20:21	1h 44m	10h 54m	Warszawa
			00:39	arrive depart	22:05			
Berlin	1d 7h 45m		17:21	depart arrive	08:59		1d 9h 11m	Berlin
TOTAL	2d 2h 45m	19h 0m				1d 16h 58m	3d 2h 9m	TOTAL

Zurzeit **9h57m**
inkl. 3h34m Umsteigen

Berlin — Tallinn
Total Average Speed:
35.0 km/h

Berlin — Tallinn
Average speed excluding dwell time at shown 3 intermediate stops: **55.9** km/h

Tallinn — Berlin
Average speed excluding dwell time at shown 3 intermediate stops: **53.5** km/h

Tallinn — Berlin
Total Average Speed:
23.9 km/h

Structural Inefficiencies

Current Berlin ↔ Tallinn Rail Timetable (1774.5km)

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TOTAL	2d 2h 45m	19h 0m	05:19	depart arrive	20:21	1d 16h 58m	3d 2h 9m	TOTAL
			00:39	arrive depart	22:05			
			17:21	depart arrive	08:59			

Zurzeit **9h57m**
inkl. 3h34m Umsteigen

Zurzeit **4h12m**
inkl. 17min Umsteigen

Berlin — Tallinn
Total Average Speed:
35.0 km/h

Berlin — Tallinn
Average speed excluding dwell time at shown 3 intermediate stops: **55.9** km/h

Tallinn — Berlin
Average speed excluding dwell time at shown 3 intermediate stops: **53.5** km/h

Tallinn — Berlin
Total Average Speed:
23.9 km/h

Structural Inefficiencies

Current Berlin ↔ Tallinn Rail Timetable (1774.5km)

Station	Travel Time	Dwell Time				Dwell Time	Travel Time	Station
Tallinn								Tallinn
	10h 6m		21:06	Zurzeit **9h57m** inkl. 3h34m Umsteigen	07:50		9h 57m	
Riga		17m	11:00		17:47	21h 41m		Riga
	4h 12m		10:43	Zurzeit **4h12m** inkl. 17min Umsteigen	15:28		4h 37m	
Kaunas		14h 3m	06:31		20:05	17h 33m		Kaunas
	10h 9m		16:28	Zurzeit **7h21m** zu anderen Tageszeiten	13:38		7h 43m	
Warszawa		4h 40m	05:19		20:21	1h 44m		Warszawa
	7h 18m		00:39	arrive depart	22:05		10h 54m	
Berlin			17:21	depart arrive	08:59			Berlin
	1d 7h 45m						1d 9h 11m	
TOTAL	2d 2h 45m	19h 0m				1d 16h 58m	3d 2h 9m	TOTAL

Berlin — Tallinn
Total Average Speed:
35.0 km/h

Berlin — Tallinn
Average speed excluding dwell time at shown 3 intermediate stops: **55.9** km/h

Tallinn — Berlin
Average speed excluding dwell time at shown 3 intermediate stops: **53.5** km/h

Tallinn — Berlin
Total Average Speed:
23.9 km/h

Structural Inefficiencies

Current Berlin ↔ Tallinn Rail Timetable (1774.5km)

Station	Travel Time	Dwell Time			Dwell Time	Travel Time	Station
Tallinn			21:06	07:50			Tallinn
	10h 6m			Zurzeit **9h57m** inkl. 3h34m Umsteigen		9h 57m	
Riga		17m	11:00	17:47	21h 41m		Riga
	4h 12m		10:43	15:28		4h 37m	
Kaunas		14h 3m	06:31	20:05	17h 33m		Kaunas
	10h 9m		16:28	13:38		7h 43m	
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	1d 7h 45m					1d 9h 11m	
TOTAL	2d 2h 45m	19h 0m			1d 16h 58m	3d 2h 9m	TOTAL

Zurzeit **4h12m** inkl. 17min Umsteigen

Zurzeit **7h21m** zu anderen Tageszeiten

Zurzeit **5h5m** zu anderen Tageszeiten

Berlin — Tallinn
Total Average Speed:
35.0 km/h

Berlin — Tallinn
Average speed excluding dwell time at shown 3 intermediate stops: **55.9** km/h

Max Speed Achievable Today
Average speed excluding transfer time (22h 44m):
78.1 km/h

with example 1h total transfer time (23h 44m):
74.8 km/h

Tallinn — Berlin
Average speed excluding dwell time at shown 3 intermediate stops: **53.5** km/h

Tallinn — Berlin
Total Average Speed:
23.9 km/h

E P M R A C

Structural Inefficiencies

Vergleich mit Rail Baltica (2030):
Tallinn ↔ Warszawa (950km) in **6h47m** angestrebt → durchschnittlich **140 km/h**

Ohne Rail Baltica heute erreichbar nach einer Fahrplankoordination:
Tallinn ↔ Warszawa (1200km) in **17h 49m** (inkl. Stoppzeiten gemäss Rail Baltica) → durchschnittlich **67.3 km/h**

Heutige unkoordinierte Fahrpläne:
Warszawa → Tallinn (1200km) **1d 14h 47m** Richtung Norden → durchschnittlich **30.9 km/h**
Tallinn → Warszawa (1200km) **2d 13h 31m** Richtung Süden → durchschnittlich **19.5 km/h**

Current Berlin ↔ Tallinn Rail Timetable (1774.5km)

Station	Travel Time	Dwell Time			Dwell Time	Travel Time	Station
Tallinn							Tallinn
	10h 6m		21:06	07:50		9h 57m	
Riga		17m	11:00	17:47	21h 41m		Riga
	4h 12m		10:43	15:28		4h 37m	
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Warszawa		4h 40m	05:19	20:21	1h 44m		Warszawa
	7h 18m		00:39	22:05		10h 54m	
Berlin			17:21	08:59			Berlin
	1d 7h 45m					1d 9h 11m	
TOTAL	2d 2h 45m	19h 0m			1d 16h 58m	3d 2h 9m	TOTAL

Zurzeit **9h57m** inkl. 3h34m Umsteigen

Zurzeit **4h12m** inkl. 17min Umsteigen

Zurzeit **7h21m** zu anderen Tageszeiten

Zurzeit **5h5m** zu anderen Tageszeiten

Berlin — Tallinn
Total Average Speed:
35.0 km/h

Berlin — Tallinn
Average speed excluding dwell time at shown 3 intermediate stops: **55.9** km/h

Max Speed Achievable Today
Average speed excluding transfer time (22h 44m):
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with example 1h total transfer time (23h 44m):
74.8 km/h

Tallinn — Berlin
Average speed excluding dwell time at shown 3 intermediate stops: **53.5** km/h

Tallinn — Berlin
Total Average Speed:
23.9 km/h

ETH

Einleitung

Problem

Methods

Results

Analysis

Conclusion

ETH

E P M R A C

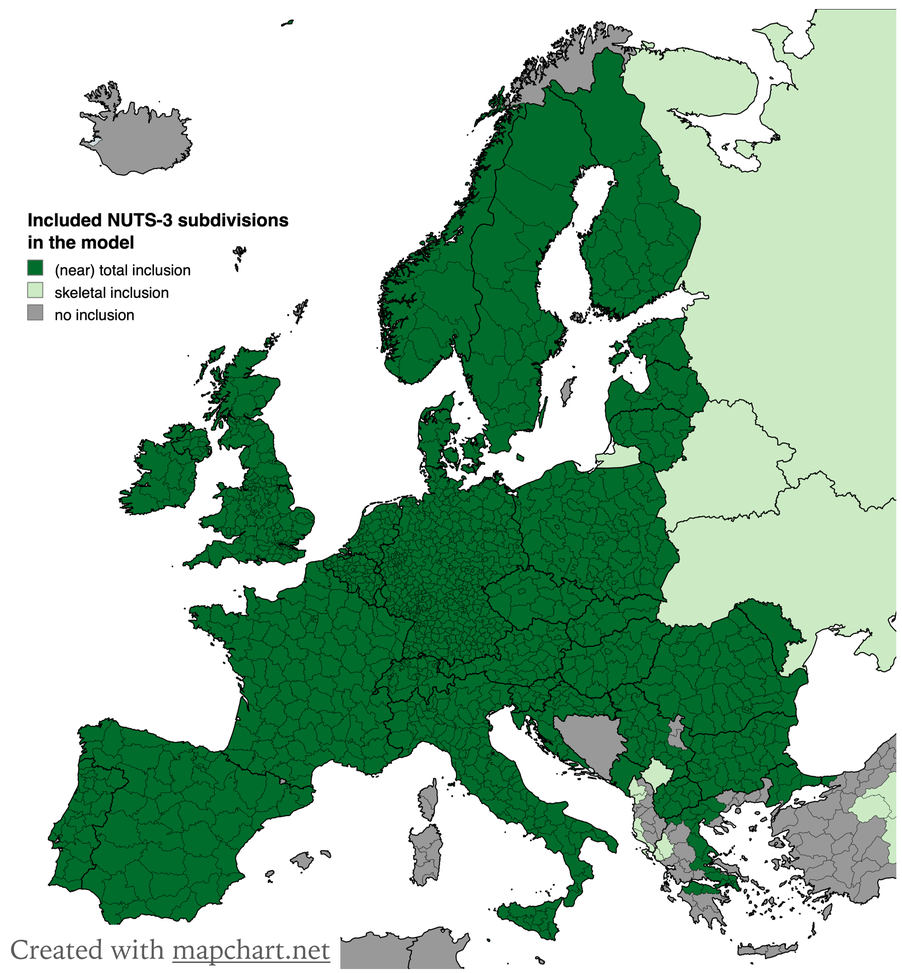
Graph

Node Database

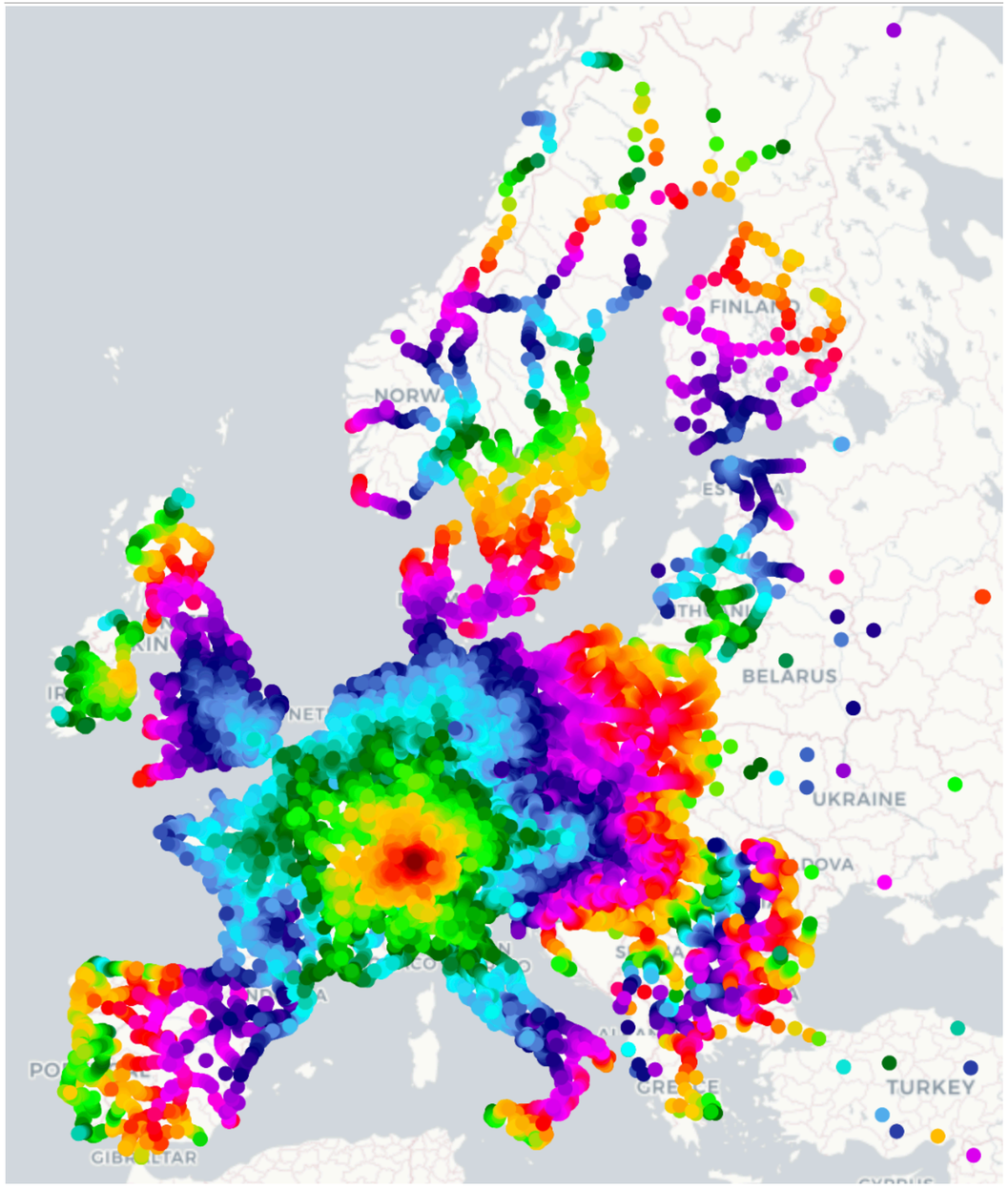
31616 Bahnhöfe

30+ Länder

Regions of Europe included in the model



Stations included in the model



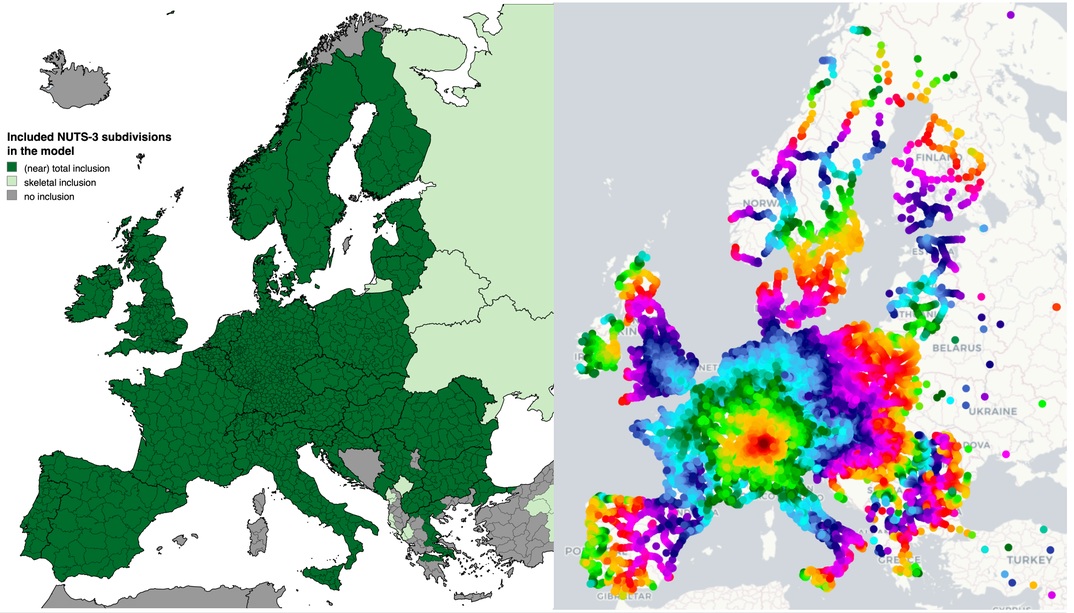
ETH

E P M R A C

Graph

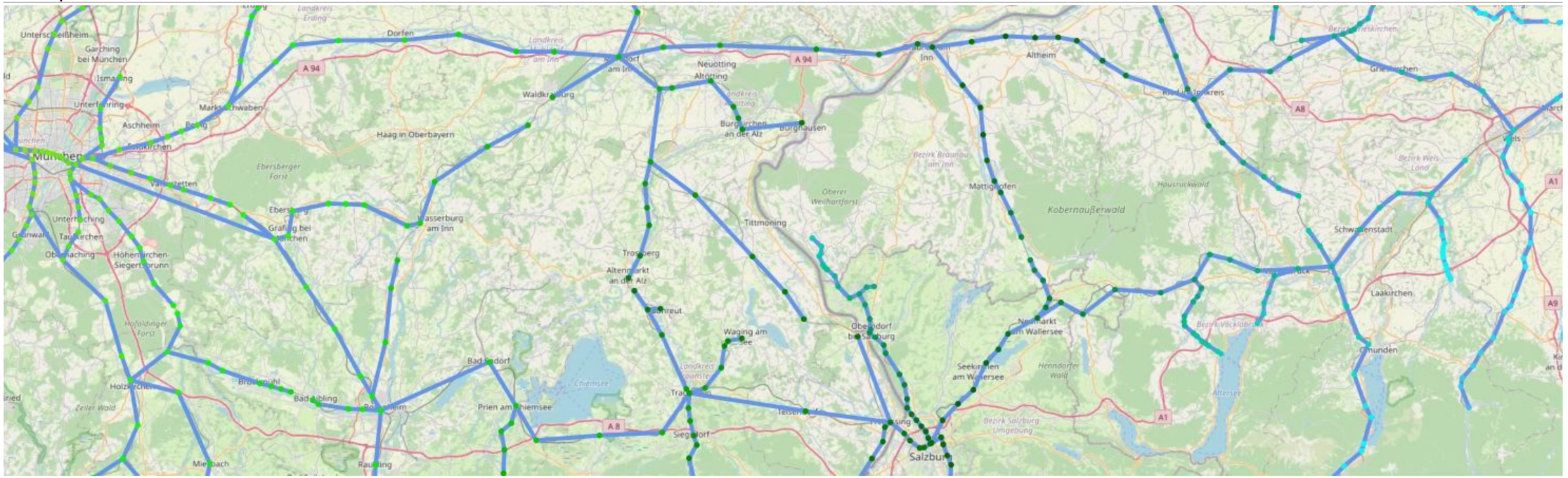
Link Database

31616 Bahnhöfe
30+ Länder



34618 links
2.16 links per station
171 future links by 2050

Example of included links

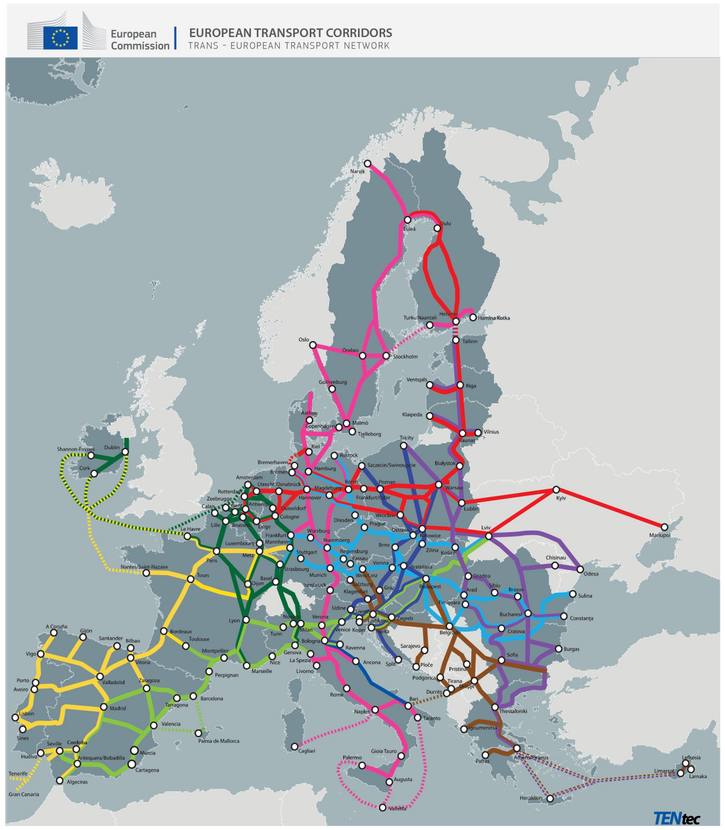


ETH

E P M R A C

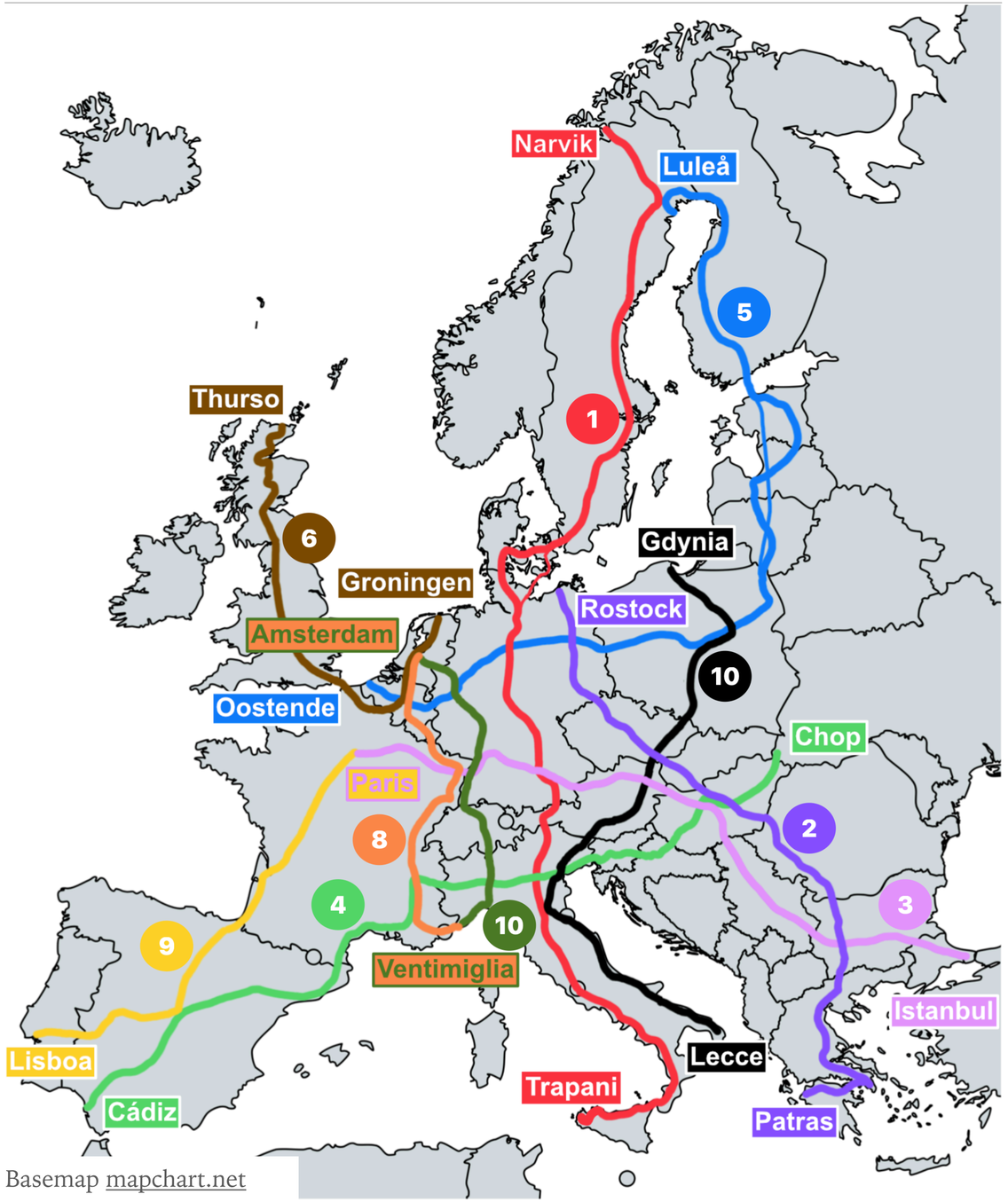
Corridor Selection

TEN-T Core Network Corridors Schematic Map



Source: European Commission (2023)

Chosen Cross-European Corridors



Basemap mapchart.net

ETH

Corridor

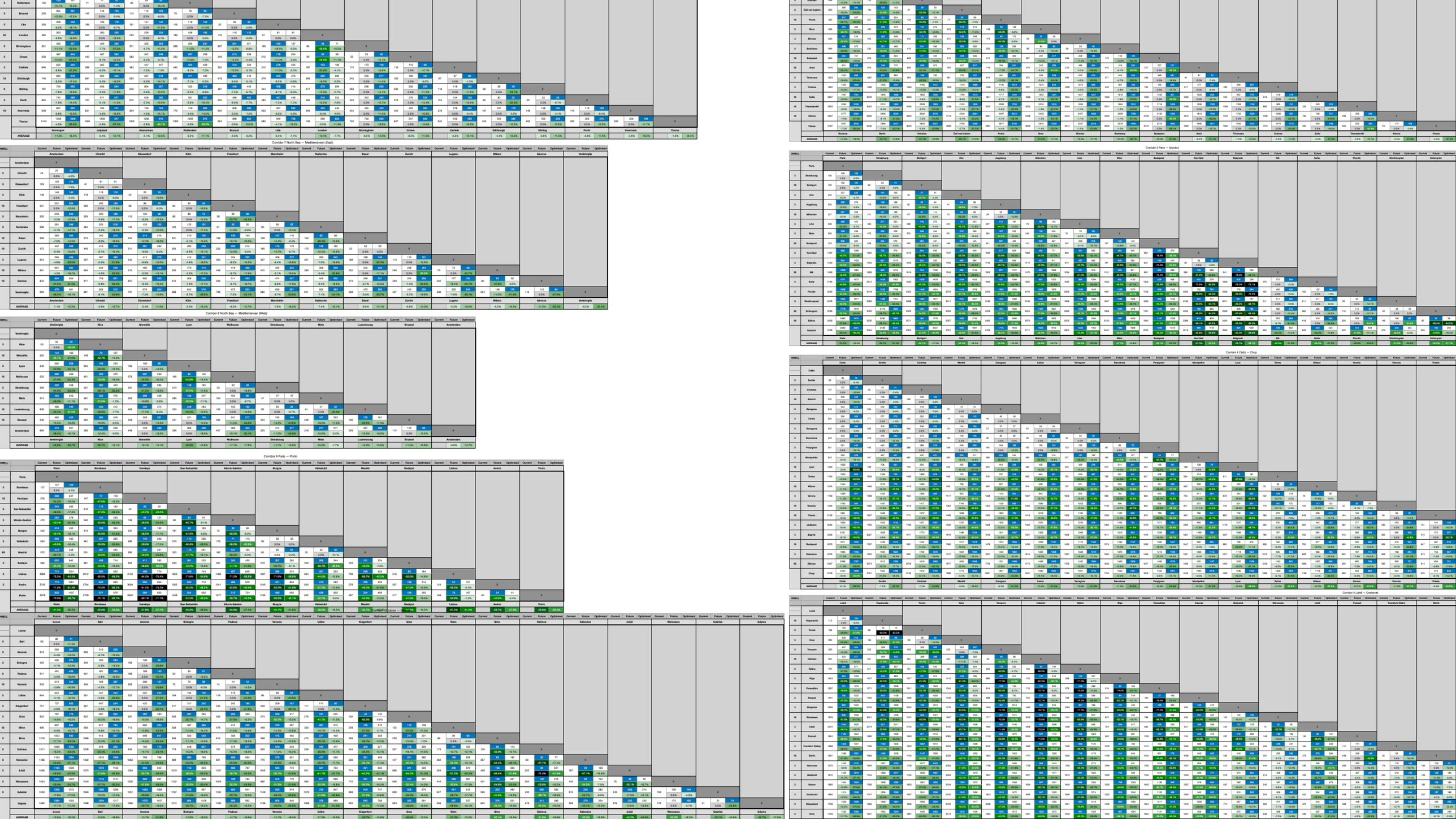
Tables

E P M R A C

	Status Quo	Future Unoptimised	Future Optimised
2050 infrastructure needed?	NO	YES	YES
Timetable Optimisation needed?	NO	NO	YES
	Scenario 1	Scenario 2A	Scenario 3

Corridor 1: Comparison of current, future (2050) and potential travel times

DWELL		Narvik	Boden	Umeå	Gävle	Stockholm	Malmö	København	Hamburg	Hannover	Würzburg	Nürnburg	München	Innsbruck	Verona	Bologna	Firenze	Roma	Napoli	Salerno	Villa San Giovanni	Messina	Palermo	Trapani
	Narvik	X																						
5	Boden	393 / 393 / 315 / 0.0% / -19.8%	X																					
5	Umeå	625 / 625 / 498 / 0.0% / -20.3%	194 / 194 / 178 / 0.0% / -8.2%	X																				
5	Gävle	995 / 995 / 773 / 0.0% / -22.3%	551 / 551 / 453 / 0.0% / -17.8%	288 / 288 / 270 / 0.0% / -6.3%	X																			
10	Stockholm	1097 / 1097 / 854 / 0.0% / -22.2%	634 / 634 / 534 / 0.0% / -15.8%	372 / 372 / 351 / 0.0% / -5.6%	81 / 81 / 76 / 0.0% / -6.2%	X																		
5	Malmö	1413 / 1304 / 1106 / -7.7% / -21.7%	902 / 793 / 786 / -12.1% / -12.9%	686 / 577 / 603 / -15.9% / -12.1%	380 / 271 / 328 / -28.7% / -13.7%	264 / 155 / 242 / -41.3% / -8.3%	X																	
10	København	1461 / 1338 / 1134 / -8.4% / -22.4%	955 / 832 / 814 / -12.9% / -14.8%	733 / 610 / 631 / -16.8% / -13.9%	433 / 310 / 356 / -28.4% / -17.8%	311 / 180 / 270 / -42.1% / -13.2%	39 / 25 / 23 / -35.9% / -41.0%	X																
5	Hamburg	1800 / 1550 / 1374 / -13.9% / -23.7%	1384 / 1134 / 1054 / -18.1% / -23.8%	1082 / 832 / 871 / -23.1% / -19.5%	765 / 515 / 596 / -32.7% / -22.1%	636 / 378 / 510 / -40.6% / -19.8%	328 / 187 / 263 / -43.0% / -19.8%	277 / 150 / 230 / -45.8% / -17.0%	X															
5	Hannover	1965 / 1696 / 1449 / -13.7% / -26.3%	1536 / 1267 / 1129 / -17.5% / -26.5%	1277 / 1008 / 946 / -21.1% / -25.9%	868 / 599 / 671 / -31.0% / -22.7%	734 / 457 / 585 / -37.7% / -20.3%	423 / 263 / 338 / -37.8% / -20.1%	372 / 226 / 305 / -39.2% / -18.0%	78 / 59 / 70 / -24.4% / -10.3%	X														
5	Würzburg	2158 / 1889 / 1563 / -12.5% / -27.6%	1708 / 1439 / 1243 / -15.7% / -27.2%	1416 / 1147 / 1060 / -19.0% / -25.1%	1050 / 781 / 785 / -25.6% / -25.2%	906 / 629 / 699 / -30.6% / -22.8%	593 / 433 / 452 / -27.0% / -23.8%	528 / 382 / 419 / -27.7% / -20.6%	205 / 186 / 184 / -9.3% / -10.2%	122 / 122 / 109 / 0.0% / -10.7%	X													
5	Nürnburg	2215 / 1924 / 1616 / -13.1% / -27.0%	1763 / 1472 / 1296 / -16.5% / -26.5%	1480 / 1189 / 1113 / -19.7% / -24.8%	1104 / 813 / 838 / -26.4% / -24.1%	961 / 662 / 752 / -31.1% / -21.7%	650 / 468 / 505 / -28.0% / -22.3%	592 / 424 / 472 / -28.4% / -20.3%	262 / 221 / 237 / -15.6% / -9.5%	177 / 155 / 162 / -12.4% / -8.5%	51 / 29 / 48 / -43.1% / -5.9%	X												
10	München	2305 / 2014 / 1682 / -12.6% / -27.0%	1835 / 1544 / 1362 / -15.9% / -25.8%	1549 / 1258 / 1179 / -18.8% / -23.9%	1200 / 909 / 904 / -24.3% / -24.7%	1034 / 735 / 818 / -28.9% / -20.9%	724 / 542 / 571 / -25.1% / -21.1%	661 / 493 / 538 / -25.4% / -18.6%	341 / 300 / 303 / -12.0% / -11.1%	254 / 232 / 228 / -8.7% / -10.2%	118 / 96 / 114 / -18.6% / -3.4%	62 / 62 / 61 / 0.0% / -1.6%	X											
5	Innsbruck	2519 / 2179 / 1771 / -13.5% / -29.7%	2046 / 1706 / 1451 / -16.6% / -29.1%	1677 / 1337 / 1268 / -20.3% / -24.4%	1383 / 1043 / 993 / -24.6% / -28.2%	1224 / 876 / 907 / -28.4% / -25.9%	855 / 624 / 660 / -27.0% / -22.8%	789 / 572 / 627 / -27.5% / -20.5%	476 / 386 / 392 / -18.9% / -17.6%	397 / 326 / 317 / -17.9% / -20.2%	250 / 179 / 203 / -28.4% / -18.8%	185 / 136 / 150 / -26.5% / -18.9%	104 / 55 / 79 / -47.1% / -24.0%	X										
10	Verona	2739 / 2272 / 1949 / -17.1% / -28.8%	2323 / 1856 / 1629 / -20.1% / -29.9%	2002 / 1535 / 1446 / -23.3% / -27.8%	1602 / 1135 / 1171 / -29.2% / -26.9%	1476 / 1001 / 1085 / -32.2% / -26.5%	1138 / 780 / 838 / -31.5% / -26.4%	1154 / 810 / 805 / -29.8% / -30.2%	696 / 479 / 570 / -31.2% / -18.1%	619 / 421 / 495 / -32.0% / -20.0%	461 / 263 / 381 / -43.0% / -17.4%	401 / 225 / 328 / -43.9% / -18.2%	322 / 146 / 257 / -54.7% / -20.2%	212 / 85 / 173 / -59.9% / -18.4%	X								
5	Bologna	2819 / 2352 / 2010 / -16.6% / -28.7%	2397 / 1930 / 1690 / -19.5% / -29.5%	2080 / 1613 / 1507 / -22.5% / -27.5%	1680 / 1213 / 1232 / -27.8% / -26.7%	1552 / 1077 / 1146 / -30.6% / -26.2%	1208 / 850 / 899 / -29.6% / -25.6%	1224 / 880 / 866 / -28.1% / -29.2%	793 / 576 / 631 / -27.4% / -20.4%	708 / 510 / 556 / -28.0% / -21.5%	540 / 342 / 442 / -36.7% / -18.1%	482 / 306 / 389 / -36.5% / -19.3%	396 / 220 / 318 / -44.4% / -19.7%	284 / 157 / 234 / -44.7% / -17.6%	51 / 51 / 51 / 0.0% / 0.0%	X							
5	Firenze	2805 / 2338 / 2048 / -16.6% / -27.0%	2389 / 1922 / 1728 / -19.5% / -27.7%	2123 / 1656 / 1545 / -22.0% / -27.2%	1726 / 1259 / 1270 / -27.1% / -26.4%	1587 / 1112 / 1184 / -29.9% / -25.4%	1249 / 891 / 937 / -28.7% / -25.0%	1265 / 921 / 904 / -27.2% / -28.5%	843 / 626 / 669 / -25.7% / -20.6%	781 / 583 / 594 / -25.4% / -23.9%	597 / 399 / 480 / -33.2% / -19.6%	539 / 363 / 427 / -32.7% / -20.8%	450 / 274 / 356 / -39.1% / -20.9%	335 / 208 / 272 / -37.9% / -18.8%	91 / 91 / 89 / 0.0% / -2.2%	33 / 33 / 33 / 0.0% / 0.0%	X						
10	Roma	2910 / 2443 / 2136 / -16.0% / -26.6%	2494 / 2027 / 1816 / -18.7% / -27.2%	2168 / 1701 / 1633 / -21.5% / -24.7%	1846 / 1379 / 1358 / -25.3% / -26.4%	1707 / 1232 / 1272 / -27.8% / -25.5%	1294 / 936 / 1025 / -27.7% / -20.8%	1385 / 1041 / 992 / -24.8% / -28.4%	914 / 697 / 757 / -23.7% / -17.2%	832 / 634 / 682 / -23.8% / -18.0%	692 / 494 / 568 / -28.6% / -17.9%	629 / 453 / 515 / -28.0% / -18.1%	546 / 370 / 444 / -32.2% / -18.7%	441 / 314 / 360 / -28.8% / -18.4%	197 / 197 / 177 / 0.0% / -10.2%	123 / 123 / 114 / 0.0% / -7.3%	90 / 90 / 83 / 0.0% / -7.8%	X						
10	Napoli	3175 / 2708 / 2209 / -14.7% / -30.4%	2584 / 2117 / 1889 / -18.1% / -26.9%	2244 / 1777 / 1706 / -20.8% / -24.0%	1847 / 1380 / 1431 / -25.3% / -22.5%	1708 / 1233 / 1345 / -27.8% / -21.3%	1370 / 1012 / 1098 / -26.1% / -19.9%	1386 / 1042 / 1065 / -24.8% / -23.2%	990 / 773 / 830 / -21.9% / -16.2%	908 / 710 / 755 / -21.8% / -16.9%	775 / 577 / 641 / -25.5% / -17.3%	712 / 536 / 588 / -24.7% / -17.4%	629 / 453 / 517 / -28.0% / -17.8%	523 / 396 / 433 / -24.3% / -17.2%	278 / 278 / 250 / 0.0% / -10.1%	203 / 203 / 187 / 0.0% / -7.9%	177 / 177 / 156 / 0.0% / -11.9%	66 / 66 / 63 / 0.0% / -4.5%	X					
5	Salerno	3267 / 2800 / 2223 / -14.3% / -32.0%	2625 / 2158 / 1903 / -17.8% / -27.5%	2439 / 1972 / 1720 / -19.1% / -29.5%	1987 / 1520 / 1445 / -23.5% / -27.3%	1860 / 1385 / 1359 / -25.5% / -26.9%	1547 / 1189 / 1112 / -23.1% / -28.1%	1518 / 1174 / 1079 / -22.7% / -28.9%	1059 / 842 / 844 / -20.5% / -20.3%	977 / 779 / 769 / -20.3% / -21.3%	808 / 610 / 655 / -24.5% / -18.9%	745 / 569 / 602 / -23.6% / -19.2%	662 / 486 / 531 / -26.6% / -19.8%	537 / 410 / 447 / -23.6% / -16.8%	292 / 292 / 264 / 0.0% / -9.6%	217 / 217 / 201 / 0.0% / -7.4%	205 / 205 / 170 / 0.0% / -17.1%	84 / 84 / 77 / 0.0% / -8.3%	34 / 34 / 31 / 0.0% / -8.8%	X				
30	Villa San Giovanni	3578 / 3042 / 2400 / -15.0% / -32.9%	2844 / 2308 / 2080 / -18.8% / -26.9%	2622 / 2086 / 1897 / -20.4% / -27.7%	2243 / 1707 / 1622 / -23.9% / -27.7%	2125 / 1581 / 1536 / -25.6% / -27.7%	1835 / 1408 / 1289 / -23.3% / -29.8%	1782 / 1369 / 1256 / -23.2% / -29.5%	1371 / 1085 / 1021 / -20.9% / -25.5%	1284 / 1017 / 946 / -20.8% / -26.3%	1057 / 790 / 832 / -25.3% / -21.3%	998 / 753 / 779 / -24.5% / -21.9%	908 / 663 / 708 / -27.0% / -22.0%	769 / 573 / 624 / -25.5% / -18.9%	505 / 436 / 441 / -13.7% / -12.7%	430 / 361 / 378 / -16.0% / -12.1%	406 / 337 / 347 / -17.0% / -14.5%	297 / 228 / 254 / -23.2% / -14.5%	243 / 174 / 208 / -28.4% / -14.4%	199 / 130 / 172 / -34.7% / -13.6%	X			
30	Messina	3605 / 3054 / 2460 / -15.3% / -31.8%	2914 / 2363 / 2140 / -18.9% / -26.6%	2857 / 2306 / 1957 / -19.3% / -31.5%	2313 / 1762 / 1682 / -23.8% / -27.3%	2187 / 1628 / 1596 / -25.6% / -27.0%	1940 / 1498 / 1349 / -22.8% / -30.5%	1889 / 1461 / 1316 / -22.7% / -30.3%	1465 / 1164 / 1081 / -20.5% / -26.2%	1362 / 1080 / 1006 / -20.7% / -26.1%	1156 / 874 / 892 / -24.4% / -22.8%	1059 / 799 / 839 / -24.6% / -20.8%	961 / 701 / 768 / -27.1% / -20.1%	841 / 630 / 684 / -25.1% / -18.7%	568 / 484 / 501 / -14.8% / -11.8%	488 / 404 / 438 / -17.2% / -10.2%	447 / 363 / 407 / -18.8% / -8.9%	375 / 291 / 314 / -22.4% / -16.3%	305 / 221 / 268 / -27.5% / -12.1%	263 / 179 / 232 / -31.9% / -11.8%	30 / 15 / 30 / -50.0% / 0.0%	X		
5	Palermo	3855 / 3304 / 2621 / -14.3% / -32.0%	3439 / 2888 / 2301 / -16.0% / -33.1%	3075 / 2524 / 2118 / -17.9% / -31.1%	2637 / 2086 / 1843 / -20.9% / -30.1%	2677 / 2118 / 1757 / -20.9% / -34.4%	2148 / 1706 / 1510 / -20.6% / -29.7%	2095 / 1667 / 1477 / -20.4% / -29.5%	1670 / 1369 / 1242 / -18.0% / -25.6%	1586 / 1304 / 1167 / -17.8% / -26.4%	1460 / 1178 / 1053 / -19.3% / -27.9%	1401 / 1141 / 1000 / -18.6% / -28.6%	1311 / 1051 / 929 / -19.8% / -29.1%	1043 / 832 / 845 / -20.2% / -19.0%	761 / 677 / 662 / -11.0% / -13.0%	686 / 602 / 599 / -12.2% / -12.7%	679 / 595 / 568 / -12.4% / -16.3%	553 / 469 / 475 / -15.2% / -14.1%	486 / 402 / 429 / -17.3% / -11.7%	449 / 365 / 393 / -18.7% / -12.5%	208 / 193 / 191 / -7.2% / -8.2%	164 / 164 / 131 / 0.0% / -20.1%	X	
	Trapani	4322 / 3771 / 2791 / -12.7% / -35.4%	3906 / 3355 / 2471 / -14.1% / -36.7%	3542 / 2991 / 2288 / -15.6% / -35.4%	3104 / 2553 / 2013 / -17.8% / -35.1%	2941 / 2382 / 1927 / -19.0% / -34.5%	2615 / 2173 / 1680 / -16.9% / -35.8%	2562 / 2134 / 1647 / -16.7% / -35.7%	2025 / 1724 / 1412 / -14.9% / -30.3%	1941 / 1659 / 1337 / -14.5% / -31.1%	1758 / 1476 / 1223 / -16.0% / -30.4%	1699 / 1439 / 1170 / -15.3% / -31.1%	1609 / 1349 / 1099 / -16.2% / -31.7%	1498 / 1287 / 1015 / -14.1% / -32.2%	1230 / 1146 / 832 / -6.8% / -32.4%	1155 / 1071 / 769 / -7.3% / -33.4%	1129 / 1045 / 738 / -7.4% / -34.6%	1017 / 933 / 645 / -8.3% / -36.6%	916 / 832 / 599 / -9.2% / -34.6%	873 / 789 / 563 / -9.6% / -35.5%	515 / 500 / 361 / -2.9% / -29.9%	462 / 462 / 301 / 0.0% / -34.8%	137 / 137 / 165 / 0.0% / 20.4%	X
		Narvik	Boden	Umeå	Gävle	Stockholm	Malmö	København	Hamburg	Hannover	Würzburg	Nürnburg	München	Innsbruck	Verona	Bologna	Firenze	Roma	Napoli	Salerno	Villa San Giovanni	Messina	Palermo	Trapani
	AVERAGE		-11.3% -27.1%		-13.9% -24.5%		-16.2% -22.6%		-21.2% -23.1%		-24.8% -21.7%		-26.4% -23.2%		-26.3% -24.2%		-22.7% -18.5%		-22.1% -20.5%		-24.3% -19.7%		-24.2% -19.4%		-25.1% -19.7%		-27.3% -21.6%		-22.5% -18.7%		-20.2% -18.2%		-19.1% -19.3%		-18.0% -18.5%		-17.6% -17.6%		-17.3% -20.0%		-22.1% -20.8%		-21.5% -21.2%		-15.4% -21.1%		-11.6% -21.2%



Sample Timetables

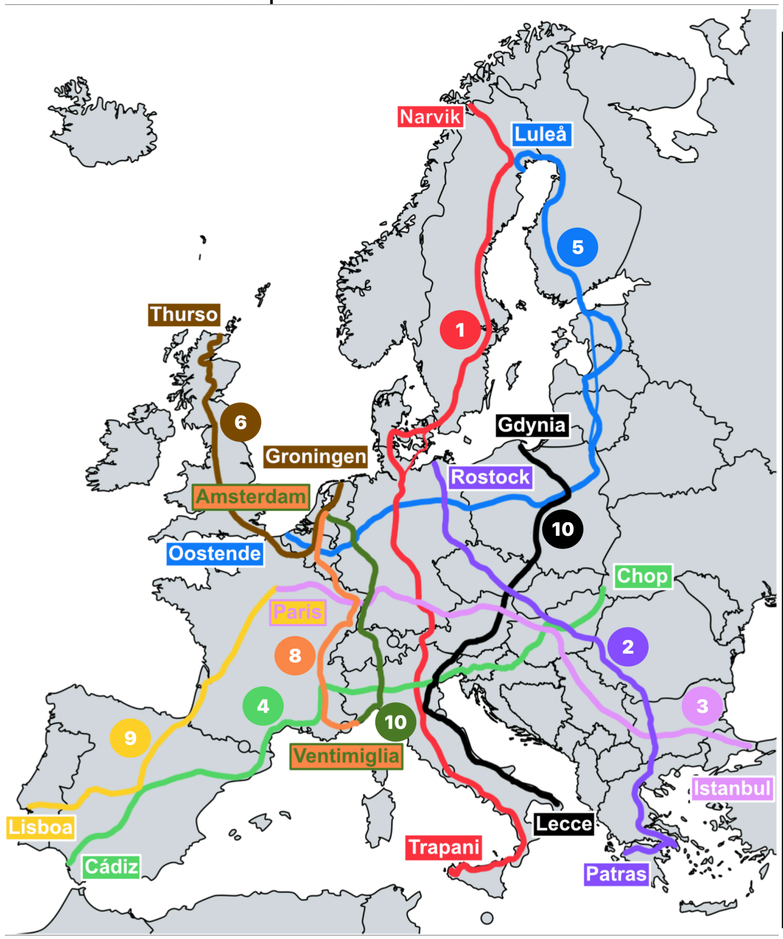
Scenario 1: Status Quo

2050 infrastructure needed? NO

Timetable Optimisation needed? NO

Scenario 1

Chosen Cross-European Corridors



Corridor 3: Current Timetable

Station	Travel Time	Dwell Time	Timings	Length	Timings	Dwell Time	Travel Time	Station
				3050 km				
Paris			10:38	depart	10:52		1h 46m	Paris
	1h 46m			arrive				
Strasbourg		5m	08:52	depart	12:38	4m	1h 22m	Strasbourg
	2h 48m		08:47	arrive	12:42			
Stuttgart		51m	05:59	depart	14:04	47m	43m	Stuttgart
	58m		05:08	arrive	14:51			
Ulm		2m	04:10	depart	15:34	2m	41m	Ulm
	39m		04:08	arrive	15:36			
Augsburg		2m	03:29	depart	16:17	2m	30m	Augsburg
	35m		03:27	arrive	16:19			
München		6m	02:52	depart	16:49	41m	2h 45m	München
	3h 16m		02:46	arrive	17:30			
Linz		2m	23:30	depart	20:15	2m	1h 15m	Linz
	1h 33m		23:28	arrive	20:17			
Wien		35m	21:55	depart	21:32	8m	2h 42m	Wien
	2h 40m		21:20	arrive	21:40			
Budapest		31m	18:40	depart	00:22	5h 28m	13h 6m	Budapest
	9h 14m		18:09	arrive	05:50			
Novi Sad		10m	08:55	depart	18:56	4m	36m	Novi Sad
	36m		08:45	arrive	19:00			
Belgrade		54m	08:09	depart	19:36	1h 54m	4h 19m	Belgrade
	3h 15m		07:15	arrive	21:30			
Niš		10h 0m	04:00	depart	01:49	2h 51m	4h 10m	Niš
	3h 0m		18:00	arrive	04:40			
Sofia		1h 10m	16:00	depart	09:50	40m	2h 37m	Sofia
	2h 59m		14:50	arrive	10:30			
Plovdiv		4m	11:51	depart	13:07	5m	58m	Plovdiv
	58m		11:47	arrive	13:12			
Dimitrovgrad		1h 34m	10:49	depart	14:10	1h 58m	54m	Dimitrovgrad
	55m		09:15	arrive	16:08			
Svilengrad		5h 39m	08:20	depart	17:02	8h 23m	1h 18m	Svilengrad
	1h 49m		02:41	arrive	01:25			
Edirne		22m	00:52	depart	02:43	5m	3h 46m	Edirne
	4h 30m		00:30	arrive	02:48			
Istanbul		47.9 km/h	20:00	depart	06:34	45.7 km/h	1d 19h 28m	Istanbul
	1d 17h 31m							
TOTAL	2d 15h 38m	22h 7m				23h 14m	2d 18h 42m	TOTAL

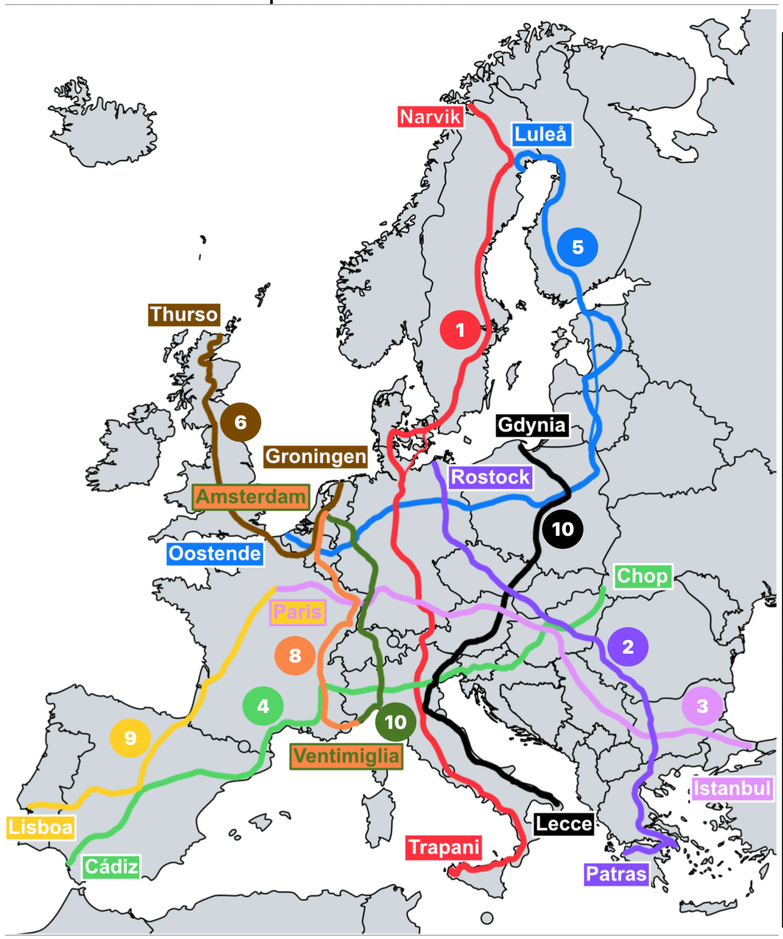
2d 17h 10m

Sample Timetables

Scenario 2: Optimised

E P M R A C

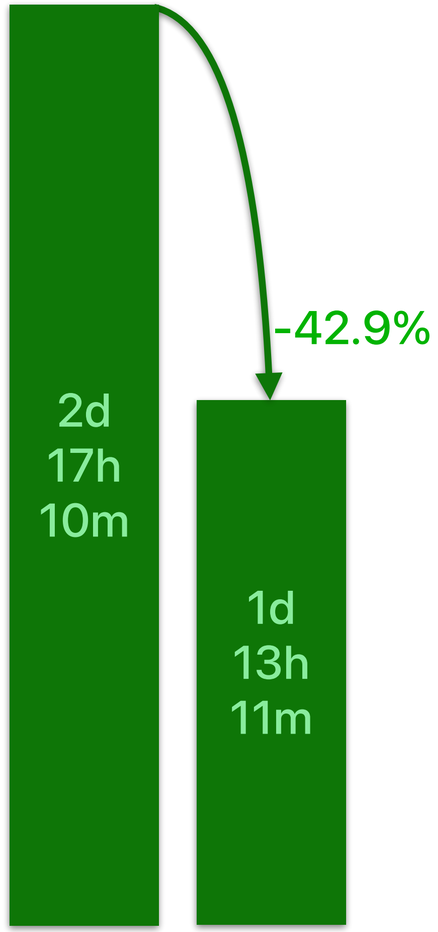
Chosen Cross-European Corridors



Corridor 3: Optimised Timetable

Station	Travel Time	Dwell Time	Timings	Length	Timings	Dwell Time	Travel Time	Station
				3050 km				
Paris			17:01	arrive depart	10:19		1h 45m	Paris
	1h 45m							
Strasbourg		5m	15:16	depart arrive	12:04	5m		Strasbourg
	1h 14m		15:11	arrive depart	12:09		1h 14m	
Stuttgart		10m	13:57	depart arrive	13:23	10m		Stuttgart
	41m		13:47	arrive depart	13:33		41m	
Ulm		5m	13:06	depart arrive	14:14	5m		Ulm
	38m		13:01	arrive depart	14:19		38m	
Augsburg		5m	12:23	depart arrive	14:57	5m		Augsburg
	25m		12:18	arrive depart	15:02		25m	
München		10m	11:53	depart arrive	15:27	10m		München
	2h 26m		11:43	arrive depart	15:37		2h 26m	
Linz		5m	09:17	depart arrive	18:03	5m		Linz
	1h 9m		09:12	arrive depart	18:08		1h 9m	
Wien		5m	08:03	depart arrive	19:17	5m		Wien
	2h 22m		07:58	arrive depart	19:22		2h 22m	
Budapest		30m	05:36	depart arrive	21:44	30m		Budapest
	6h 14m		05:06	arrive depart	22:14		6h 14m	
Novi Sad		5m	22:52	depart arrive	04:28	5m		Novi Sad
	35m		22:47	arrive depart	04:33		35m	
Belgrade		5m	22:12	depart arrive	05:08	5m		Belgrade
	4h 10m		22:07	arrive depart	05:13		4h 10m	
Niš		25m	17:57	depart arrive	09:23	25m		Niš
	4h 24m		17:32	arrive depart	09:48		4h 24m	
Sofia		5m	14:08	depart arrive	15:12	5m		Sofia
	2h 20m		14:03	arrive depart	15:17		2h 20m	
Plovdiv		5m	11:43	depart arrive	17:37	5m		Plovdiv
	48m		11:38	arrive depart	17:42		48m	
Dimitrovgrad		5m	10:50	depart arrive	18:30	5m		Dimitrovgrad
	43m		10:45	arrive depart	18:35		43m	
Svilengrad		20m	10:02	depart arrive	19:18	20m		Svilengrad
	34m		09:42	arrive depart	19:38		34m	
Edirne		40m	09:08	depart arrive	20:12	40m		Edirne
	3h 38m		08:28	arrive depart	20:52		3h 38m	
Istanbul		82.0 km/h	04:50	depart arrive	00:30	82.0 km/h		Istanbul
	1d 10h 6m		-41.6%		-44.3%		1d 10h 6m	
TOTAL	1d 13h 11m	3h 5m				3h 5m	1d 13h 11m	TOTAL

	Scenario 1	Scenario 2B
2050 infrastructure needed?	NO	NO
Timetable Optimisation needed?	NO	YES



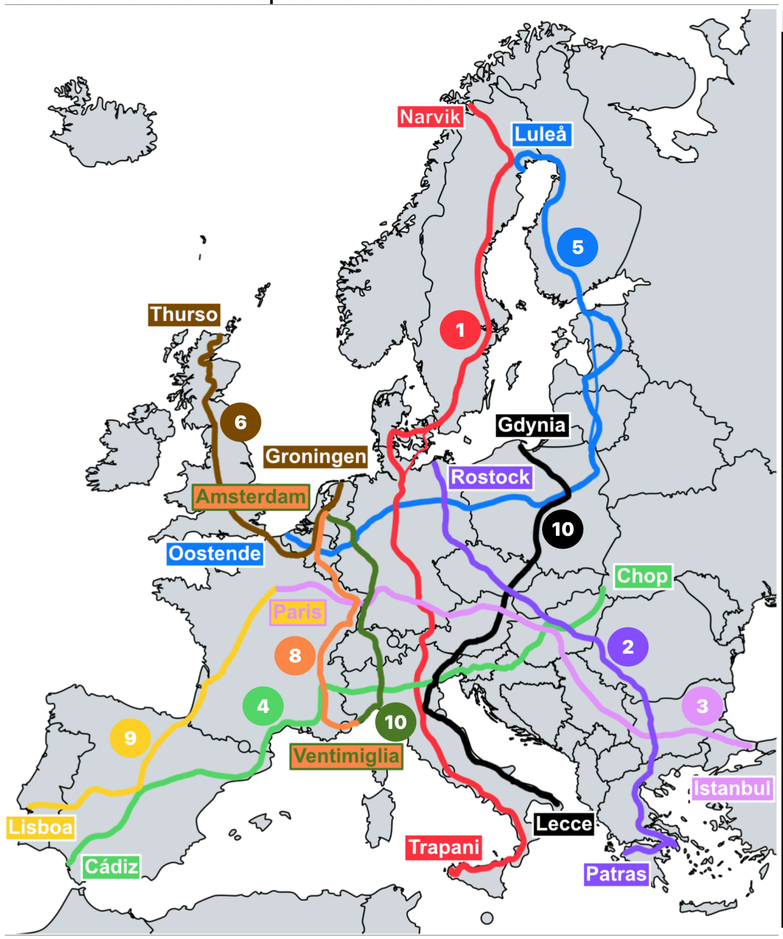
E P M R A C

Sample Timetables

Scenario 3: Future Optimised

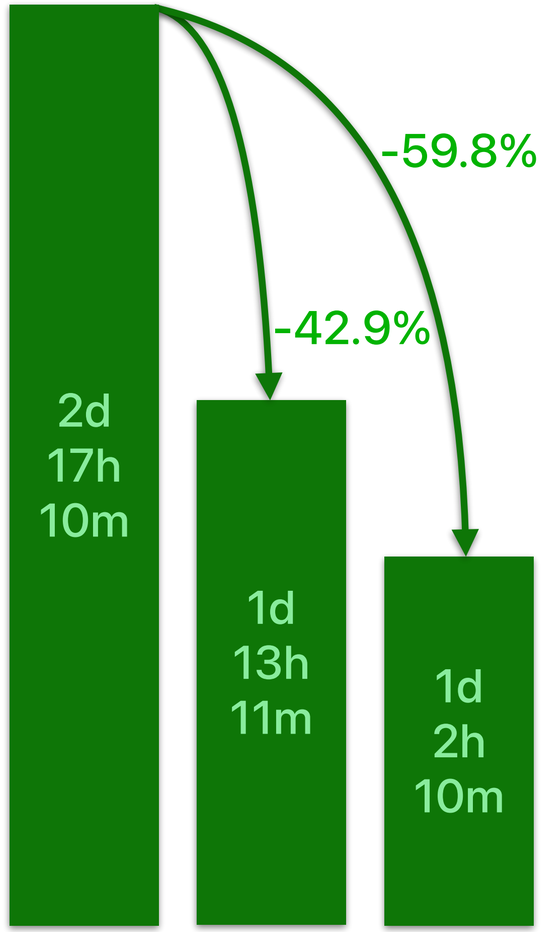
	Scenario 1	Scenario 2B	Scenario 3
2050 infrastructure needed?	NO	NO	YES
Timetable Optimisation needed?	NO	YES	YES

Chosen Cross-European Corridors



Corridor 3: Future Optimised Timetable

Station	Travel Time	Dwell Time	Timings	Length	Timings	Dwell Time	Travel Time	Station
				2850 km				
Paris			17:10	arrive depart	09:49		1h 45m	Paris
	1h 45m							
Strasbourg		5m	15:25	depart arrive	11:34	5m		Strasbourg
	1h 14m		15:20	arrive depart	11:39		1h 14m	
Stuttgart		10m	14:06	depart arrive	12:53	10m		Stuttgart
	27m		13:56	arrive depart	13:03		27m	
Ulm		5m	13:29	depart arrive	13:30	5m		Ulm
	26m		13:24	arrive depart	13:35		26m	
Augsburg		5m	12:58	depart arrive	14:01	5m		Augsburg
	25m		12:53	arrive depart	14:06		25m	
München		10m	12:28	depart arrive	14:31	10m		München
	1h 20m		12:18	arrive depart	14:41		1h 20m	
Linz		5m	10:58	depart arrive	16:01	5m		Linz
	1h 9m		10:53	arrive depart	16:06		1h 9m	
Wien		5m	09:44	depart arrive	17:15	5m		Wien
	2h 20m		09:39	arrive depart	17:20		2h 20m	
Budapest		30m	07:19	depart arrive	19:40	30m		Budapest
	2h 4m		06:49	arrive depart	20:10		2h 4m	
Novi Sad		5m	04:45	depart arrive	22:14	5m		Novi Sad
	35m		04:40	arrive depart	22:19		35m	
Belgrade		5m	04:05	depart arrive	22:54	5m		Belgrade
	1h 15m		04:00	arrive depart	22:59		1h 15m	
Niš		25m	02:45	depart arrive	00:14	25m		Niš
	4h 24m		02:20	arrive depart	00:39		4h 24m	
Sofia		5m	22:56	depart arrive	06:03	5m		Sofia
	2h 20m		22:51	arrive depart	06:08		2h 20m	
Plovdiv		5m	20:31	depart arrive	08:28	5m		Plovdiv
	48m		20:26	arrive depart	08:33		48m	
Dimitrovgrad		5m	19:38	depart arrive	09:21	5m		Dimitrovgrad
	43m		19:33	arrive depart	09:26		43m	
Svilengrad		20m	18:50	depart arrive	10:09	20m		Svilengrad
	30m		18:30	arrive depart	10:29		30m	
Edirne		40m	18:00	depart arrive	10:59	40m		Edirne
	1h 20m		17:20	arrive depart	11:39		1h 20m	
Istanbul		108.9 km/h	16:00	depart arrive	12:59	108.9 km/h		Istanbul
	23h 5m		-58.9%		-60.8%		23h 5m	
TOTAL	1d 2h 10m	3h 5m				3h 5m	1d 2h 10m	TOTAL





Einleitung

Problem

Methods

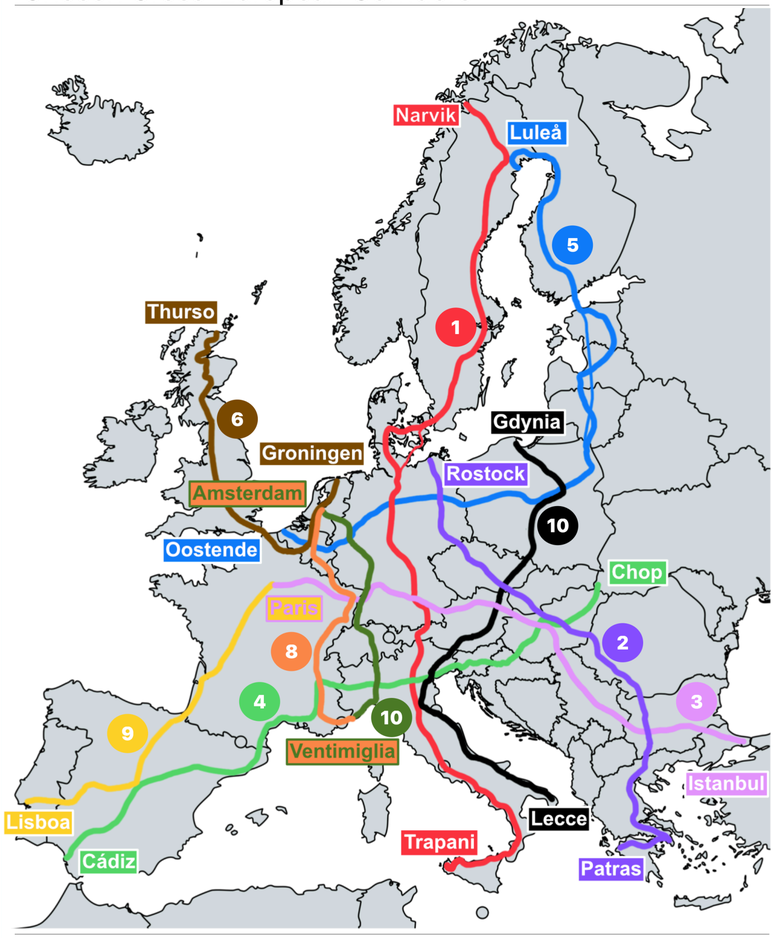
Results

Analysis

Conclusion

Corridor Tables

Chosen Cross-European Corridors

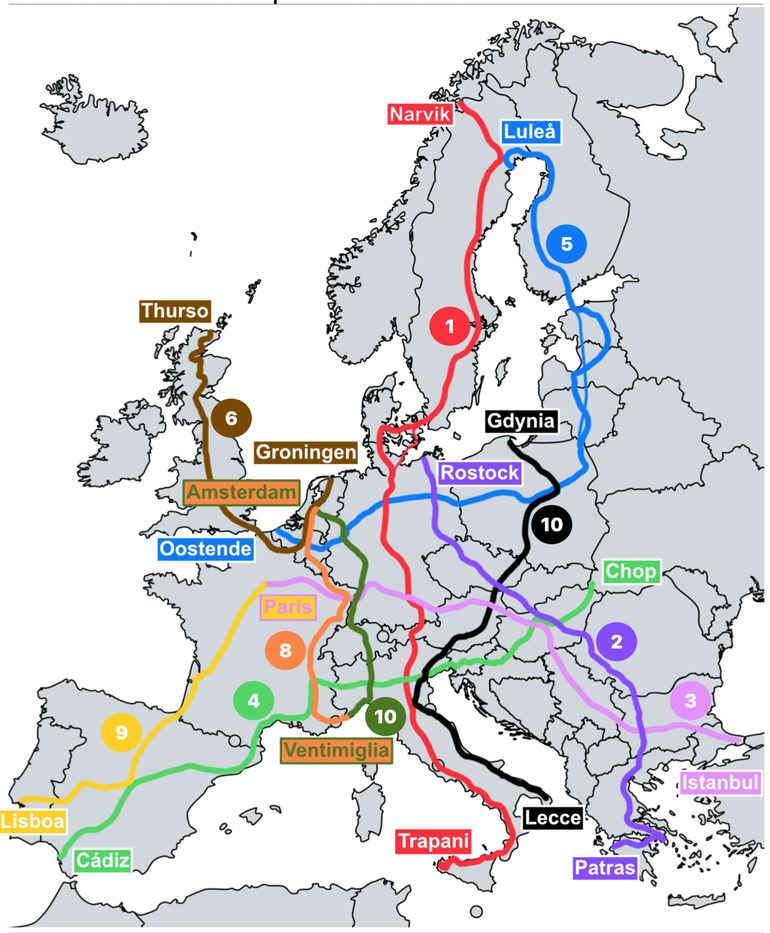


Average potential travel time improvement between corridor stations

Bahnhöfe (Gewichte)	Korridore	Fahrzeit künftig mit Infrastruktur-ausbau	Fahrzeit heute mit Fahrplan-optimierung	Fahrzeit-minimierende Strategie	Um [% Points]
23	Korridor 1	-20.49%	-21.41%	Optimierung	-0.93%
16	Korridor 2	-14.16%	-18.95%	Optimierung	-4.79%
18	Korridor 3	-36.98%	-25.43%	Ausbau	11.55%
22	Korridor 4	-10.60%	-25.60%	Optimierung	-15.01%
28	Korridor 5	-28.92%	-23.24%	Ausbau	5.68%
15	Korridor 6	-6.01%	-11.31%	Optimierung	-5.30%
13	Korridor 7	-6.89%	-16.47%	Optimierung	-9.59%
10	Korridor 8	-17.16%	-15.46%	Ausbau	1.69%
12	Korridor 9	-50.74%	-28.27%	Ausbau	22.48%
17	Korridor 10	-22.86%	-18.30%	Ausbau	4.56%
DURCHSCHNITT (gew.)		-21.58%	-21.01%	Ausbau	0.57%
Standardabweichung		12.27%	4.66%		

Sample Timetables

Chosen Cross-European Corridors



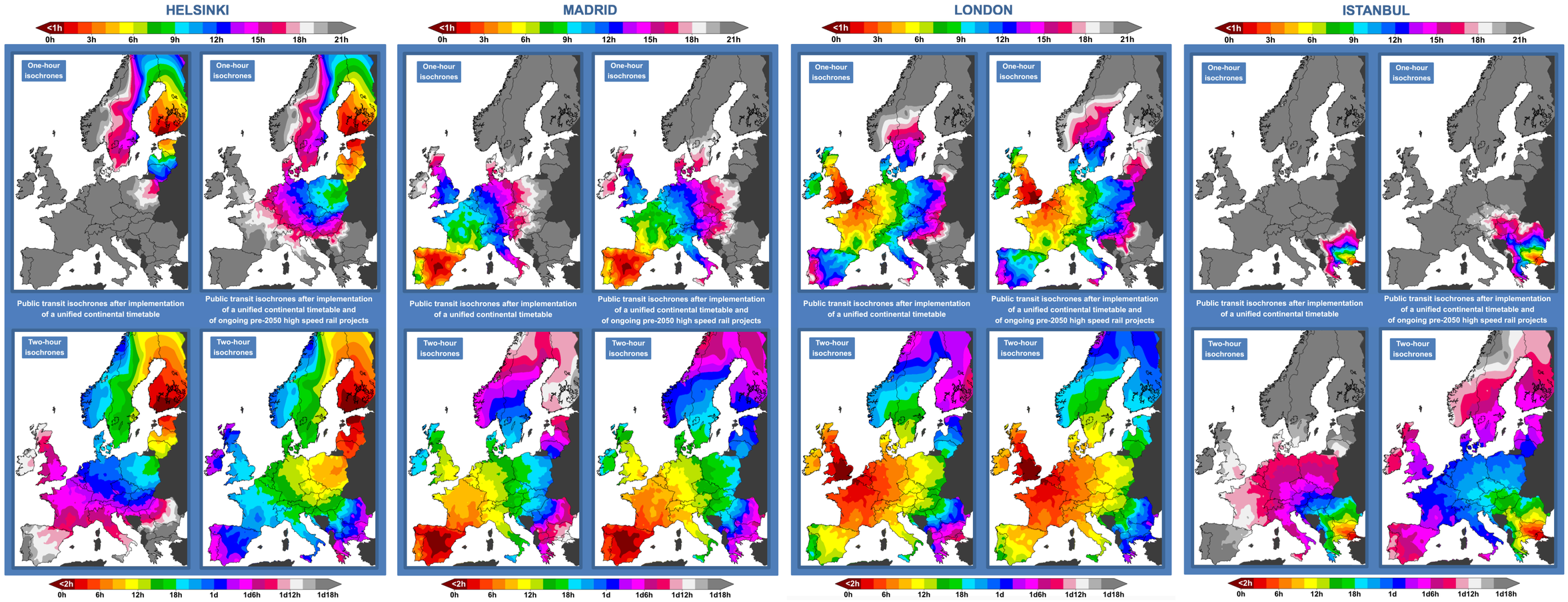
Potential end-to-end travel time and average speed improvement for each corridor

AVG Time [min]	Corridors	Current End-To-End	Optimised End-To-End	Future Optimised End-To-End	Optimisable Today	Optimisable Future	New Infrastructure Portion
2621	Corridor 1	2d 22h 37m	1d 22h 58m	1d 16h 24m	-33.48%	-42.78%	-9.30%
		75.8 km/h	113.9 km/h	128.7 km/h	50.3%	69.8%	
2459	Corridor 2	2d 15h 11m	1d 18h 20m	1d 15h 37m	-32.16%	-36.52%	-4.35%
		52.9 km/h	78.0 km/h	82.0 km/h	47.4%	55.0%	
1901	Corridor 3	2d 17h 10m	1d 13h 11m	1d 2h 10m	-42.91%	-59.82%	-16.91%
		46.8 km/h	82.0 km/h	108.9 km/h	75.2%	133%	
1880	Corridor 4	2d 13h 0m	1d 8h 25m	1d 6h 14m	-44.58%	-48.31%	-3.73%
		63.3 km/h	114.1 km/h	120.7 km/h	80.3%	90.7%	
1764	Corridor 5	4d 16h 37m	1d 14h 25m	20h 23m	-65.63%	-81.76%	-16.14%
		34.0 km/h	98.9 km/h	176.6 km/h	191%	419%	
964	Corridor 6	1d 1h 22m	17h 20m	16h 27m	-31.51%	-35.00%	-3.49%
		83.0 km/h	121.2 km/h	138.7 km/h	46.0%	67.1%	
778	Corridor 7	0d 19h 10m	13h 15m	12h 37m	-30.03%	-33.42%	-3.39%
		71.3 km/h	101.9 km/h	107.0 km/h	42.9%	50.1%	
771	Corridor 8	1d 2h 40m	13h 46m	11h 56m	-48.36%	-55.23%	-6.88%
		65.7 km/h	127.1 km/h	142.5 km/h	93.5%	117%	
869	Corridor 9	1d 7h 34m	17h 11m	11h 46m	-45.53%	-62.70%	-17.17%
		66.6 km/h	122.2 km/h	165.7 km/h	83.5%	149%	
1325	Corridor 10	1d 12h 58m	23h 13m	20h 56m	-36.65%	-42.88%	-6.23%
		69.6 km/h	109.8 km/h	121.8 km/h	57.8%	75.0%	
WEIGHTED TIME		2d 11h 37m	1d 9h 16m	1d 3h 18m	-40.90%	-49.85%	-8.95%
Standard Deviation		1d 1h 30m	11h 22m	10h 30m	10.55%	14.27%	
WEIGHTED SPEED		60.9 km/h	103 km/h	125 km/h	76.8%	124%	
Standard Deviation		14.2 km/h	16.3 km/h	27.9 km/h	43.8%	110%	
UNWEIGHTED TOTAL		21d 8h 17m	11d 18h 4m	9d 14h 30m	-44.94%	-55.01%	-10.07%

E P M R A C

Reachability

Variable Starting Points

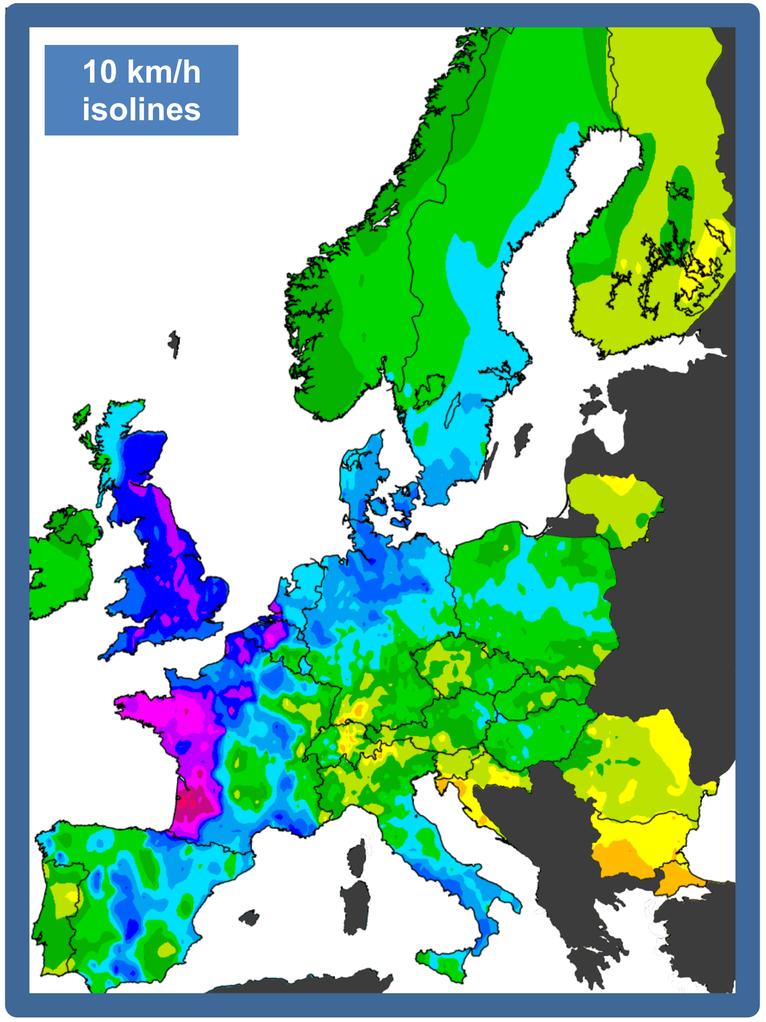


E P M R A C

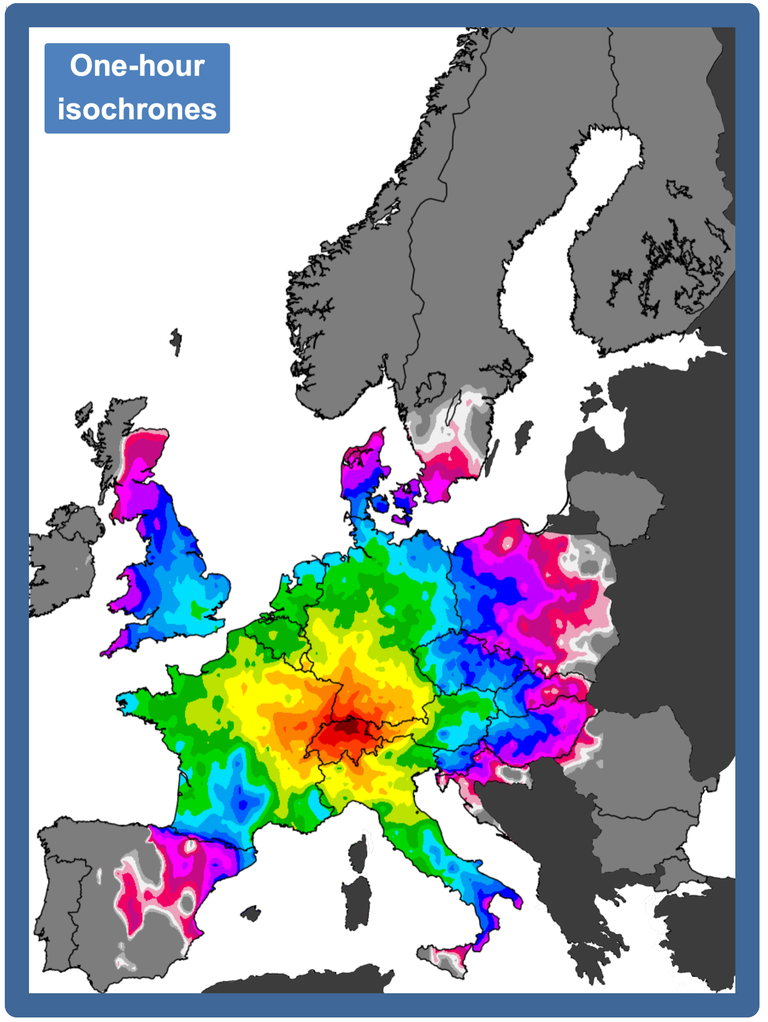
Reachability

Scenario 1: Status Quo
Scenario 2: Optimised
Scenario 3: Future Optimised

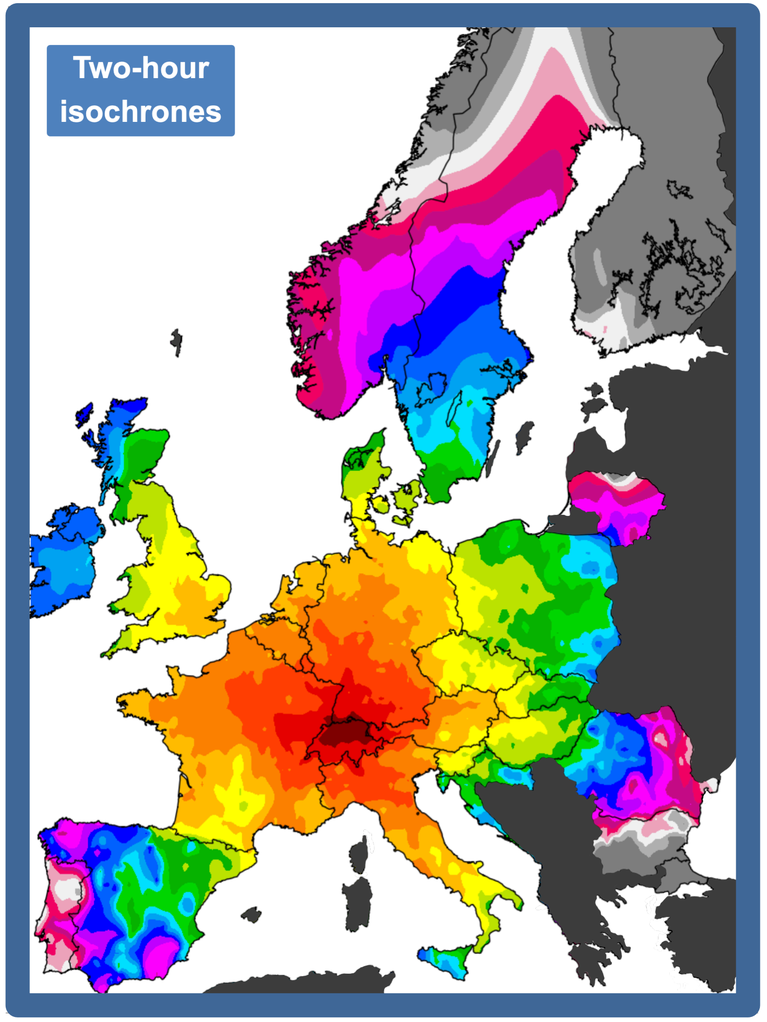
Average Current Speed from Zurich



Current Reachability from Zurich (1h intervals)



Current Reachability from Zurich (2h intervals)



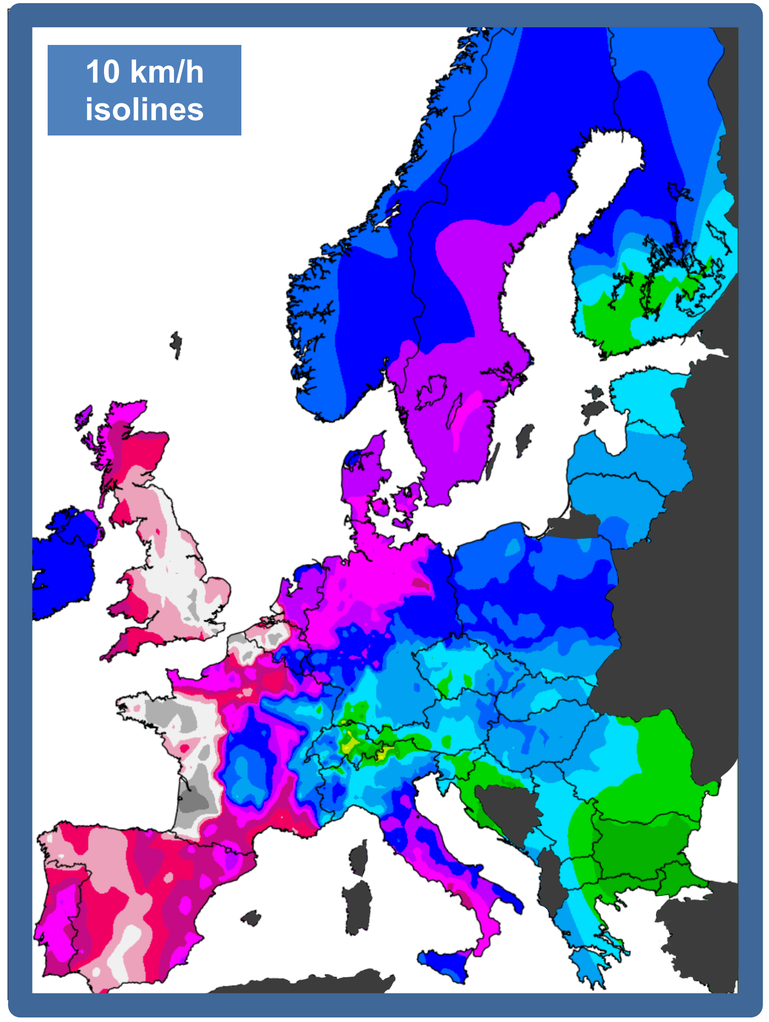
ETH

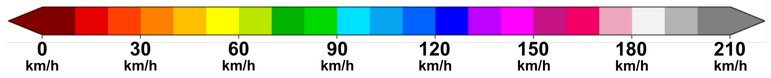
E P M R A C

Reachability

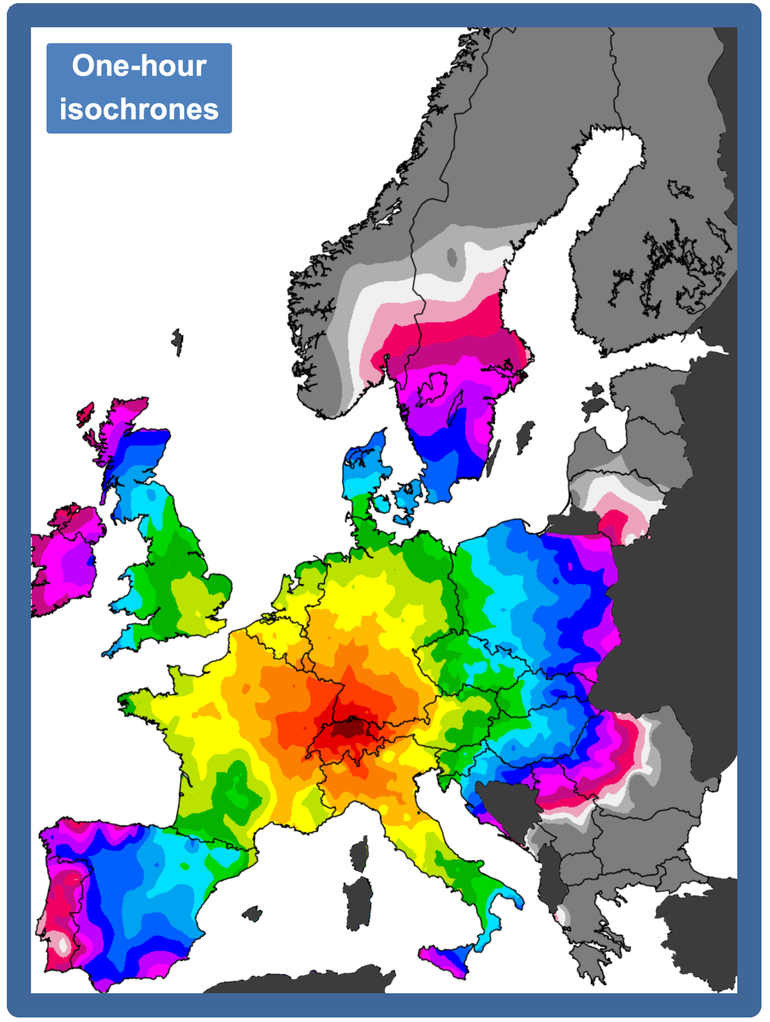
Scenario 1: Status Quo
Scenario 2: Optimised
Scenario 3: Future Optimised

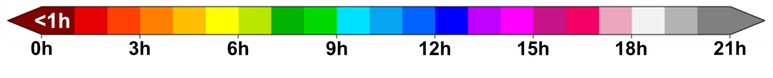
Average Optimised Speed from Zurich



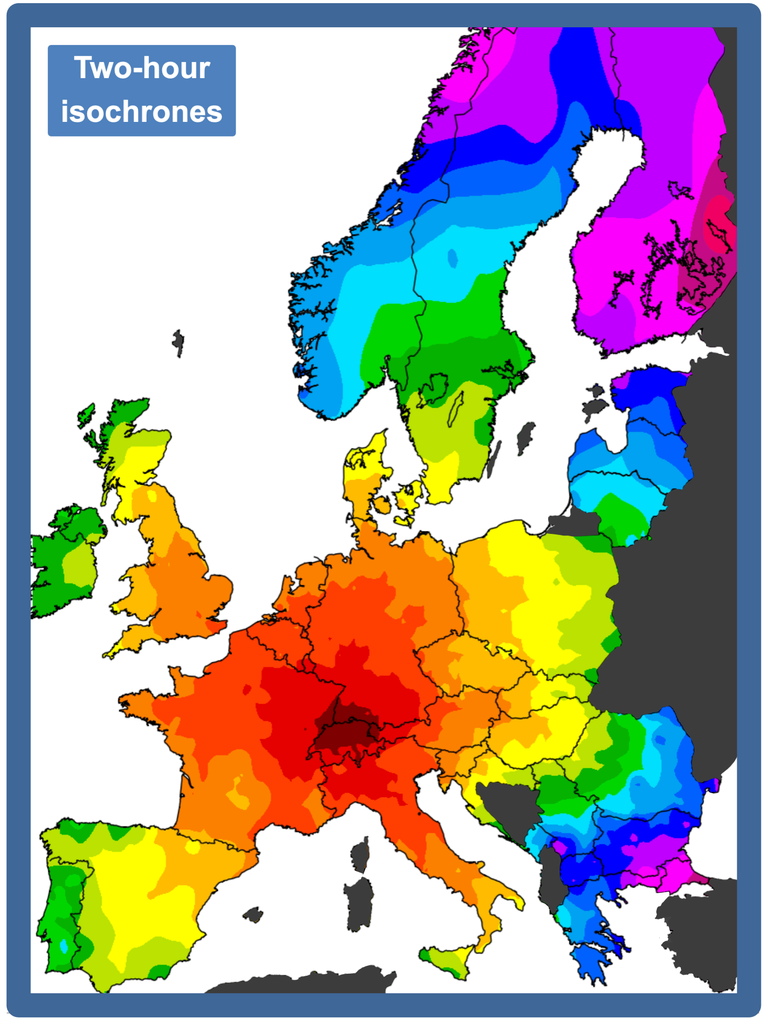


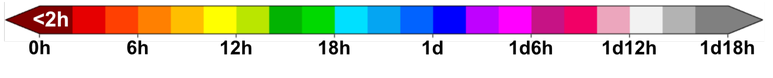
Optimised Reachability from Zurich (1h intervals)





Optimised Reachability from Zurich (2h intervals)





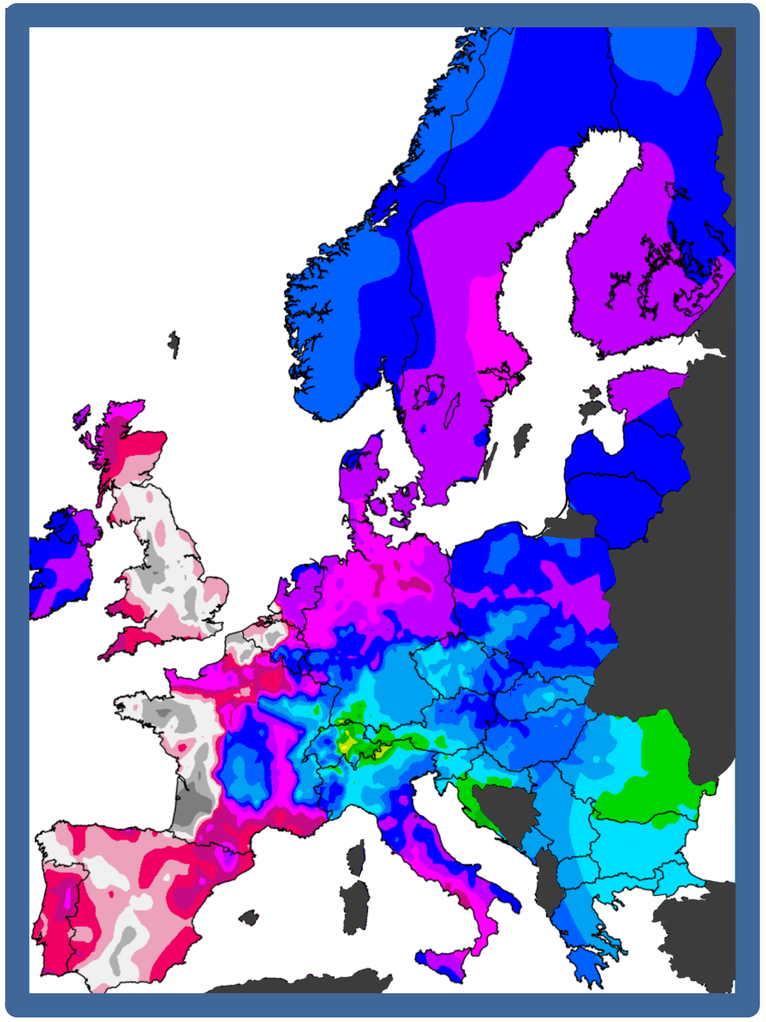
ETH

E P M R A C

Reachability

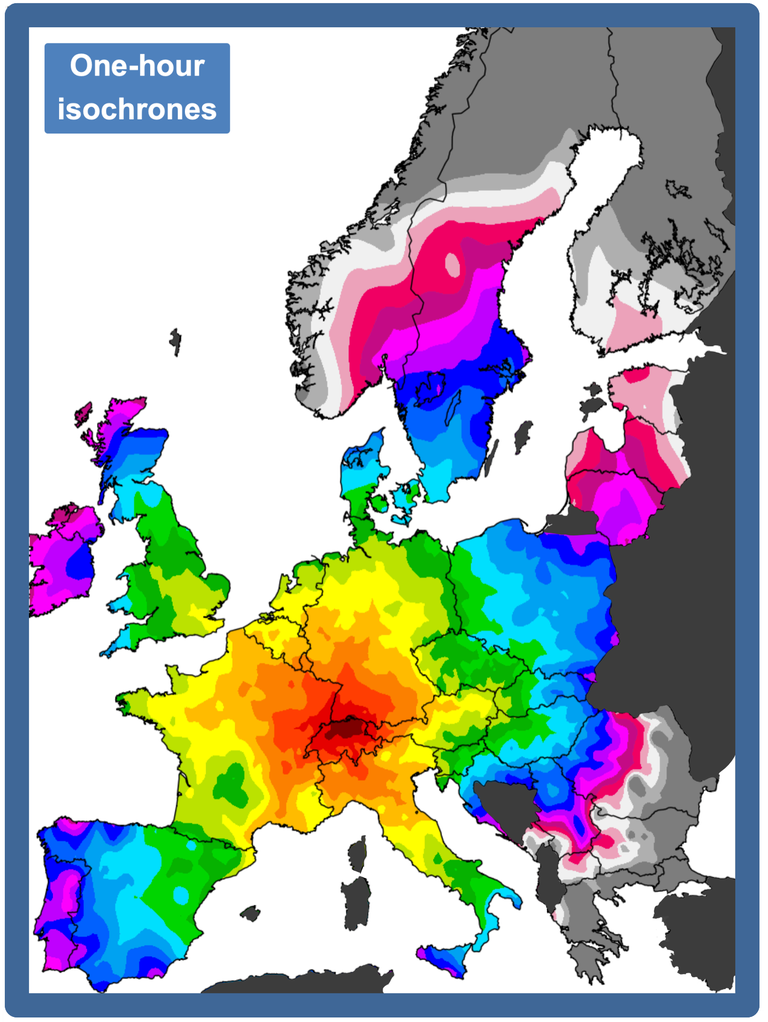
Scenario 1: Status Quo
Scenario 2: Optimised
Scenario 3: Future Optimised

Average Future Optimised Speed from Zurich



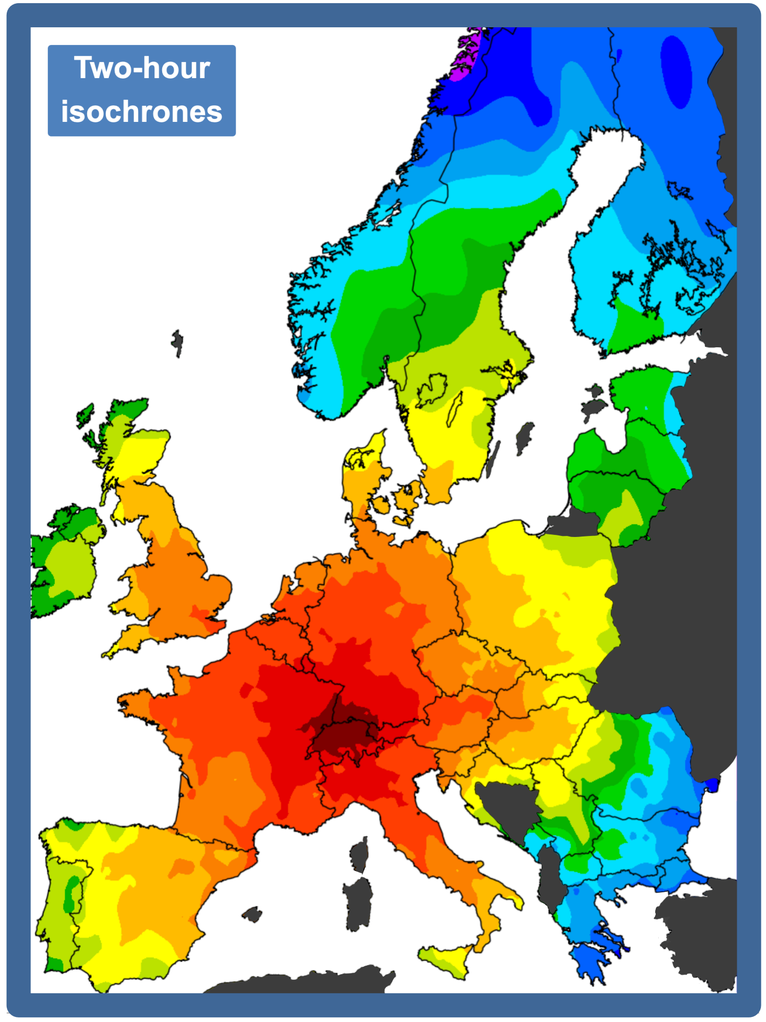
0 km/h | 30 km/h | 60 km/h | 90 km/h | 120 km/h | 150 km/h | 180 km/h | 210 km/h

Optimised Future Reachability from Zurich (1h intervals)



<1h | 0h | 3h | 6h | 9h | 12h | 15h | 18h | 21h

Optimised Future Reachability from Zurich (2h intervals)



<2h | 0h | 6h | 12h | 18h | 1d | 1d6h | 1d12h | 1d18h

ETH

Einleitung
Problem
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Conclusion

How would **optimised timetables** *impact future European reachability?*

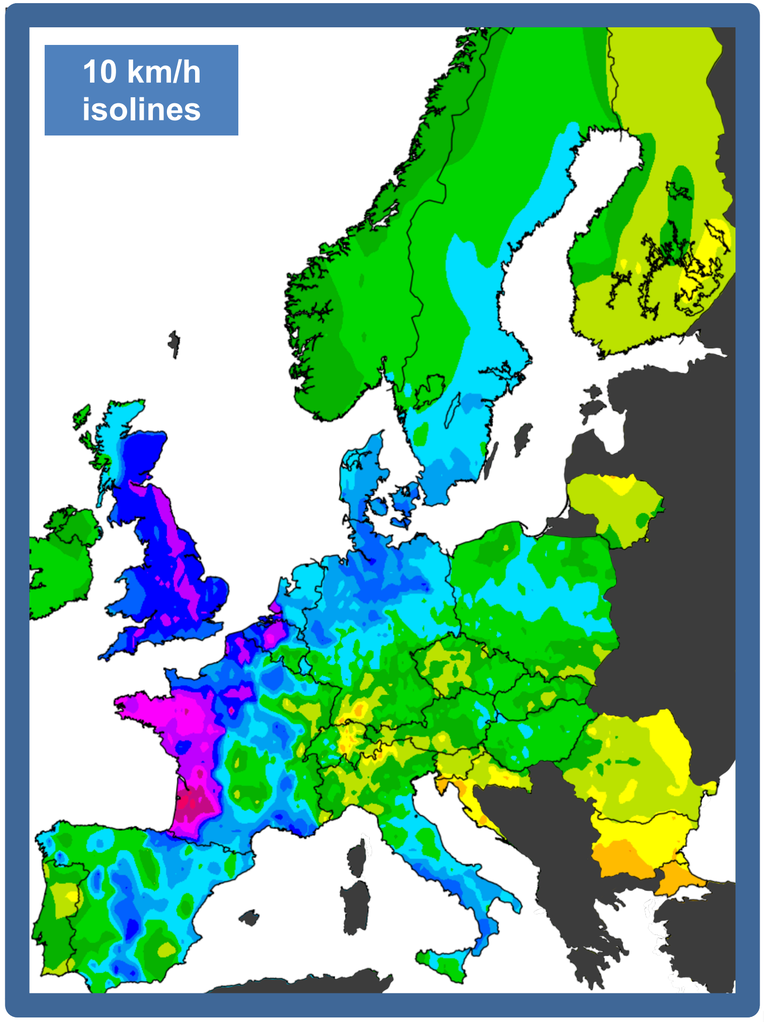
How would this differ from the impact of **planned HSR construction***?*

E P M R A C

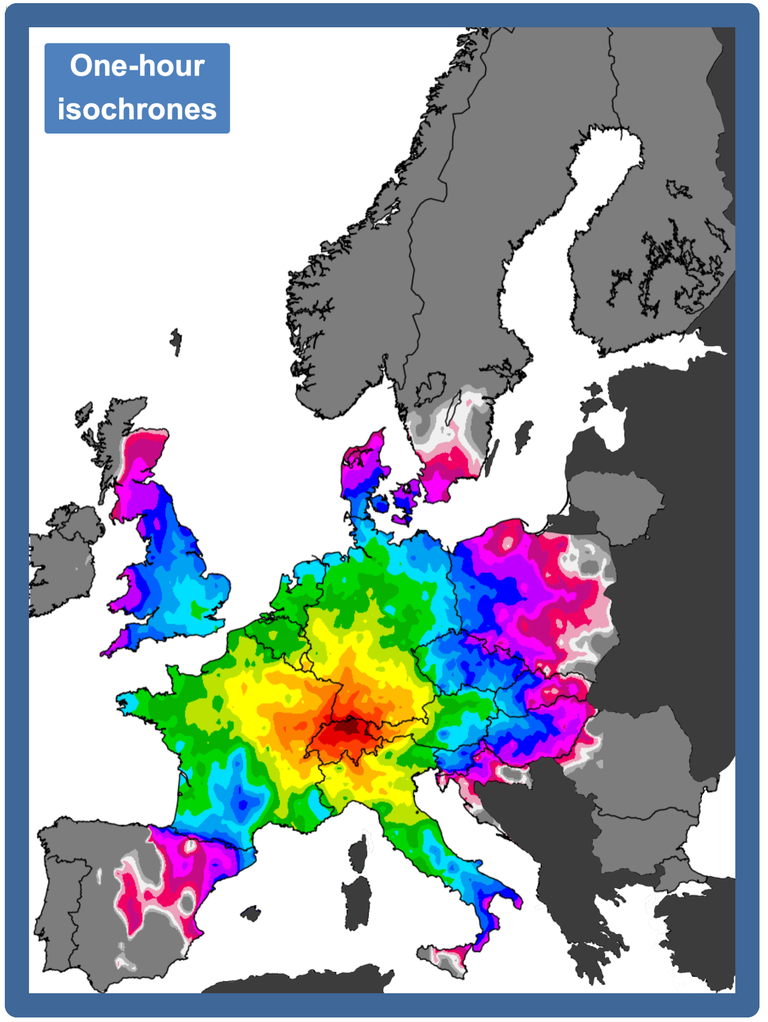
Reachability

Scenario 1: Status Quo
Scenario 2: Optimised
Scenario 3: Future Optimised

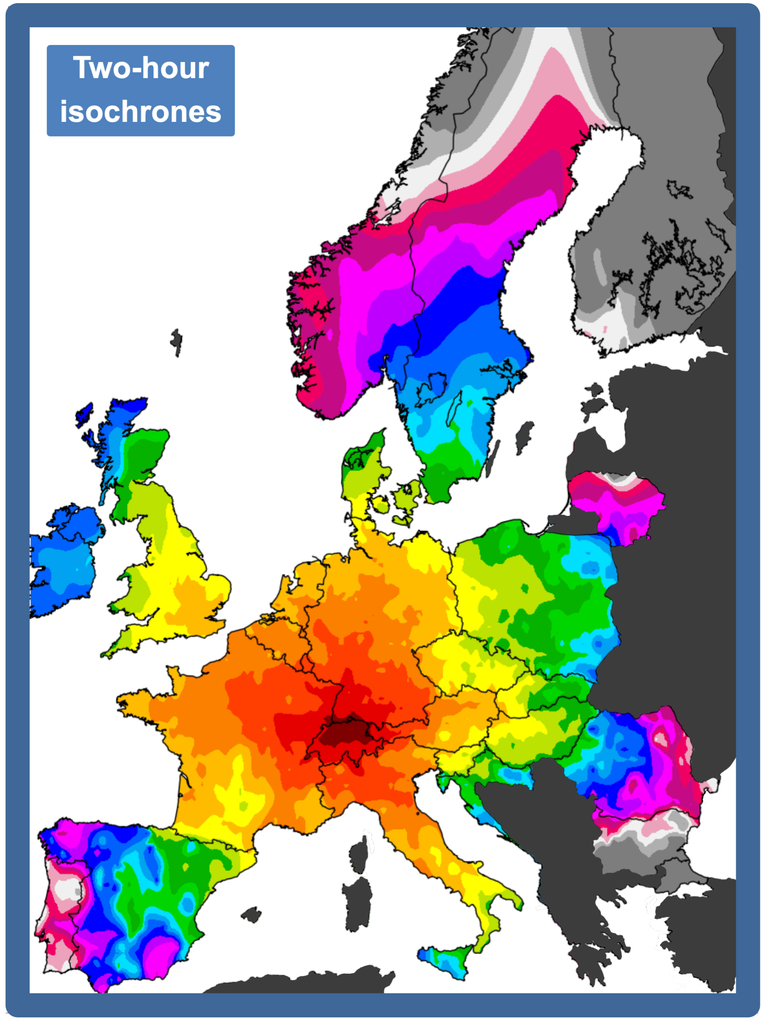
Average Current Speed from Zurich



Current Reachability from Zurich (1h intervals)



Current Reachability from Zurich (2h intervals)



ETH

E P M R A C

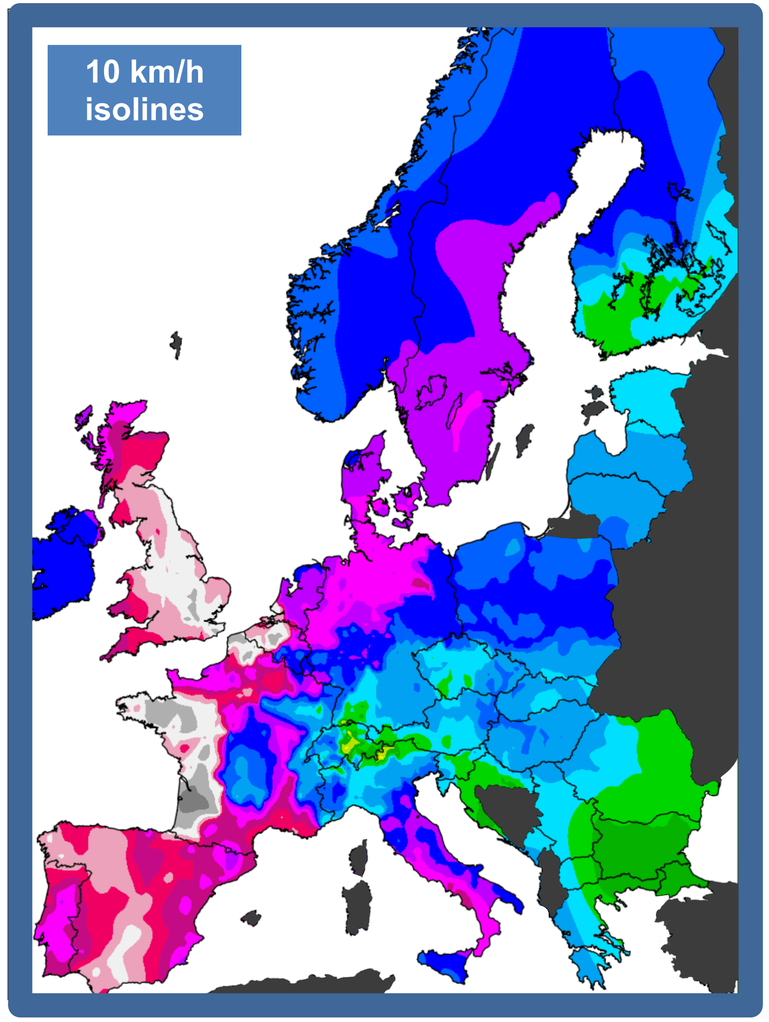
Reachability

Scenario 1: Status Quo

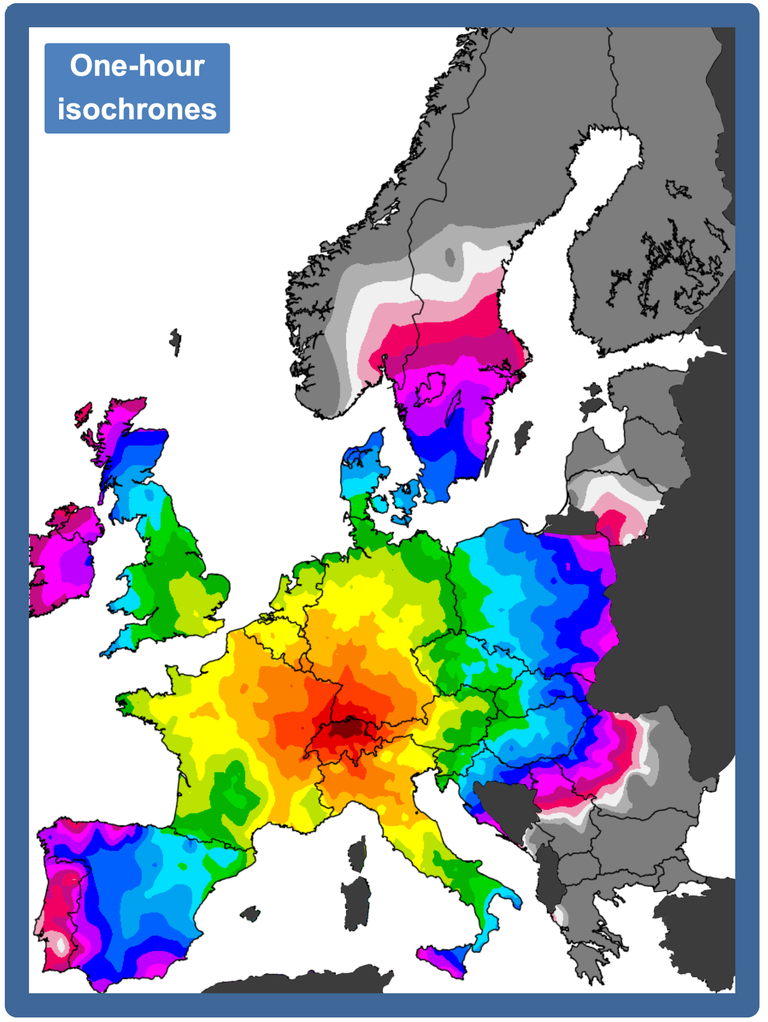
Scenario 2: Optimised

Scenario 3: Future Optimised

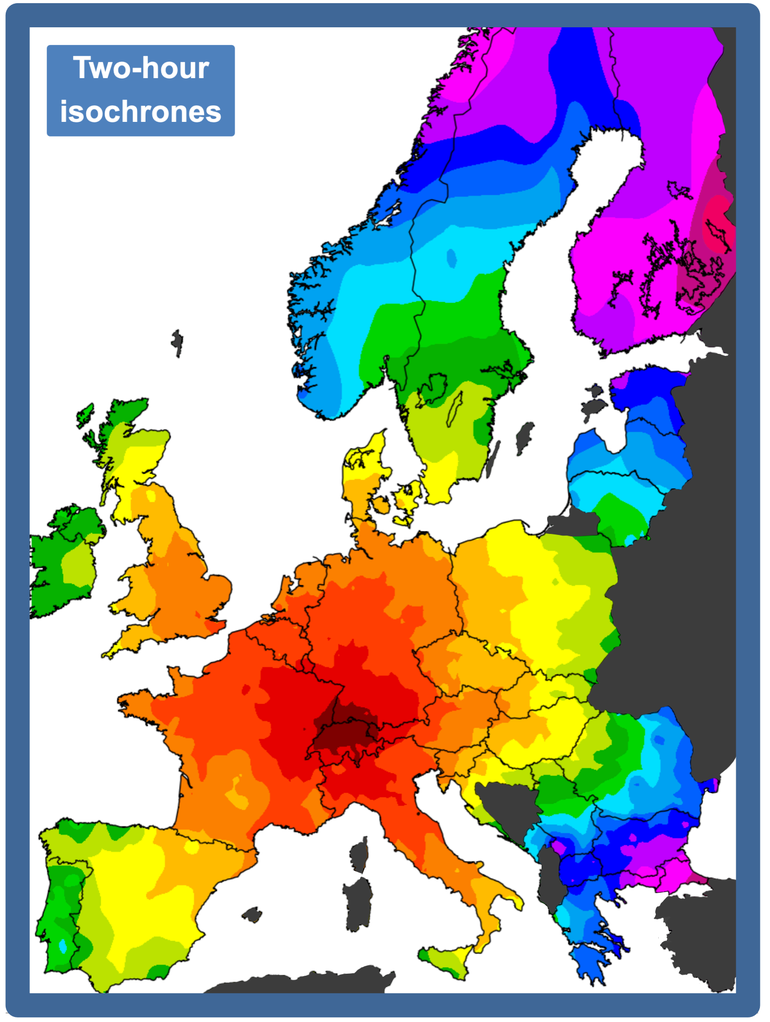
Average Optimised Speed from Zurich



Optimised Reachability from Zurich (1h intervals)



Optimised Reachability from Zurich (2h intervals)



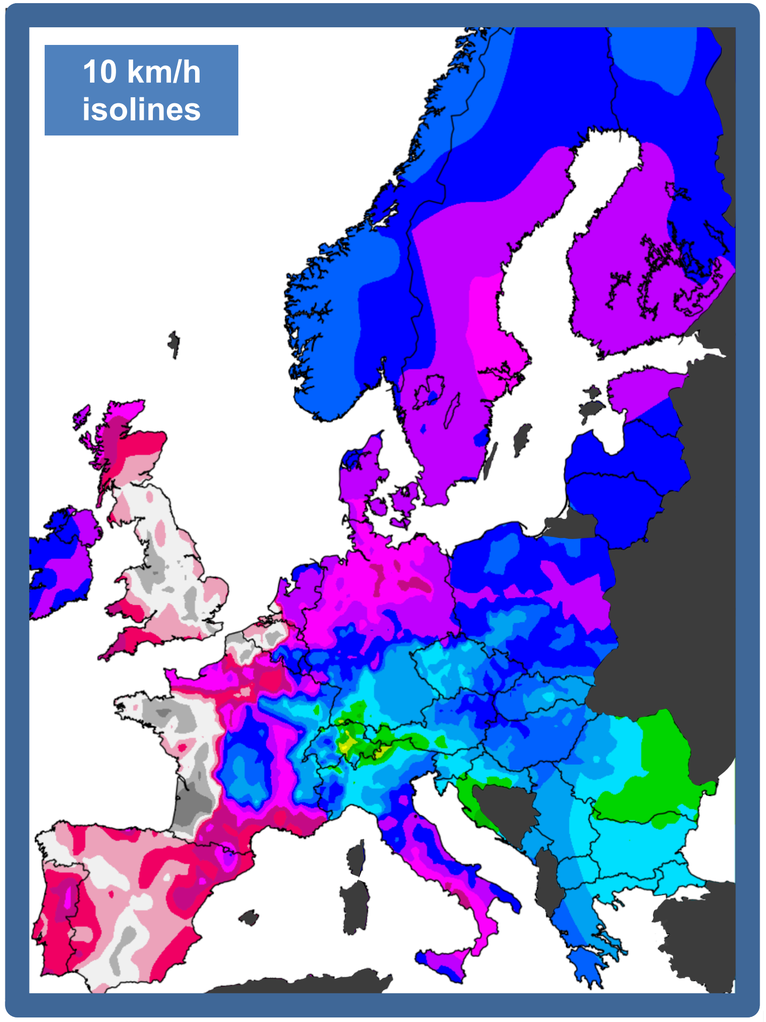
ETH

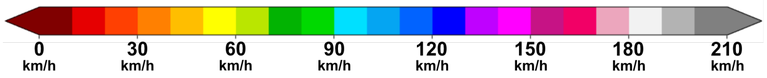
E P M R A C

Reachability

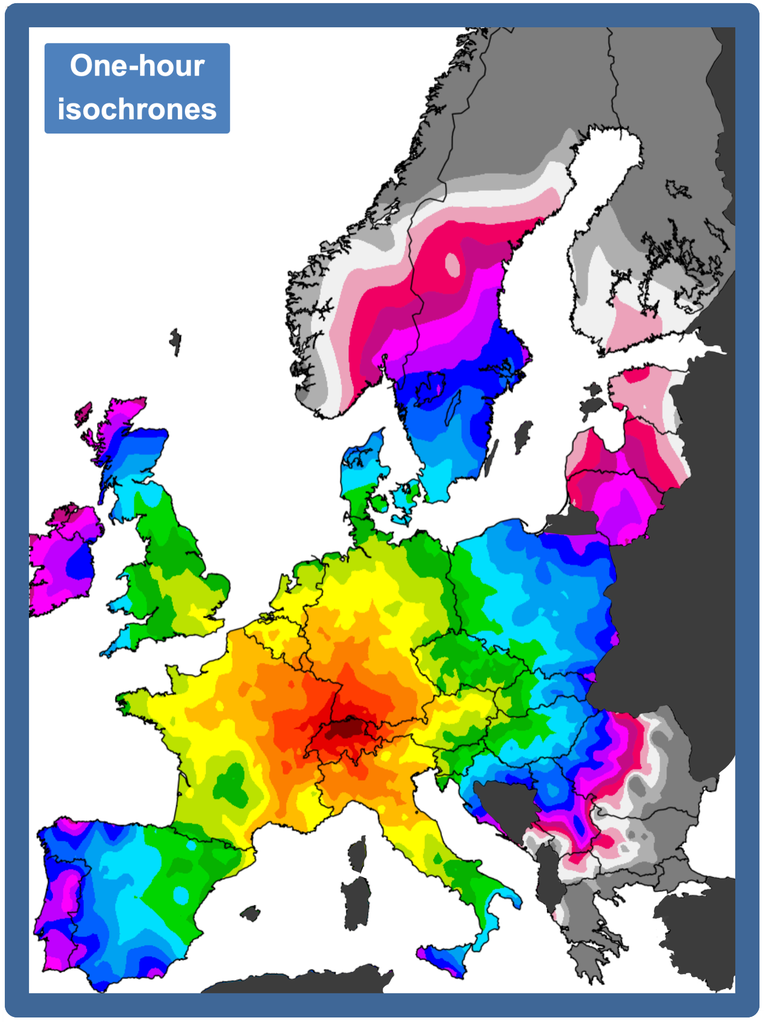
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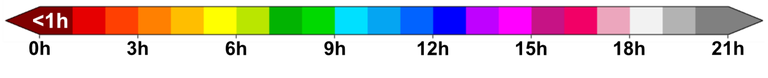
Average Future Optimised Speed from Zurich



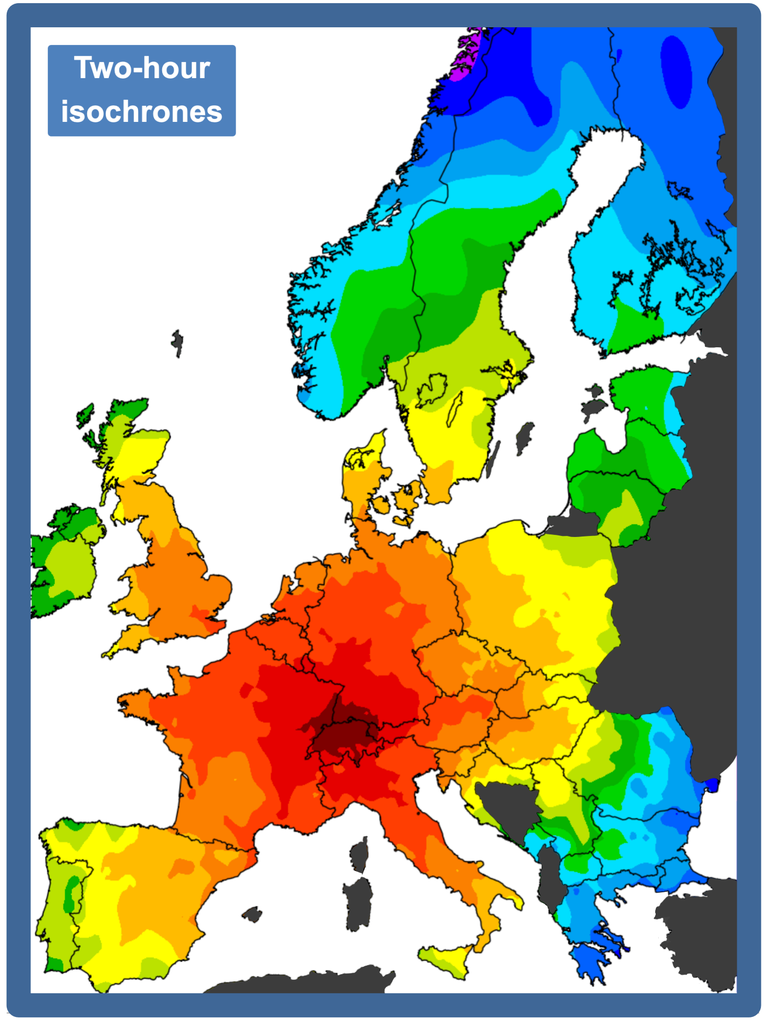


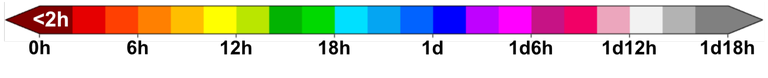
Optimised Future Reachability from Zurich (1h intervals)





Optimised Future Reachability from Zurich (2h intervals)





ETH

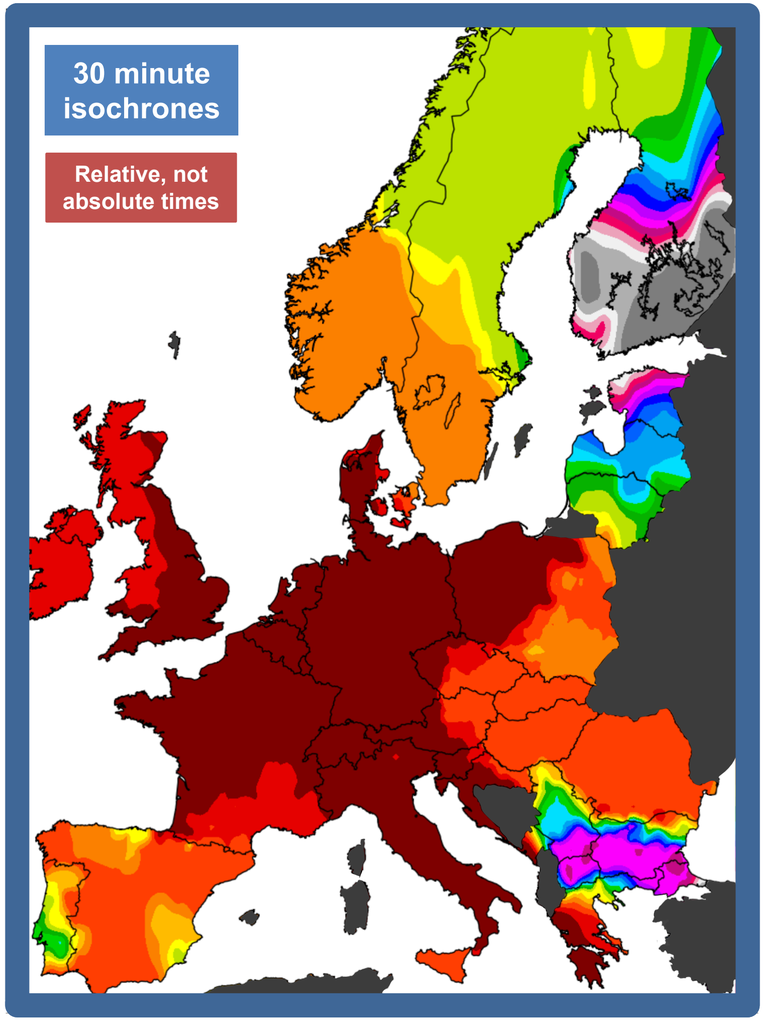
E P M R A C

Reachability

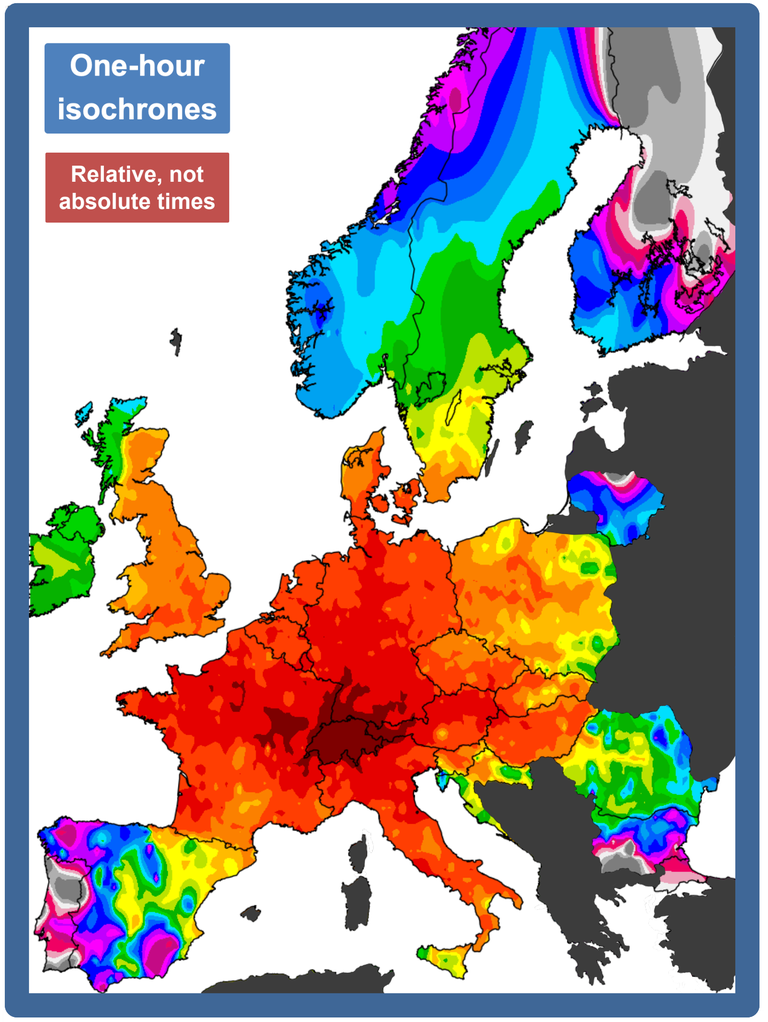
Scenario Comparisons

These are *relative* maps: smaller rings imply a higher *r*eachability improvement

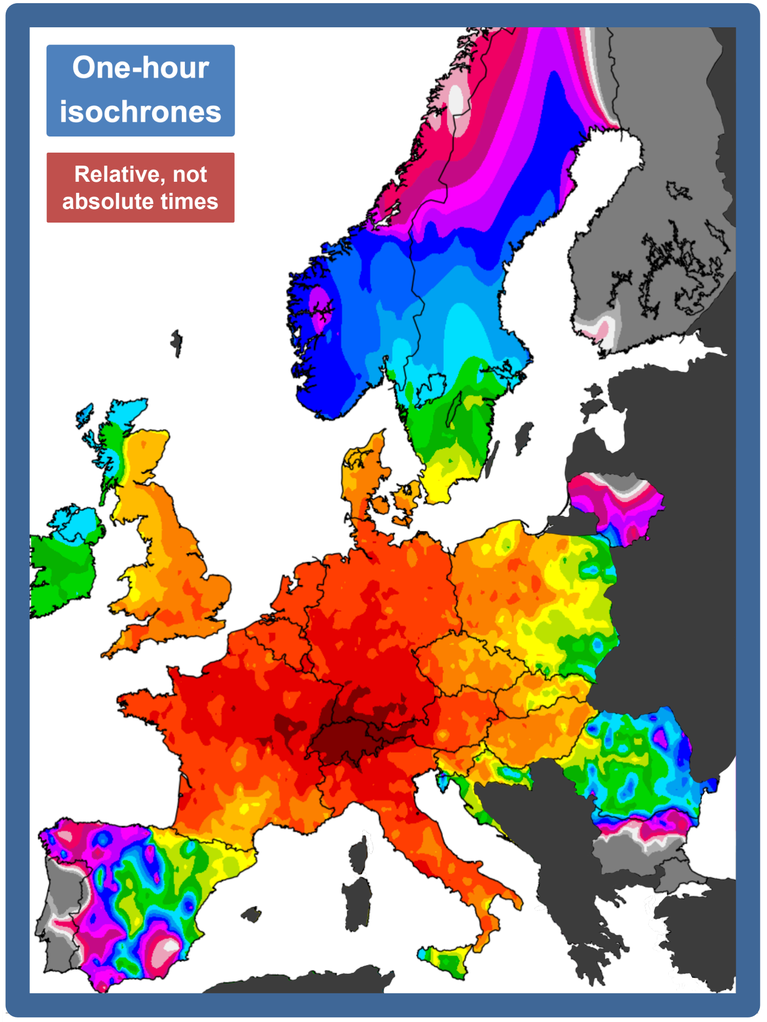
Impact of HSR Construction



Impact of Schedule Optimisation



Impact of Both Strategies



ETH

Corridors

Time Reduction Potential

2A + 2B ≈ 3

Scenario Number	1	2A	2B	3
2050 infrastructure	NO	YES	NO	YES
Timetable Optimisation	NO	NO	YES	YES

Average potential travel time improvement between corridor stations

Bahnhöfe (Gewichte)	Korridore	Fahrzeit künftig mit Infrastruktur-ausbau	Fahrzeit heute mit Fahrplan-optimierung	Fahrzeit-minimierende Strategie	Um [% Points]
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DURCHSCHNITT (gew.)		-21.58%	-21.01%	Ausbau	0.57%
Standardabweichung		12.27%	4.66%		

2A 2B

Potential end-to-end travel time and average speed improvement for each corridor

AVG Time [min]	Corridors	Current End-To-End	Optimised End-To-End	Future Optimised End-To-End	Optimisable Today	Optimisable Future	New Infrastructure Portion
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		75.8 km/h	113.9 km/h	128.7 km/h	50.3%	69.8%	
2459	Corridor 2	2d 15h 11m	1d 18h 20m	1d 15h 37m	-32.16%	-36.52%	-4.35%
		52.9 km/h	78.0 km/h	82.0 km/h	47.4%	55.0%	
1901	Corridor 3	2d 17h 10m	1d 13h 11m	1d 2h 10m	-42.91%	-59.82%	-16.91%
		46.8 km/h	82.0 km/h	108.9 km/h	75.2%	133%	
1880	Corridor 4	2d 13h 0m	1d 8h 25m	1d 6h 14m	-44.58%	-48.31%	-3.73%
		63.3 km/h	114.1 km/h	120.7 km/h	80.3%	90.7%	
1764	Corridor 5	4d 16h 37m	1d 14h 25m	20h 23m	-65.63%	-81.76%	-16.14%
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		66.6 km/h	122.2 km/h	165.7 km/h	83.5%	149%	
1325	Corridor 10	1d 12h 58m	23h 13m	20h 56m	-36.65%	-42.88%	-6.23%
		69.6 km/h	109.8 km/h	121.8 km/h	57.8%	75.0%	
WEIGHTED TIME		2d 11h 37m	1d 9h 16m	1d 3h 18m	-40.90%	-49.85%	-8.95%
Standard Deviation		1d 1h 30m	11h 22m	10h 30m	10.55%	14.27%	
WEIGHTED SPEED		60.9 km/h	103 km/h	125 km/h	76.8%	124%	
Standard Deviation		14.2 km/h	16.3 km/h	27.9 km/h	43.8%	110%	
UNWEIGHTED TOTAL		21d 8h 17m	11d 18h 4m	9d 14h 30m	-44.94%	-55.01%	-10.07%

1 2B 3 2B 3

E P M R A C

ETH

Einleitung

Problem

Methods

Results

Analysis

Conclusion

E P M R A C

Travel time reduction measures	Inter-European Reachability	Associated Costs	Average travel-time reduction along long-distance railway corridors	End-To-End travel-time reduction on long-distance railway corridors
Pan-European Optimised Timetables	+ ++	-	+	+ +
Planned High Speed Rail Construction	++	- - -	+	(+)
Both measures in concert	+ + +	- - -	(+ +)	+ + +

A timetable optimisation has been shown to have substantial time-saving effects for long-distance travel, on par with or surpassing those from HSR construction — and with orders-of-magnitude lower costs.

Further research is needed into how best to implement this in a manner most acceptable to all involved stakeholders.

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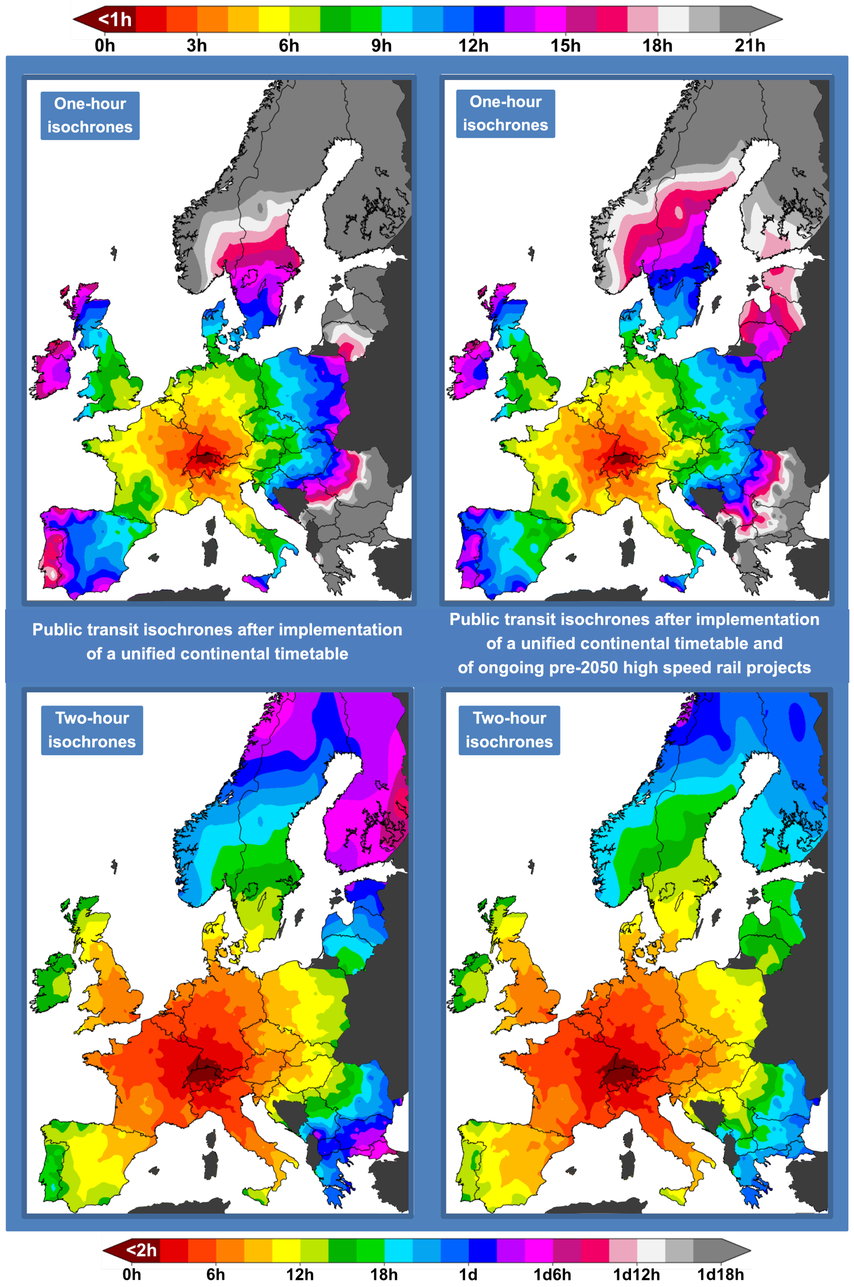
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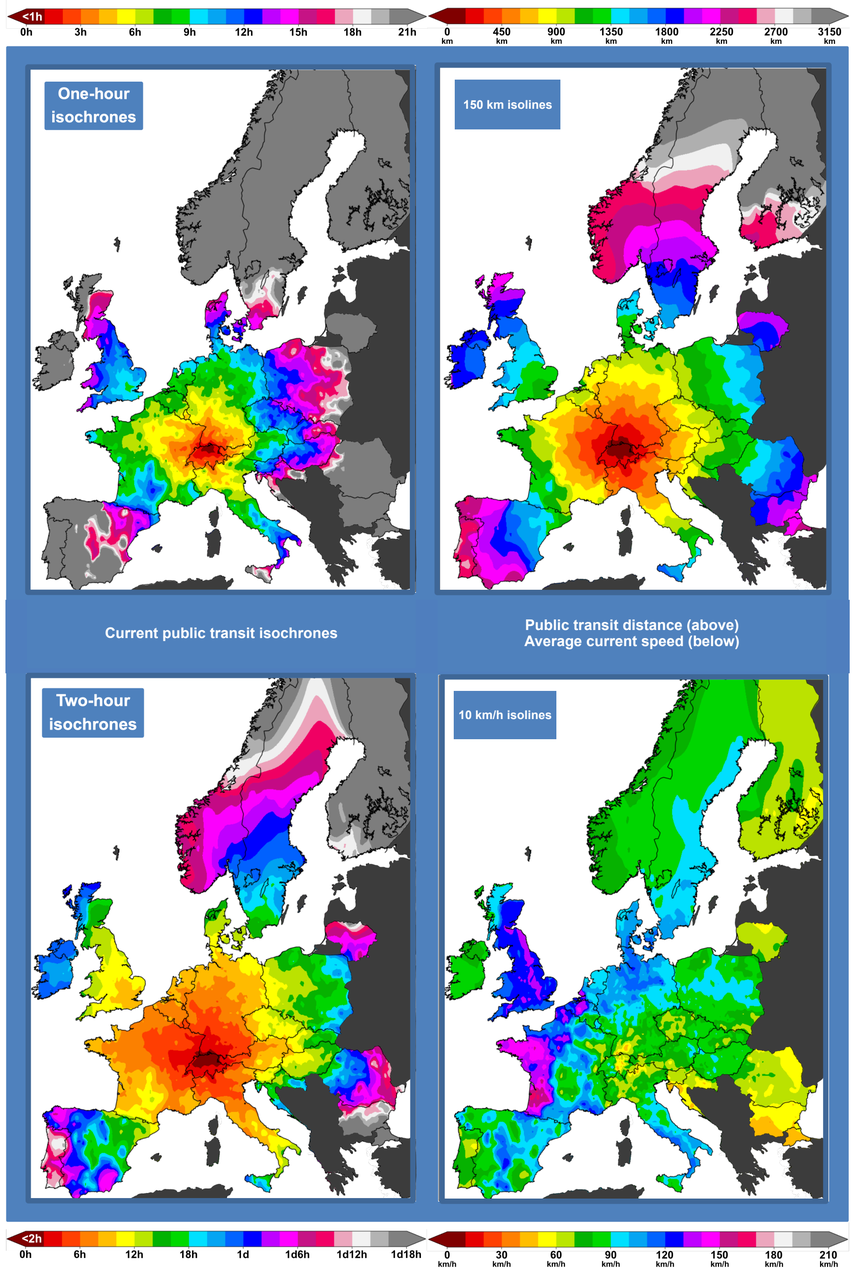
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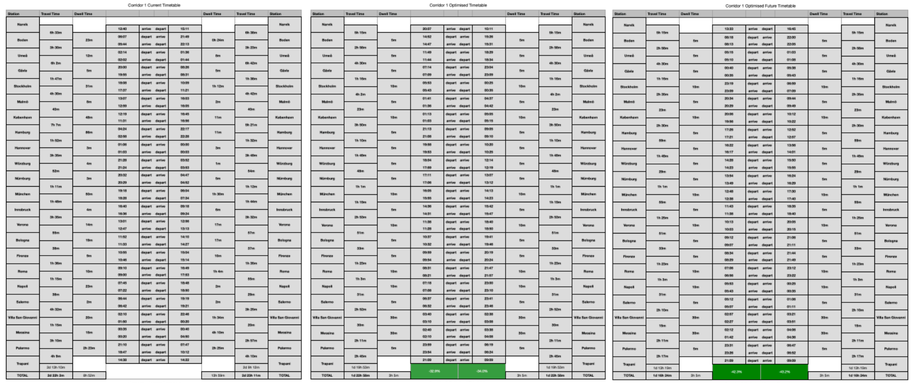
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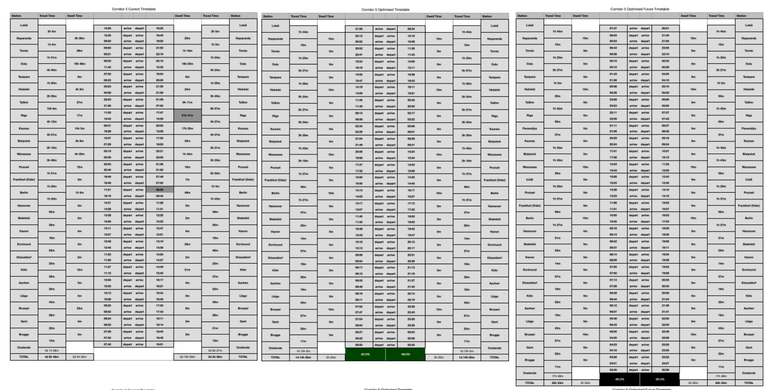
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Corridor 1 Current Timetable

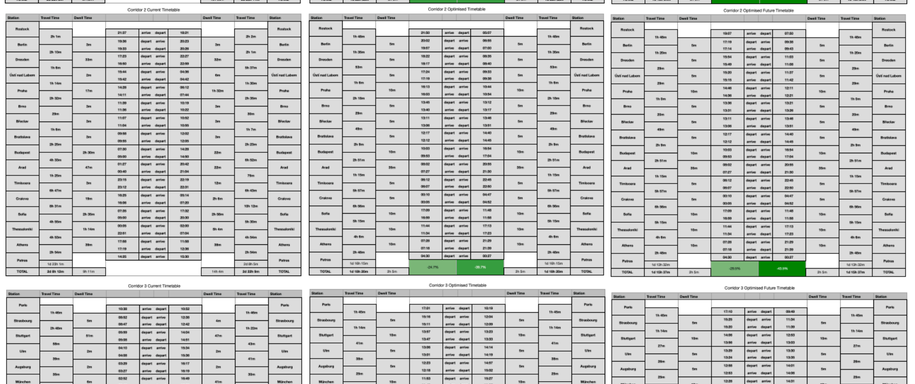
Corridor 1 Optimised Timetable

Corridor 1 Optimised Future Timetable


Corridor 5 Current Timetable

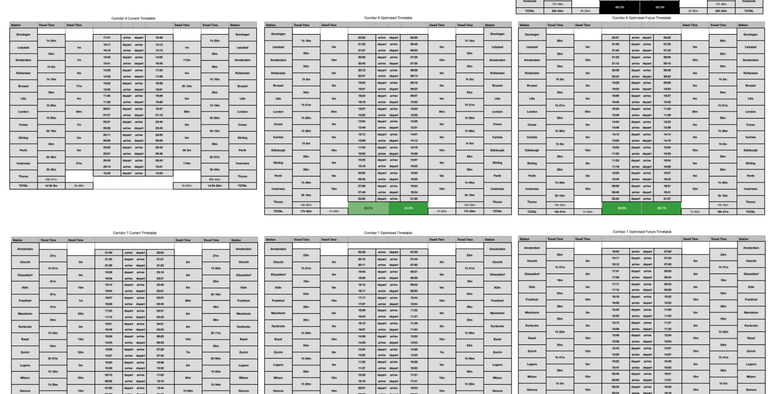
Corridor 5 Optimised Timetable

Corridor 5 Optimised Future Timetable


Corridor 2 Current Timetable

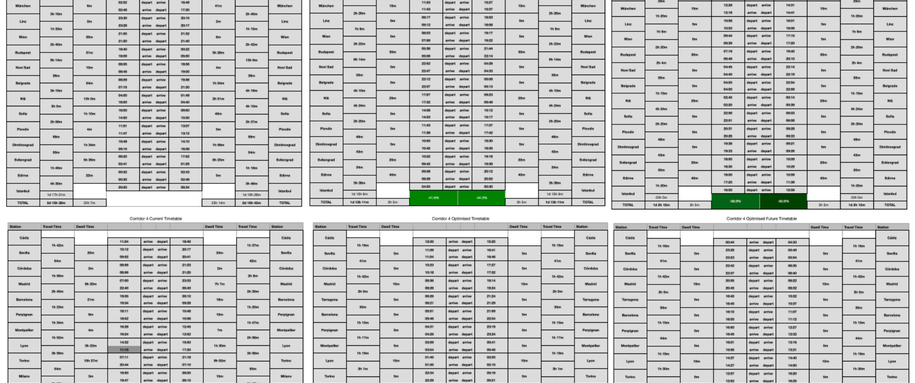
Corridor 2 Optimised Timetable

Corridor 2 Optimised Future Timetable


Corridor 6 Current Timetable

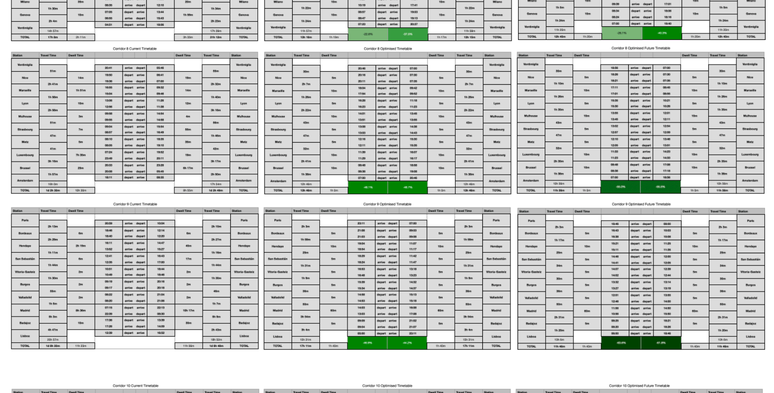
Corridor 6 Optimised Timetable

Corridor 6 Optimised Future Timetable


Corridor 3 Current Timetable

Corridor 3 Optimised Timetable

Corridor 3 Optimised Future Timetable


Corridor 7 Current Timetable

Corridor 7 Optimised Timetable

Corridor 7 Optimised Future Timetable

Corridor 4 Current Timetable

Corridor 4 Optimised Timetable

Corridor 4 Optimised Future Timetable

Corridor 8 Current Timetable

Corridor 8 Optimised Timetable

Corridor 8 Optimised Future Timetable

Corridor 10 Current Timetable

Corridor 10 Optimised Timetable

Corridor 10 Optimised Future Timetable

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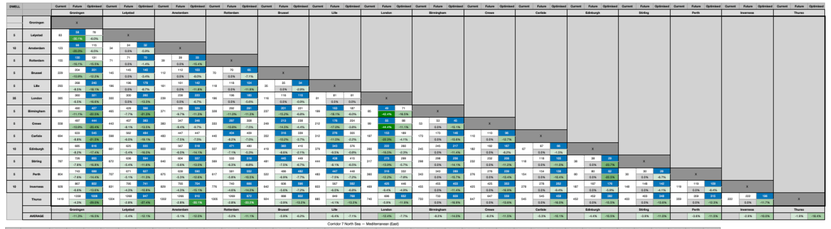
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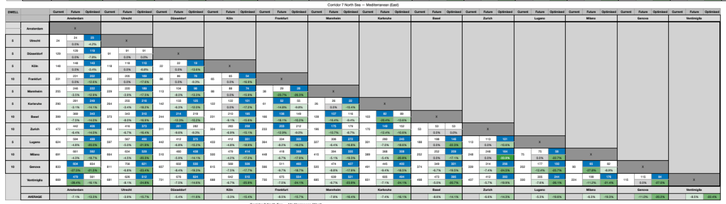
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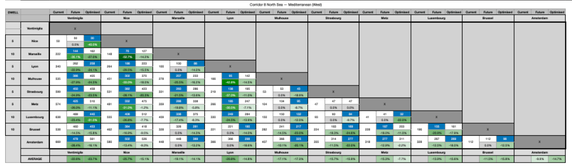
Conclusion

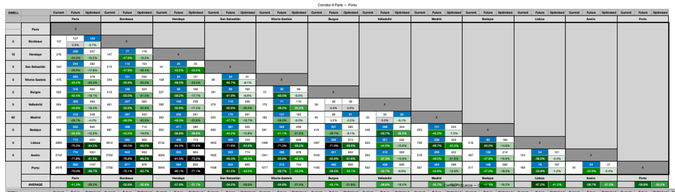
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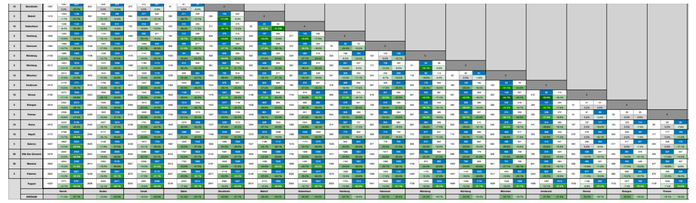


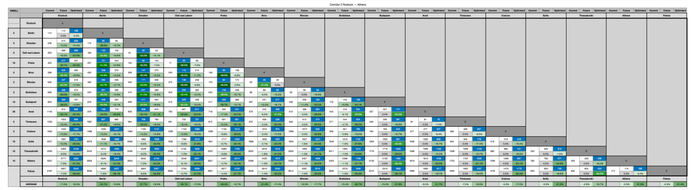


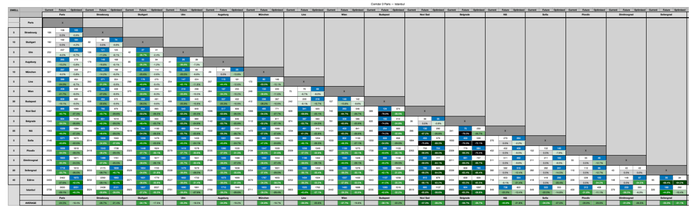


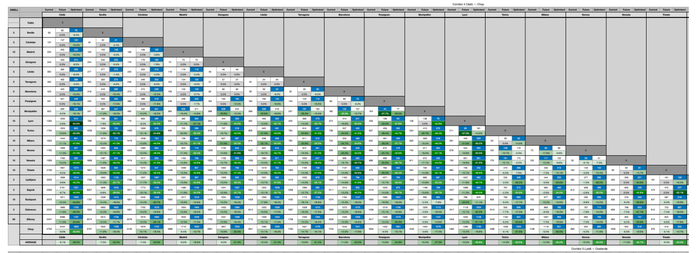


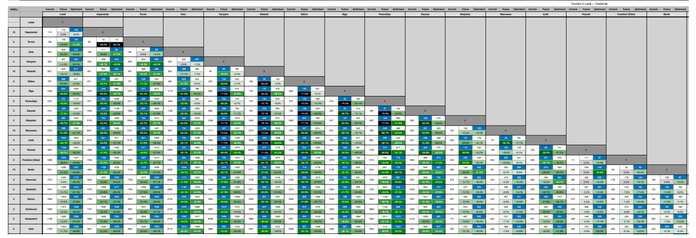








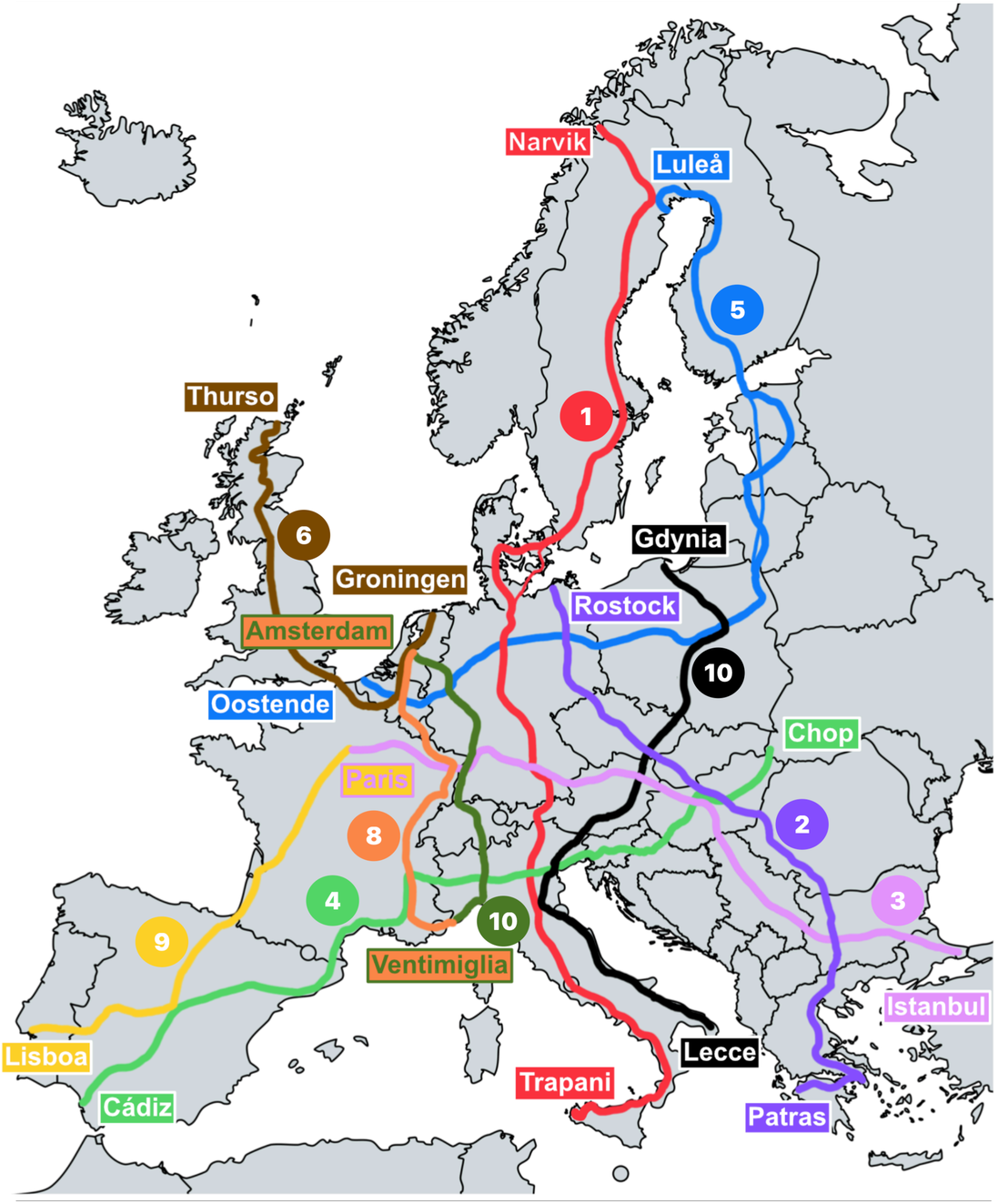




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Chosen Cross-European Corridors



Corridors

Time Reduction Potential

EMPRACP A

2A + 2B ≈ 3

Scenario Number	1	2A	2B	3
2050 infrastructure	NO	YES	NO	YES
Timetable Optimisation	NO	NO	YES	YES

Average potential travel time improvement between corridor stations

Bahnhöfe (Gewichte)	Korridore	Fahrzeit künftig mit Infrastruktur-ausbau	Fahrzeit heute mit Fahrplan-optimierung	Fahrzeit-minimierende Strategie	Um [% Points]
23	Korridor 1	-20.49%	-21.41%	Optimierung	-0.93%
16	Korridor 2	-14.16%	-18.95%	Optimierung	-4.79%
18	Korridor 3	-36.98%	-25.43%	Ausbau	11.55%
22	Korridor 4	-10.60%	-25.60%	Optimierung	-15.01%
28	Korridor 5	-28.92%	-23.24%	Ausbau	5.68%
15	Korridor 6	-6.01%	-11.31%	Optimierung	-5.30%
13	Korridor 7	-6.89%	-16.47%	Optimierung	-9.59%
10	Korridor 8	-17.16%	-15.46%	Ausbau	1.69%
12	Korridor 9	-50.74%	-28.27%	Ausbau	22.48%
17	Korridor 10	-22.86%	-18.30%	Ausbau	4.56%
DURCHSCHNITT (gew.)		-21.58%	-21.01%	Ausbau	0.57%
Standardabweichung		12.27%	4.66%		

2A 2B

Potential end-to-end travel time and average speed improvement for each corridor

AVG Time [min]	Corridors	Current End-To-End	Optimised End-To-End	Future Optimised End-To-End	Optimisable Today	Optimisable Future	New Infrastructure Portion
2621	Corridor 1	2d 22h 37m	1d 22h 58m	1d 16h 24m	-33.48%	-42.78%	-9.30%
		75.8 km/h	113.9 km/h	128.7 km/h	50.3%	69.8%	
2459	Corridor 2	2d 15h 11m	1d 18h 20m	1d 15h 37m	-32.16%	-36.52%	-4.35%
		52.9 km/h	78.0 km/h	82.0 km/h	47.4%	55.0%	
1901	Corridor 3	2d 17h 10m	1d 13h 11m	1d 2h 10m	-42.91%	-59.82%	-16.91%
		46.8 km/h	82.0 km/h	108.9 km/h	75.2%	133%	
1880	Corridor 4	2d 13h 0m	1d 8h 25m	1d 6h 14m	-44.58%	-48.31%	-3.73%
		63.3 km/h	114.1 km/h	120.7 km/h	80.3%	90.7%	
1764	Corridor 5	4d 16h 37m	1d 14h 25m	20h 23m	-65.63%	-81.76%	-16.14%
		34.0 km/h	98.9 km/h	176.6 km/h	191%	419%	
964	Corridor 6	1d 1h 22m	17h 20m	16h 27m	-31.51%	-35.00%	-3.49%
		83.0 km/h	121.2 km/h	138.7 km/h	46.0%	67.1%	
778	Corridor 7	0d 19h 10m	13h 15m	12h 37m	-30.03%	-33.42%	-3.39%
		71.3 km/h	101.9 km/h	107.0 km/h	42.9%	50.1%	
771	Corridor 8	1d 2h 40m	13h 46m	11h 56m	-48.36%	-55.23%	-6.88%
		65.7 km/h	127.1 km/h	142.5 km/h	93.5%	117%	
869	Corridor 9	1d 7h 34m	17h 11m	11h 46m	-45.53%	-62.70%	-17.17%
		66.6 km/h	122.2 km/h	165.7 km/h	83.5%	149%	
1325	Corridor 10	1d 12h 58m	23h 13m	20h 56m	-36.65%	-42.88%	-6.23%
		69.6 km/h	109.8 km/h	121.8 km/h	57.8%	75.0%	
WEIGHTED TIME		2d 11h 37m	1d 9h 16m	1d 3h 18m	-40.90%	-49.85%	-8.95%
Standard Deviation		1d 1h 30m	11h 22m	10h 30m	10.55%	14.27%	
WEIGHTED SPEED		60.9 km/h	103 km/h	125 km/h	76.8%	124%	
Standard Deviation		14.2 km/h	16.3 km/h	27.9 km/h	43.8%	110%	
UNWEIGHTED TOTAL		21d 8h 17m	11d 18h 4m	9d 14h 30m	-44.94%	-55.01%	-10.07%

1 2B 3 2B 3