

# Comparison of High Speed Lines' CAPEX

## Final report

Hamburg, November, 2009

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- **Objectives and preliminary remarks**
- Selection of comparators
- HSL CAPEX in comparison
- Conclusions
- Next steps

# The goal of the study on high speed lines' CAPEX is to get a better understanding of line characteristics and cost structures

## Objectives

Comparison of investment costs of selected high speed lines in Western Europe with a focus on:

- Total investment costs for each selected line
- General conditions and frameworks in different countries with impact on high speed lines' developing and constructing costs
- Particular cost breakdown by project phases
- Analyses by cost positions including cost-driving assets
- Understanding key cost drivers and its impacts on various cost elements
- Unit costs of selected asset groups

# Information on line characteristics and investment costs of each compared high speed line is presented anonymously

## Preliminary remarks

- A general overview on each line in the comparison is given based on published data and therefore is presented disclosed
- Detailed line characteristics are presented anonymously, e.g. as share of total route-km (%) or per route-km (number/route-km)
- Cost data on each line is presented inflation adjusted and PPP-normalised to GBP
- Total investment costs are shown anonymously related to route-km (million GBP per route-km)
- The cost breakdown by project phases and assets as costs per route-km (million GBP/route-km) and share of total costs per route-km (%) provide an anonymous and normalised comparison
- The comparators are coded by the letters A, B, C etc. depending on the number of lines which provided particular data for the specific topic
- The sequence of comparators is randomized for each chart in line with customary anonymisation in comparison projects, e.g. comparator A on one chart changes to comparator D on another chart

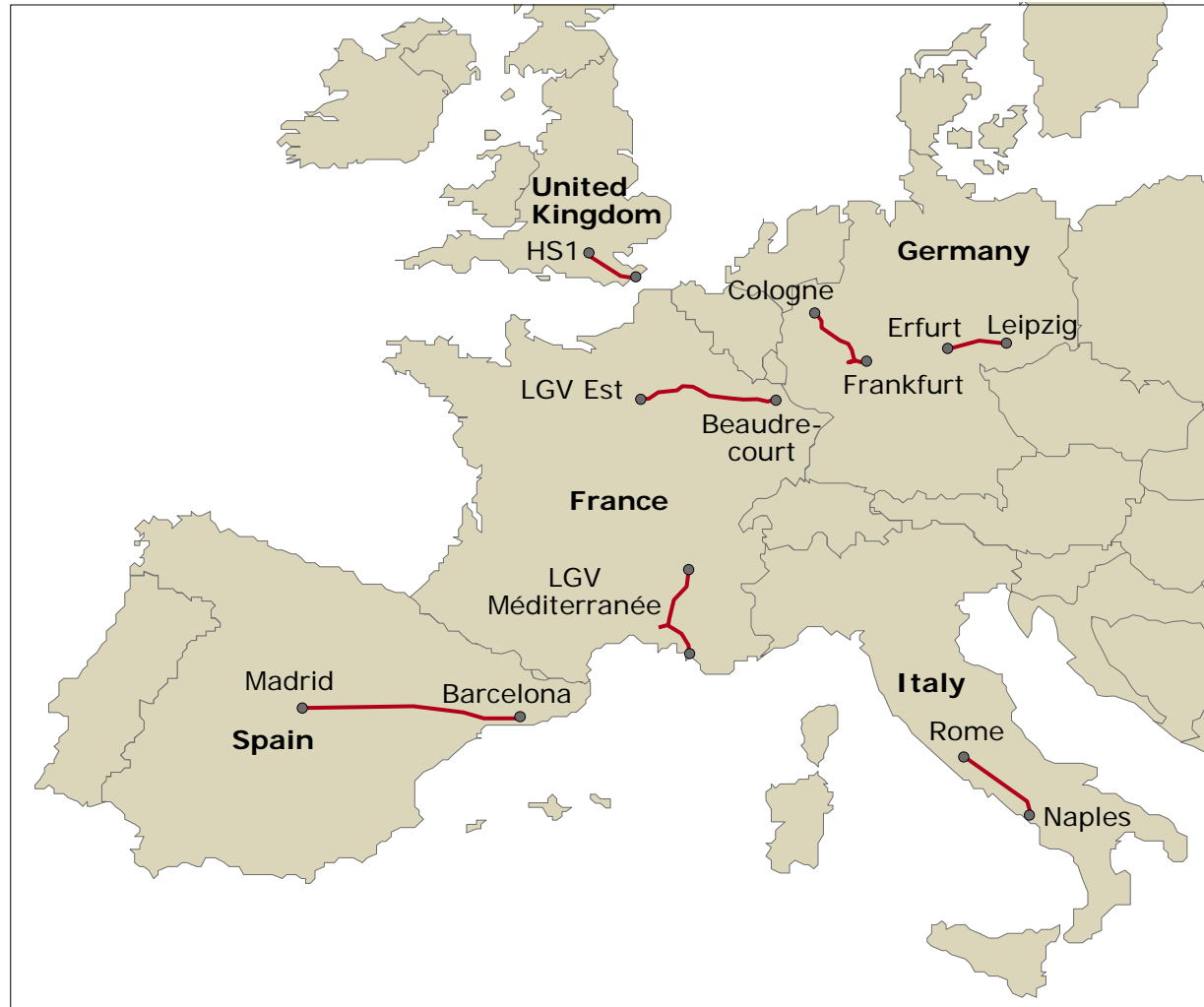
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  - **Overview on lines**
  - Line characteristics
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- Conclusions











# The comparison comprises two lines in Germany, two lines in France and one in each Italy and Spain

## Routing of high speed lines



# The "wish-list" of comparator lines was mainly driven by the similarity of general and regulatory conditions in these countries

## Overview of contacts

Line	Characteristics	Contacts established	Interview
TGV Méditerranée (RFF) 	<ul style="list-style-type: none"> <li>Mainland Europe; applying European jurisdiction</li> <li>Opening year &gt; 2000 or under construction</li> <li>Similar safety standards (safety and signalling)</li> <li>Rather high standards regarding environmental issues</li> <li>Interesting civil engineering works (tunnels, bridges)</li> <li>Design speed 300kmh or more</li> </ul>	RFF	
Vaires-sur-Marne – Baudrecourt (RFF) 		RFF	– 1)
Cologne – Rhine/Main (DB) 		DB ProjektBau	
Erfurt – Leipzig/Halle (DB) 		DB ProjektBau	
Madrid – Barcelona (ADIF) 		ADIF	– 2)
Rome – Naples (RFI) 		Italferr	

# Collected data of the high speed lines is rather comprehensive on line characteristics and - with some constraints - on costs

## Data sources of comparator lines

	Comparators' data
<b>Line characteristics</b>	<ul style="list-style-type: none"> <li>▪ Comprehensive information with no relevant data gaps for 50% of the comparators</li> <li>▪ Information at least on cost driving elements for the other 50% of the comparators provided by the railways and completed by published data with some gaps, e.g. distribution of route-km on embankments and cuttings, number of points and interlockings</li> </ul>
<b>Costs I</b> Total investment	<ul style="list-style-type: none"> <li>▪ Provided by railways via questionnaire and presentations</li> <li>▪ CAPEX are largely covering all activities and assets</li> </ul>
<b>Costs II</b> Project phases, cost positions	<ul style="list-style-type: none"> <li>▪ Breakdown by project phases for around 70% of the lines with some constraints, e.g.:                             <ul style="list-style-type: none"> <li>▫ Estimated allocation of lump-sums, as "planning costs" and consultation</li> <li>▫ No full separation of all activities and allocation by defined phases as commissioning, political and environmental issues (included in other phases)</li> </ul> </li> <li>▪ Cost break down for the other lines based on experience of average cost structures derived from comparable projects and no further cost break down where data was not available</li> </ul>
<b>Costs III</b> Assets	<ul style="list-style-type: none"> <li>▪ Allocation to asset categories and single assets for four lines with some constraint in regard to one line (no particular breakdown of civil engineering work by assets groups)</li> <li>▪ Cost break down for the other lines based on average cost values of assets derived from several comparable projects and no further break down where data was not available</li> </ul>

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Where readily available, data for High Speed 1 is also included structural data is complete, but only high-level cost data is used

## Data sources of HS1

	HS1's data
<b>Line characteristics</b>	<ul style="list-style-type: none"><li>▪ All relevant data on line characteristics provided by HS2</li><li>▪ No relevant data gaps</li></ul>
<b>Costs I / II</b> Total investment Phase costs	<ul style="list-style-type: none"><li>▪ Provided by HS2</li><li>▪ Including costs on discussed line characteristics</li></ul>

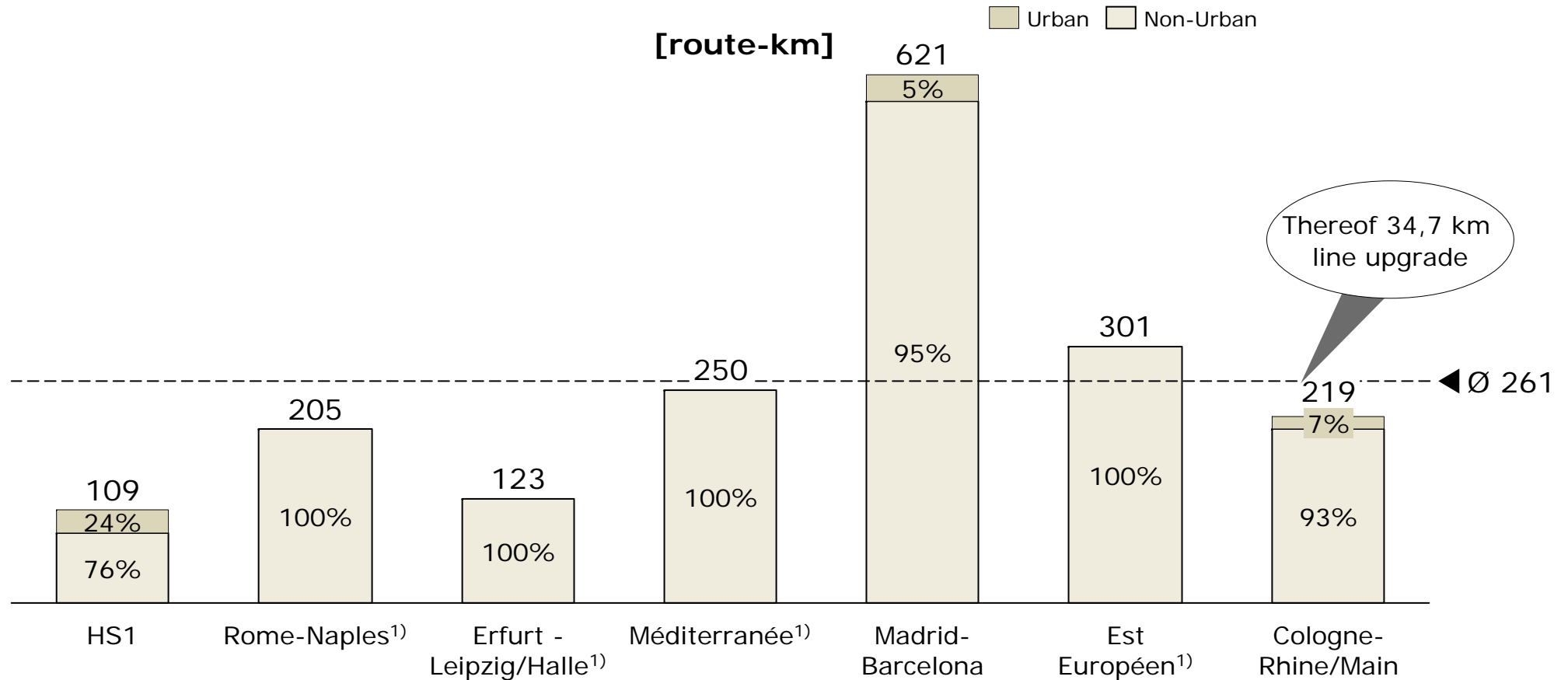
# One line was already opened in 2001, one is still under construction and will not be completed until 2015

## Overview of high speed lines

Year of opening	Line name	Route Length [km]	Designed for ...
<b>2001</b>	LGV Méditerranée	250	Passenger, freight
<b>2002</b>	Cologne – Rhine/Main	219	Passenger
...			
<b>2005</b>	Rome – Naples	205	Passenger, freight
...			
<b>2007</b>	HS1	109	Passenger, freight
	LGV Est Européen	301	Passenger, freight
<b>2008</b>	Madrid – Barcelona	621	Passenger, freight
...			
<b>2015</b>	Erfurt – Leipzig/Halle	123	Passenger, freight

# The average route length is about 260 km; HS1 is the shortest route in the comparison

## Total length of route



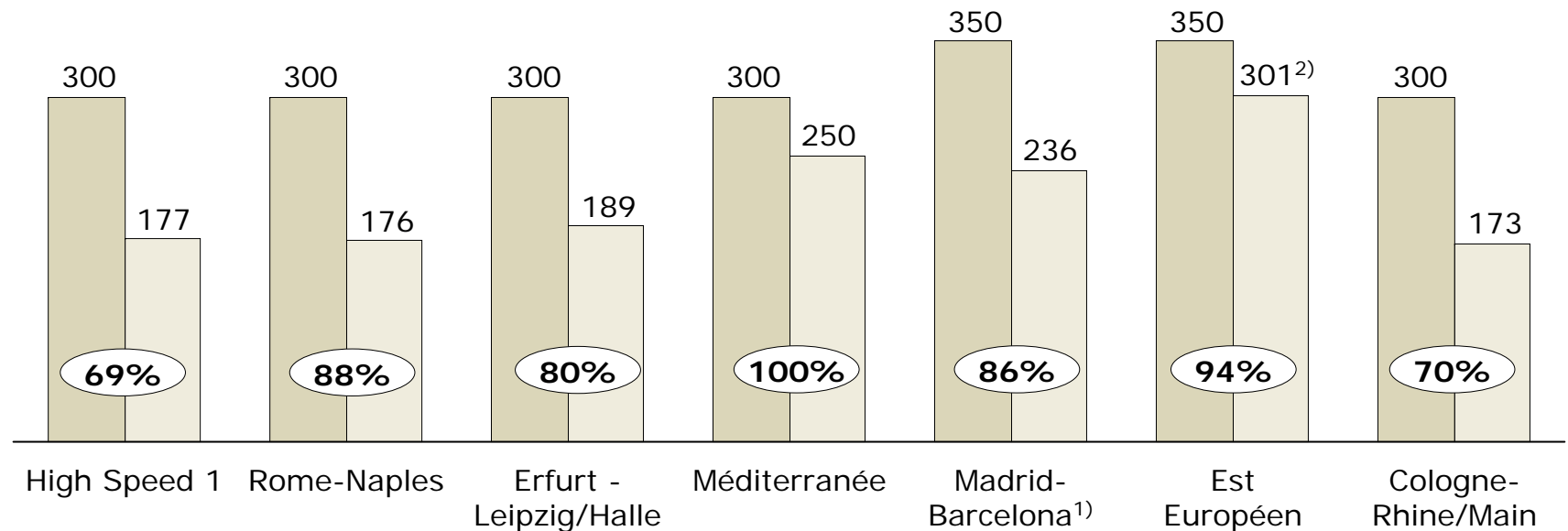
All lines are designed as double track lines

# The actual average speed of the Méditerranée comes closest to the design speed

## Maximum design speed and realised average speed (non-stop)

Maximum design speed
  Average speed
 % Share of track allowed for maximum design speed

[kph]



<b>From station</b>	London St. Pancras	Roma Termini	Erfurt Hbf	Valence TGV	Madrid Atocha	Vaires-sur-Marne	Köln Hbf
<b>To station</b>	Channel Tunnel	Napoli Centrale	Leipzig Hbf	Marseille Saint Charles	Barcelona Sants	Baudrecourt	Frankfurt a.M. Hbf
<b>Distance [km]</b>	109	205	123	250	621	301	219
<b>Time [hh:mm]</b>	00:35	01:10	00:39	1:00	02:38	01:00	01:16

# Particular line characteristics lead to very different average speeds realised

## Speed-influencing factors

- Intra-urban line sections
- Number of stops (intermediate stations)
- Percentage of track allowed for maximum speed e.g. depending on:
  - Radii
  - Gradients
  - Elevation
  - Number of railway overpasses and road bridges
  - Wind conditions and wind protection
- Speed limits due to external factors such as environment and noise protection
- Traffic intensity on line (slots in stations, need for waiting)
- Acceleration, speed and slowdown of vehicle type

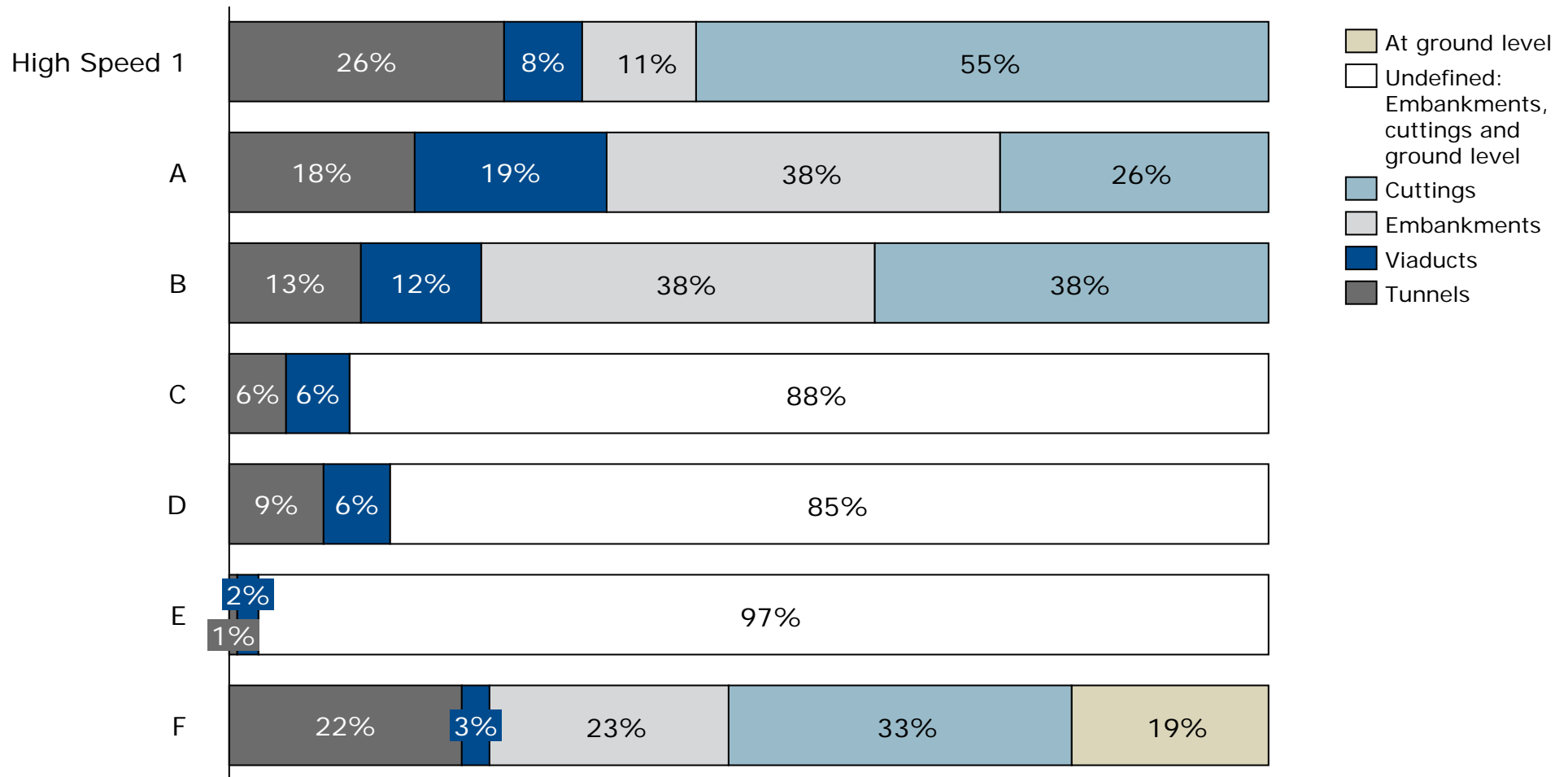
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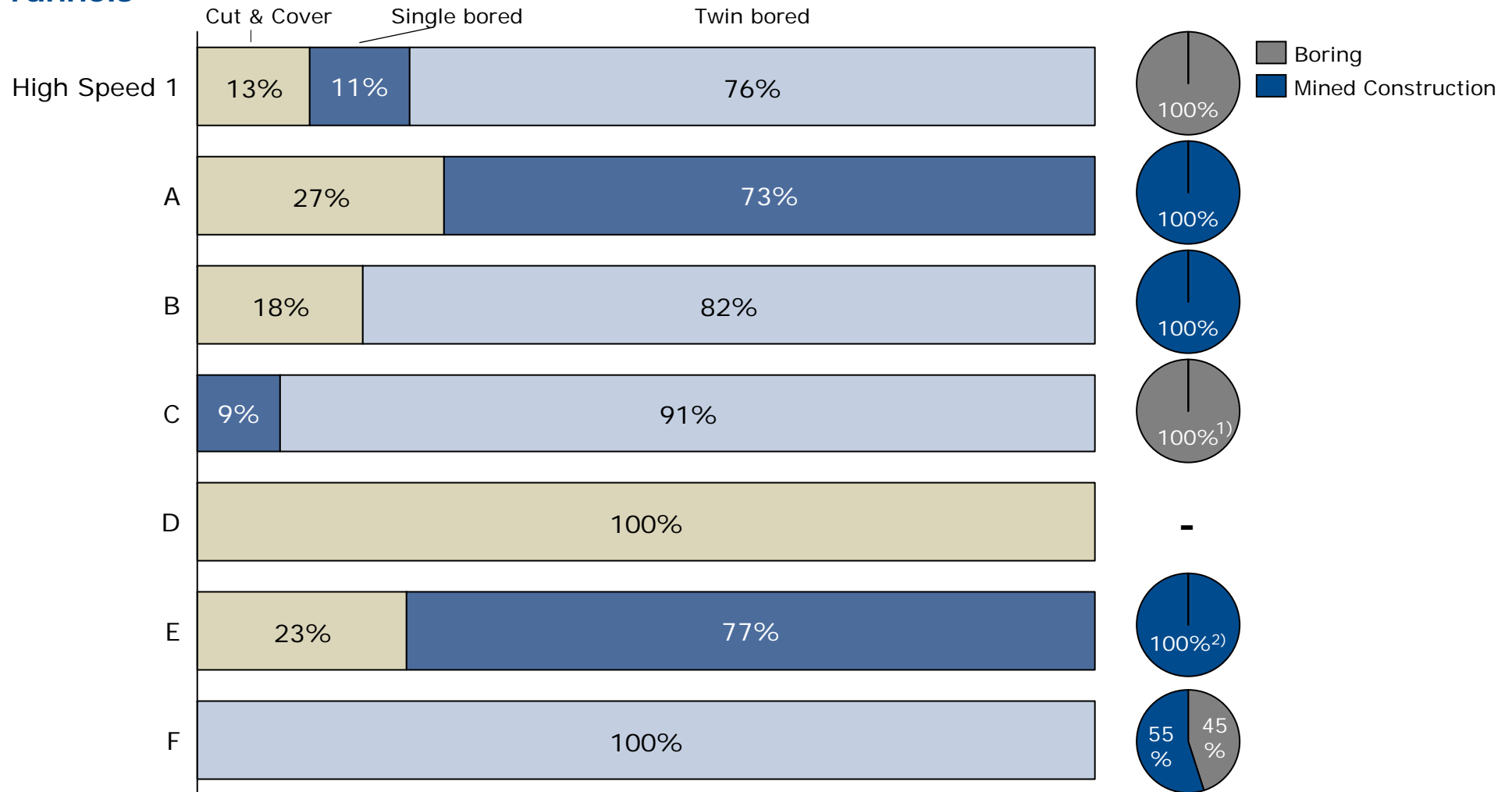
# The overall distribution of tunnels, viaducts, cuttings and embankments varies significantly between the comparators

## Line structure



# Most tunnels are natural and among the natural tunnels most are either exclusively twin bored or single bored

## Tunnels

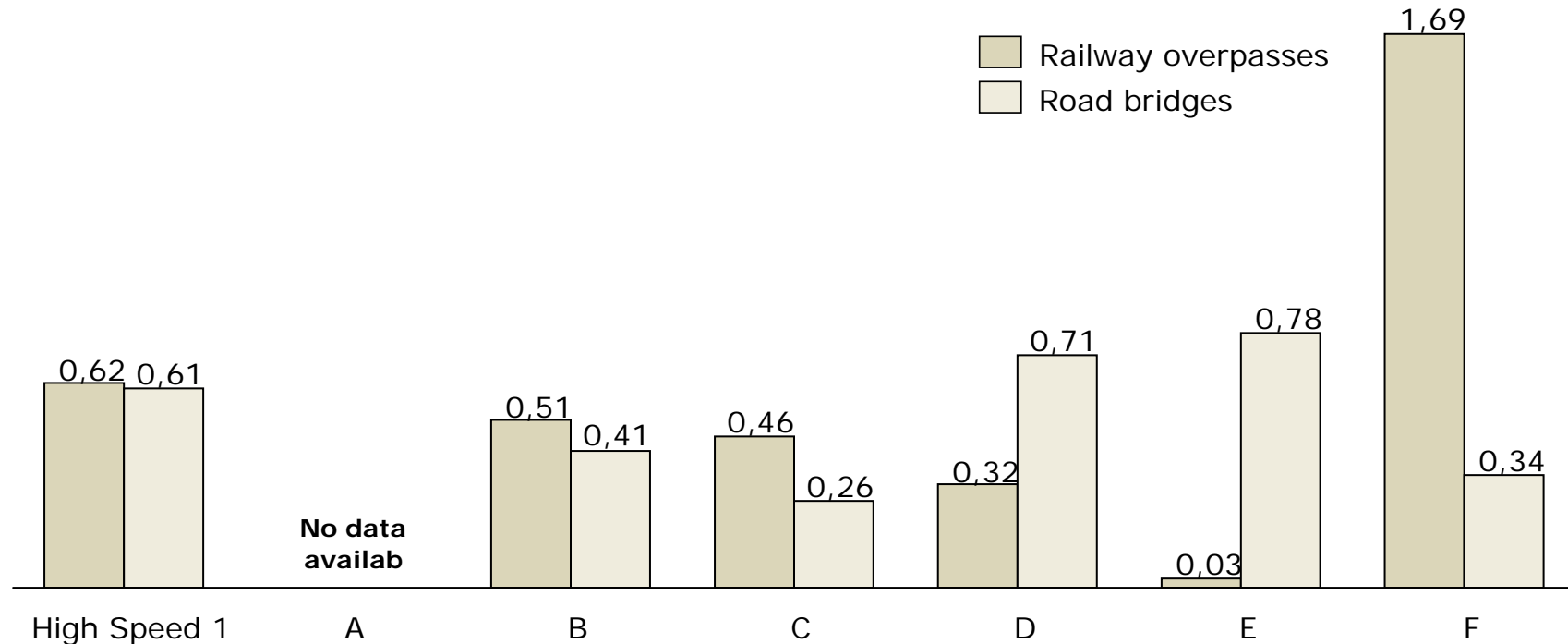


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1) Assumption due to routing of line  
2) Mined construction, only very few parts of individual tunnels with boring machines

# One comparator has a very high number of railway overpasses and water crossings

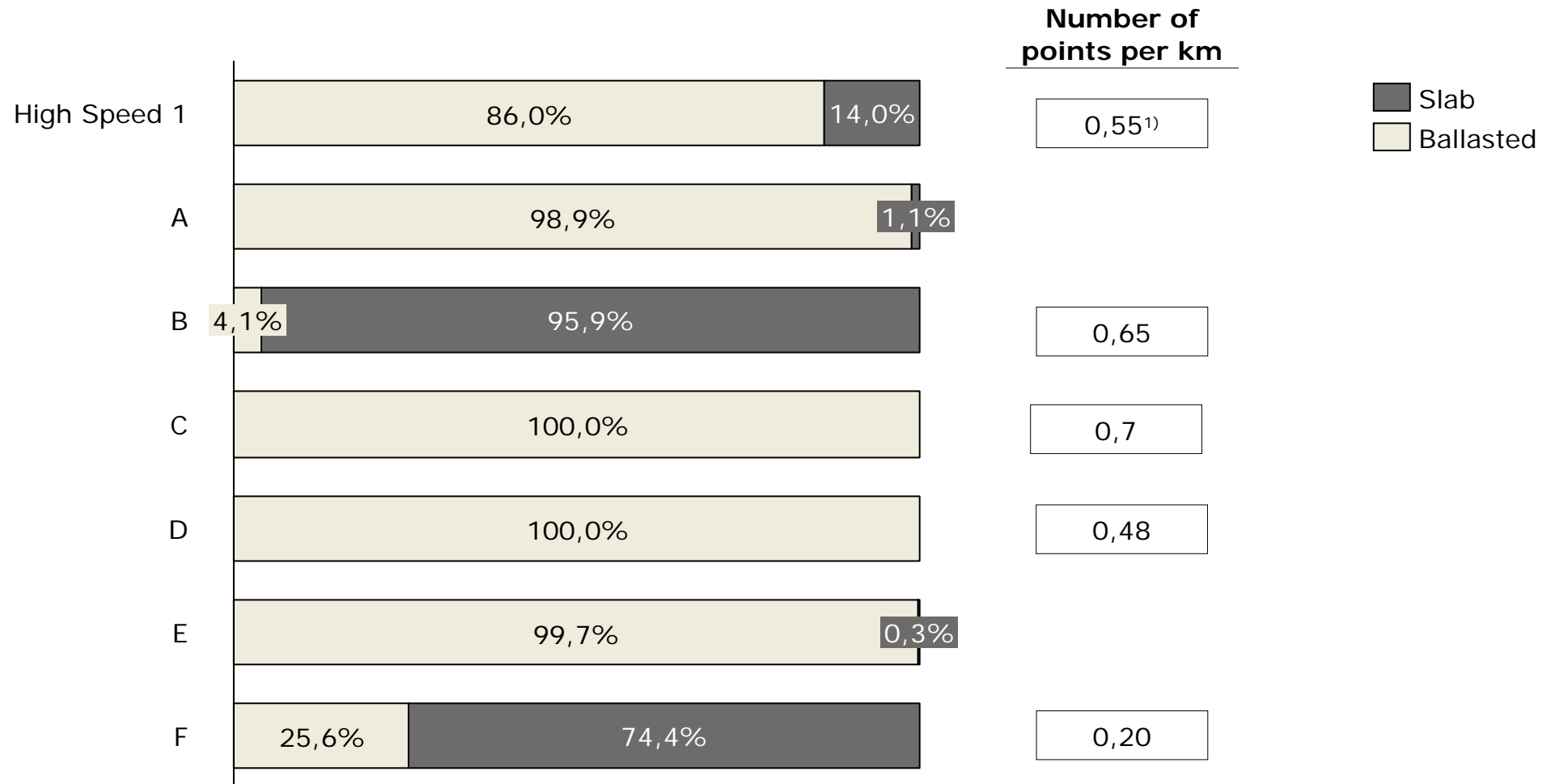
## Railway overpasses and road bridges [# /route-km]



Comparator F additionally has a total number of 1,2 water crossings/route-km

The compared lines mostly either have ballasted or slab track, only one line has significant shares of both types

**Slab versus ballasted track and number of points**

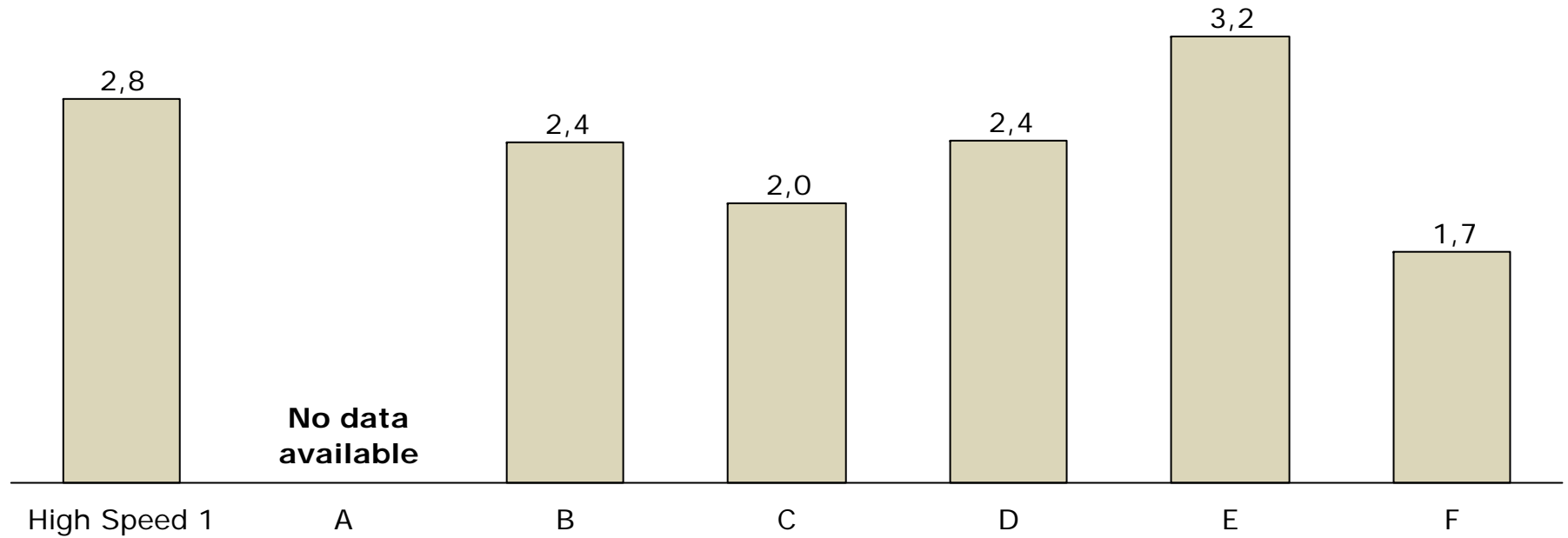


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1) Assumption: 3 point machines per point with 180 point machines

# The relative prevalence of substations is similar for most of the lines

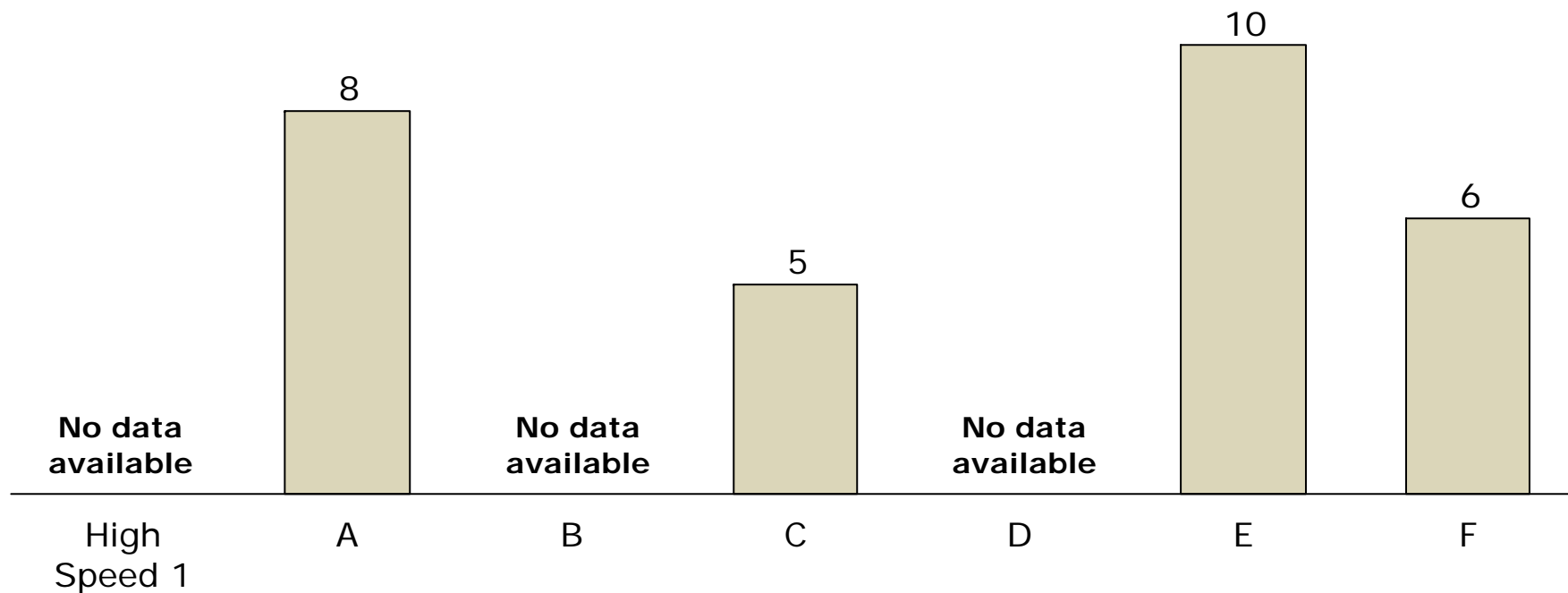
## Substations [# / 100 route-km] and type of electrification



Electrification	High Speed 1	A	B	C	D	E	F
	25 kV 50 Hz	25 kV 50 Hz	15 kV 16,7 Hz	25 kV 50 Hz	25 kV	15 kV 16,7 Hz	25 kV 50 Hz

# Due to different years of line opening there are differences in signalling technology

## Interlockings [# / 100 route-km] and signalling systems



<b>Signalling System</b>	TVM 430 and KVB	ETCS 2	TVM 430 and ETCS 2	ATC	ETCS 2	ETCS 2	TVM 430
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# The high speed lines differ greatly concerning the amount of intermediate stations, termini and buildings included

## Intermediate stations, termini built new

	Termini	Intermediate Stations	New Platforms	Buildings <sup>1)</sup>
High Speed 1			27	3 <sup>2)</sup>
A	-	Only roof/ platforms  Only platforms	4	None
B			8	2 Fleet Serving Facilities
C			?	?
D	-		8	?
E	-	-	-	Only small technical buildings
F			4	None

Only major refurbishment

1) Workshops, fleet serving facilities, administration

2) 1 administrative and 2 technical facilities; 1 depot not included in investment volume

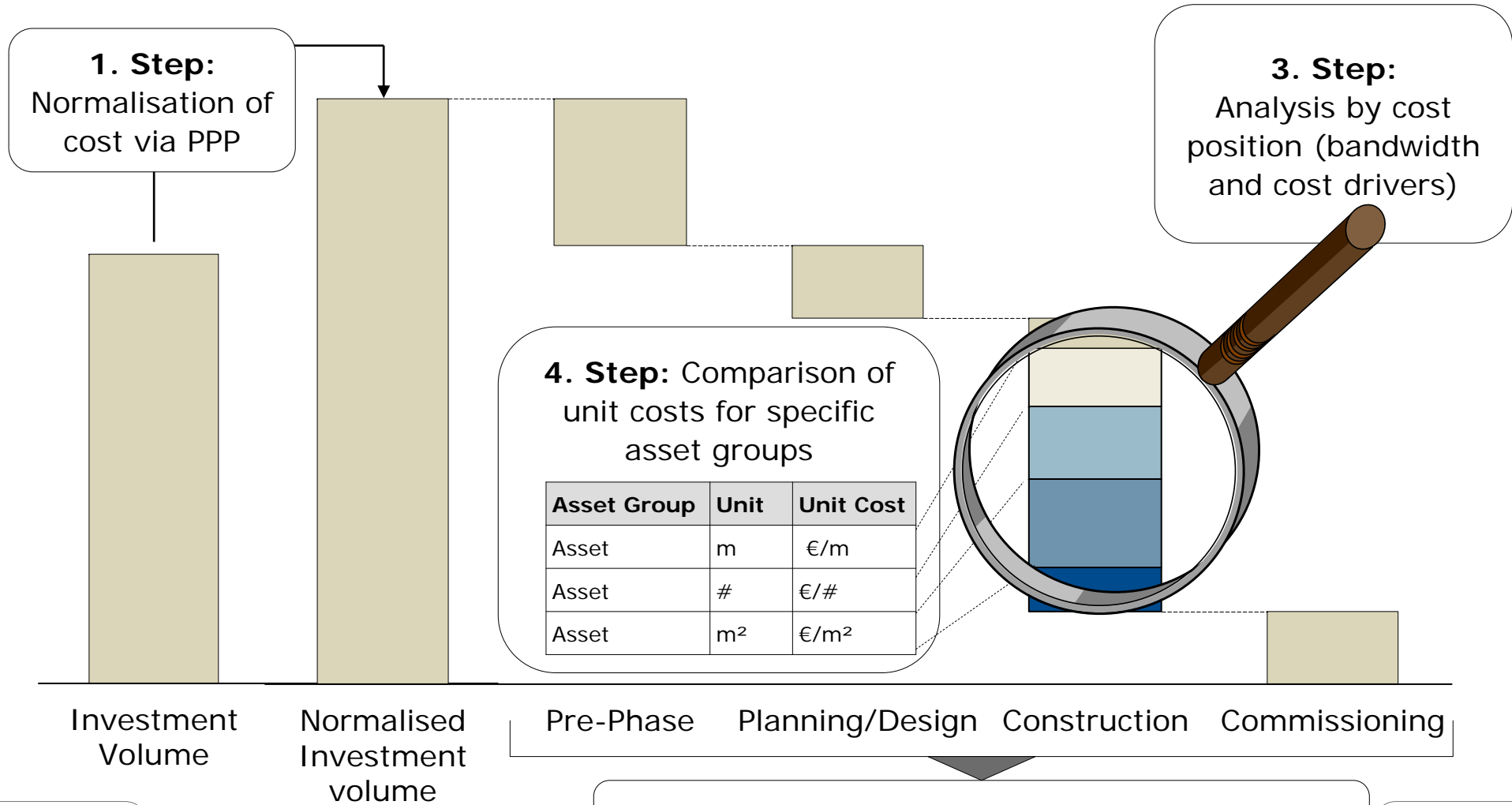
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# Investment volumes were be compared in a four step approach

## Approach Cost Comparison



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# All investment costs were first adjusted to 2008 price levels before converting national currencies to the Pound Sterling

## Steps

**Adjustment to  
2008 price level**

**Currency  
conversion**

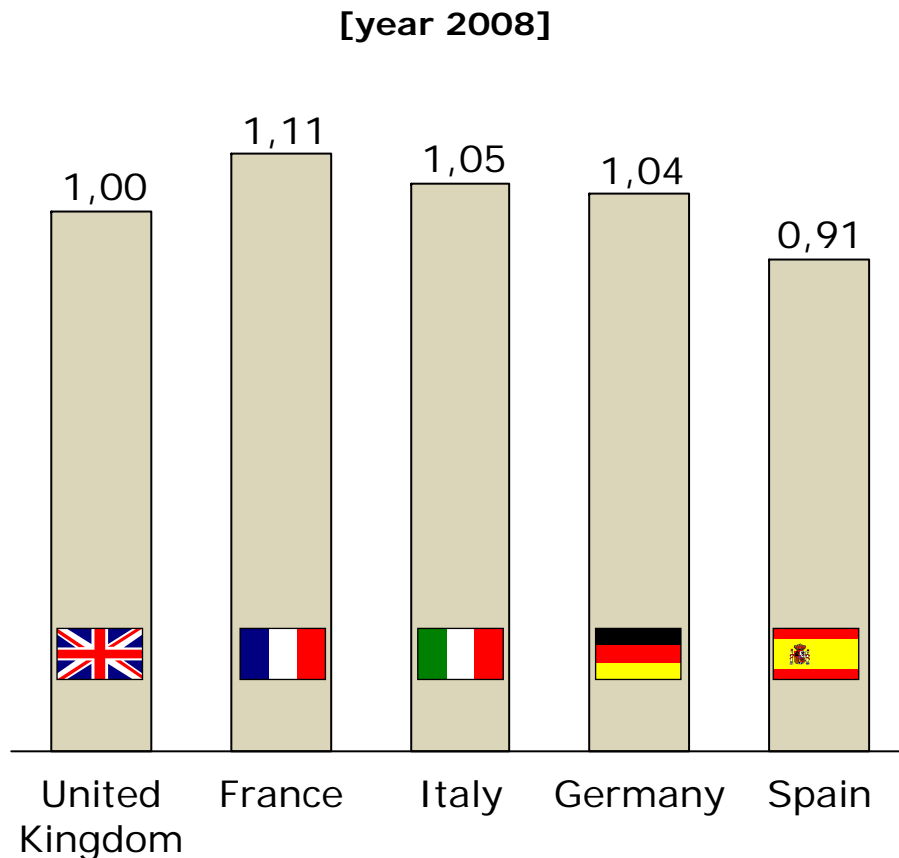
## Remarks

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- Price base year usually is the year of opening the line<sup>1)</sup>
- All costs were adjusted using country-specific annual GDP deflators as published by the World Bank
- A conversion to the Pound Sterling was made by dividing the national currencies by the 2008 purchasing power parities as published by the OECD (see next page)

# All currency conversions are based on purchasing power parities which vary widely in international comparison

Comparative price levels (= purchasing power parities / currency exchange rates)

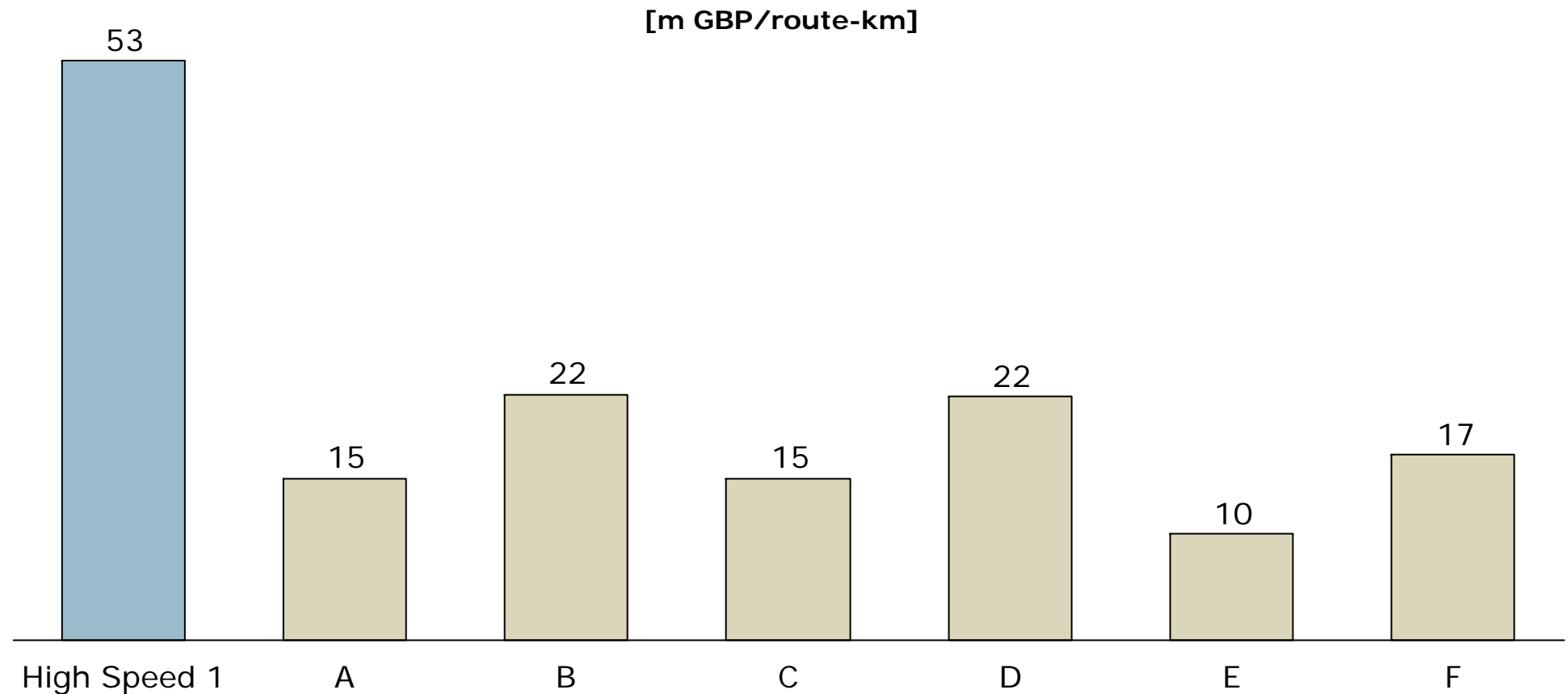


## Methodology

- The Bank of England publishes currency exchange rates based on national currency units (NCU) per Pound Sterling (GBP)
- OECD publishes purchasing power parities based on national currency units per US Dollar (USD)
- In order to base purchasing power parities to the Pound Sterling, all national OECD figures were divided by the value for the United Kingdom
- A first step is the currency conversion to Pound Sterling based on currency exchange rates, i.e. divide the national currencies by exchange rate
- The second step is the normalisation of costs by national purchasing power parities, i.e. multiplying the converted value by the currency exchange rate dividing by the purchasing power parity, which equals to divide the original national currencies by the purchasing power parities based on Pound Sterling in one step

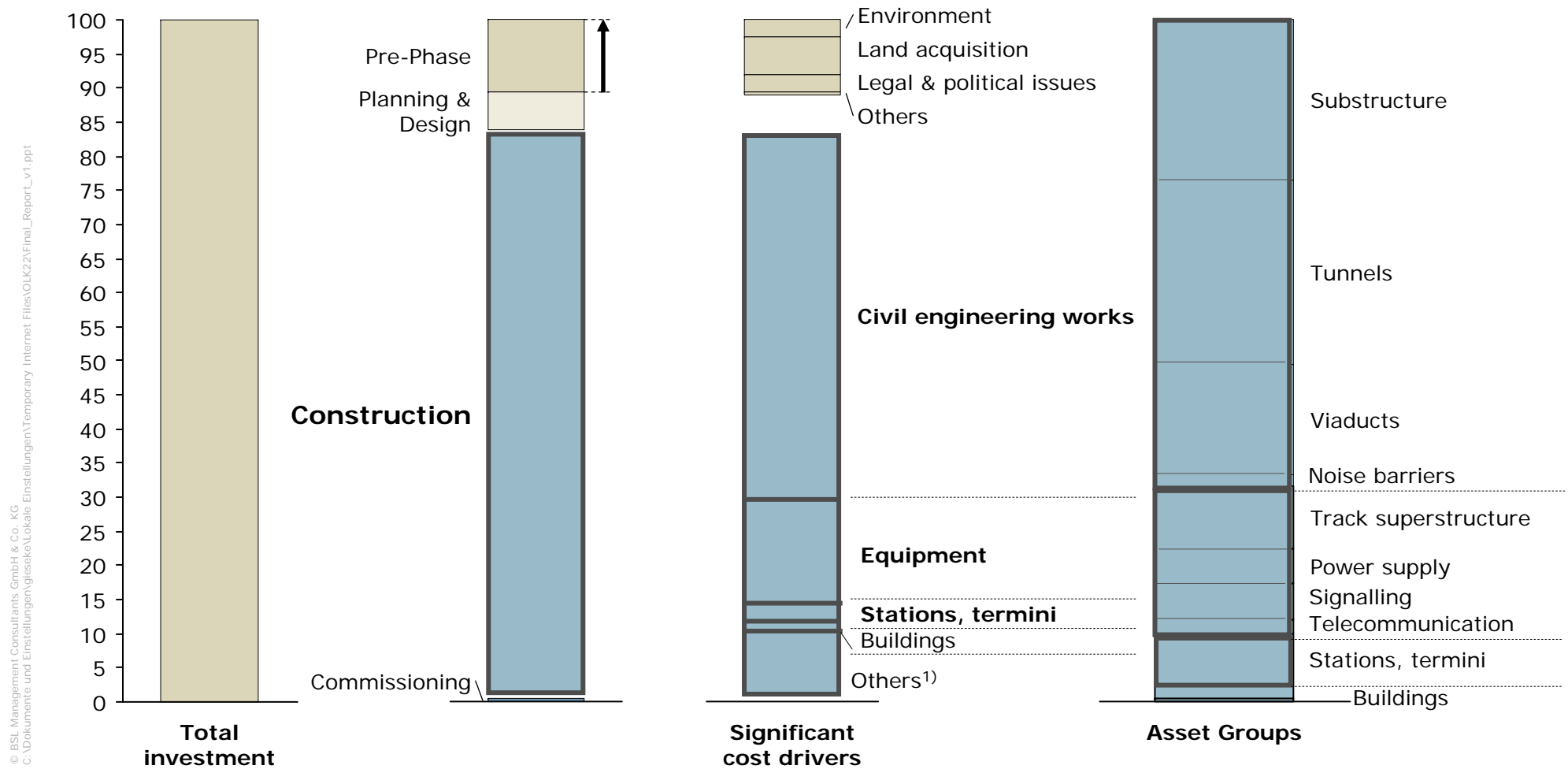
# The PPP-normalised investment cost per route-km vary by more than a factor of 5

Total investment costs (price level 2008), normalised by PPP



# For the phases, significant cost drivers and relevant asset groups were individually analysed

Average Costs (price level 2008), normalised by PPP [m GBP/route-km]



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1) Mostly services for third parties (utilities, highways/roads) and project management

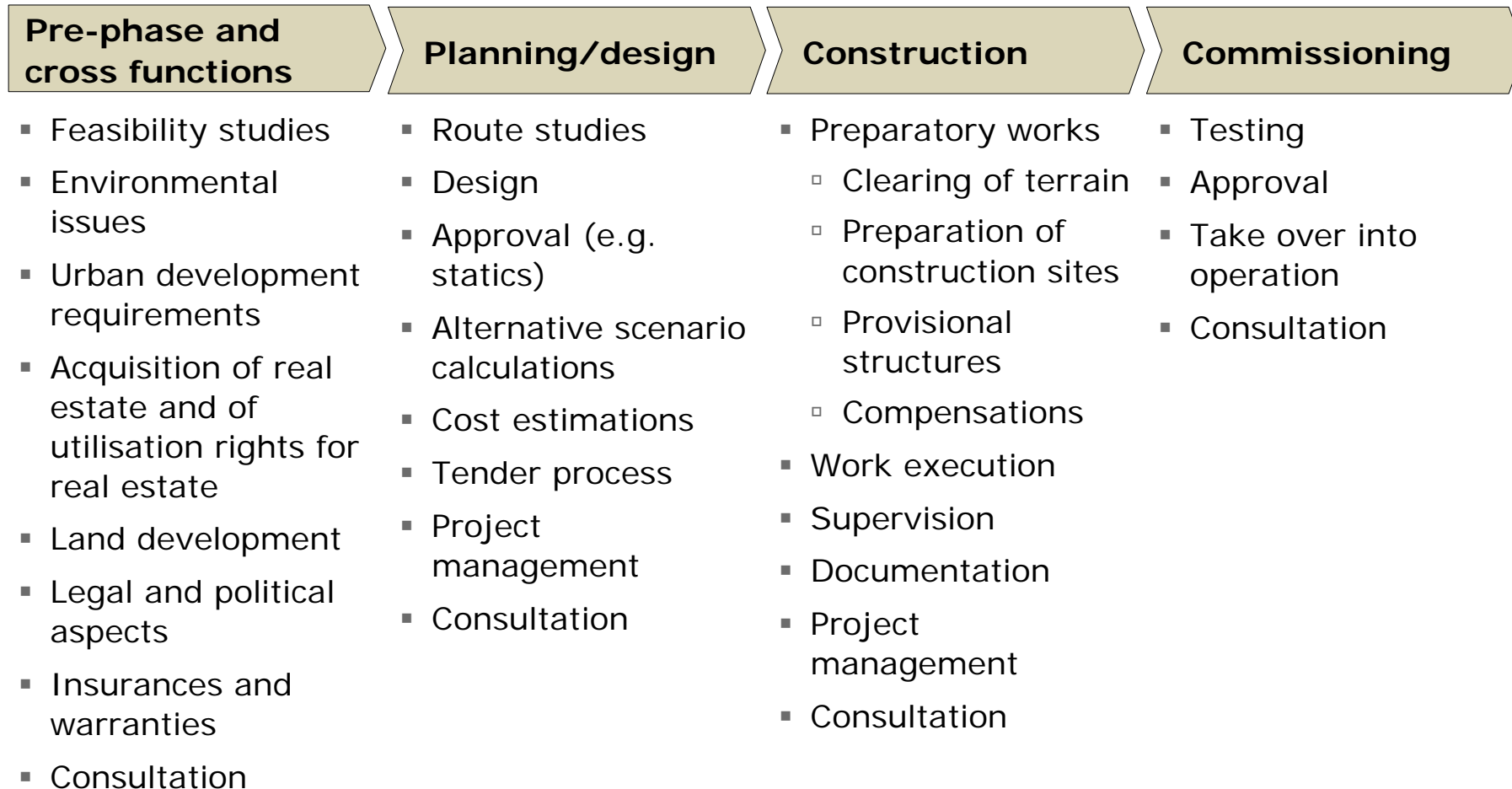
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# Total investment costs cover a number of different activities in four phases

## Cost Breakdown



Cross-functional topics are integrated in the particular phases

# Most major cost drivers are included in the project costs for all projects











## Overview on included cost positions (1/2)

Activity	A	B	C	D	E	F
<b>Pre-phase</b>	10,1%	13,5%	?	3%	10,4%	8,3%
Land acquisitions and land development	X	X	?	X	X	X
Environmental issues (without construction costs)	X	X	?	-	- <sup>1)</sup>	X
Legal and political aspects	X	X	?	X	- <sup>1)</sup>	X
<b>Planning/design</b>	8,3%	3,5%	?	7%	6,2%	5,4%
Design/planning	X	X	?	X	X	X
Tender	X	X	?	X	X	X
Project Management	X	X	?	?	X	X

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# Most major cost drivers are included in the project costs for all projects

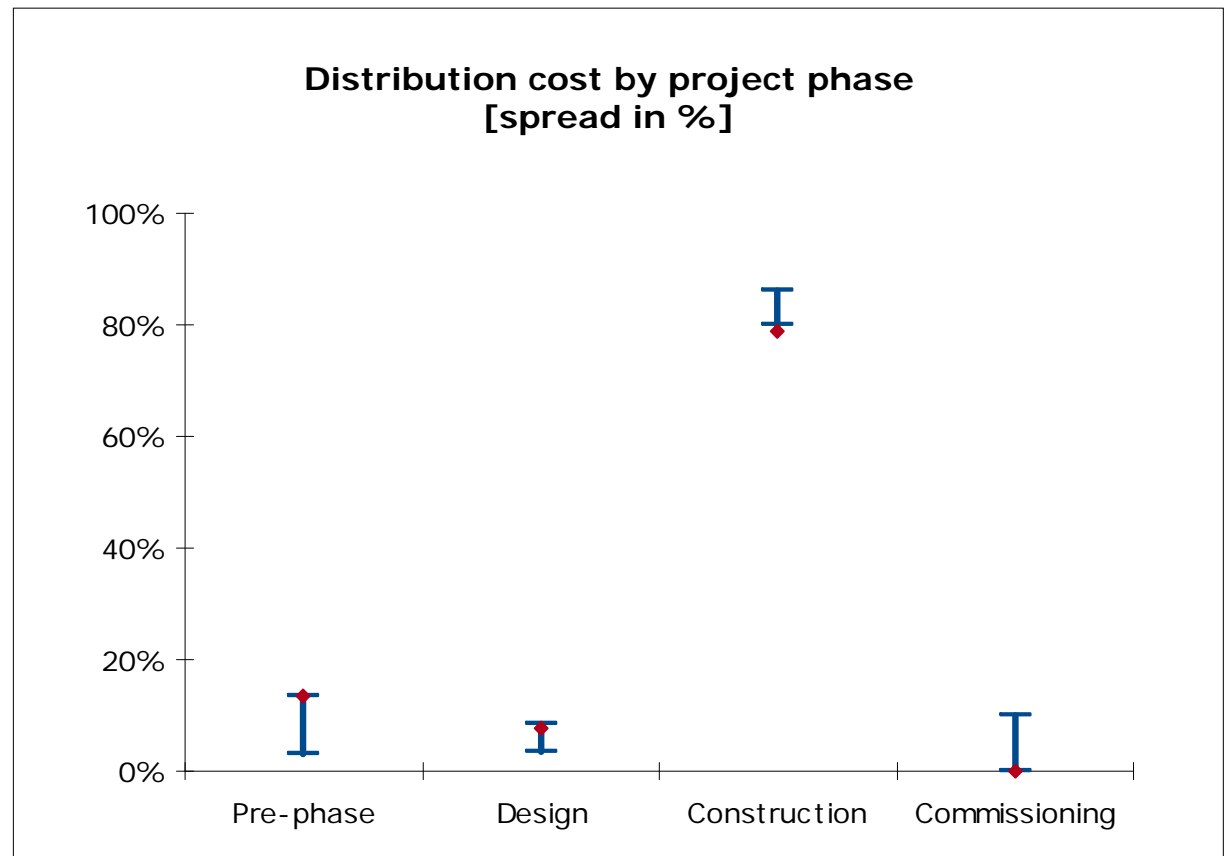
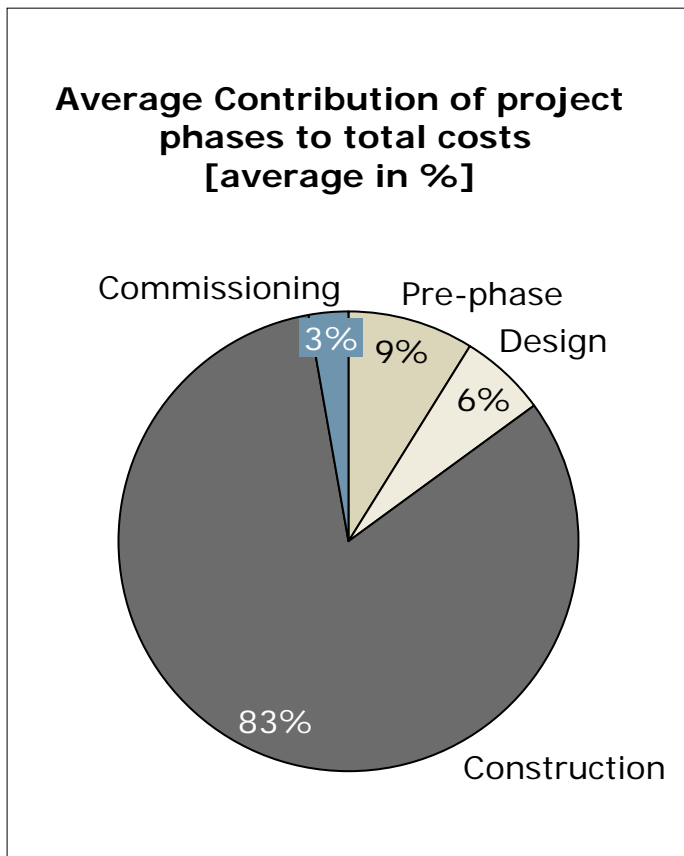
## Overview on included cost positions (2/2)

Activity	A	B	C	D	E	F
<b>Construction</b>	 81,2%	 82,5%	?	 80%	 83,5%	 86%
Work Execution	X	X	?	X	X	X
Supervision and Documentation	X	X	?	X	X	X
Noise protection	X	X	?	X	?	X
Project Management	X	X	?	?	X	X
<b>Commissioning</b>	 0,4%	 0,6%	?	 10% <sup>1)</sup>	 0% <sup>2)</sup>	 0,2%
Testing	X	X	?	X	-	X
Commissioning/Approval	X	X	?	X	-	X

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# Construction makes up for around 80% of all costs

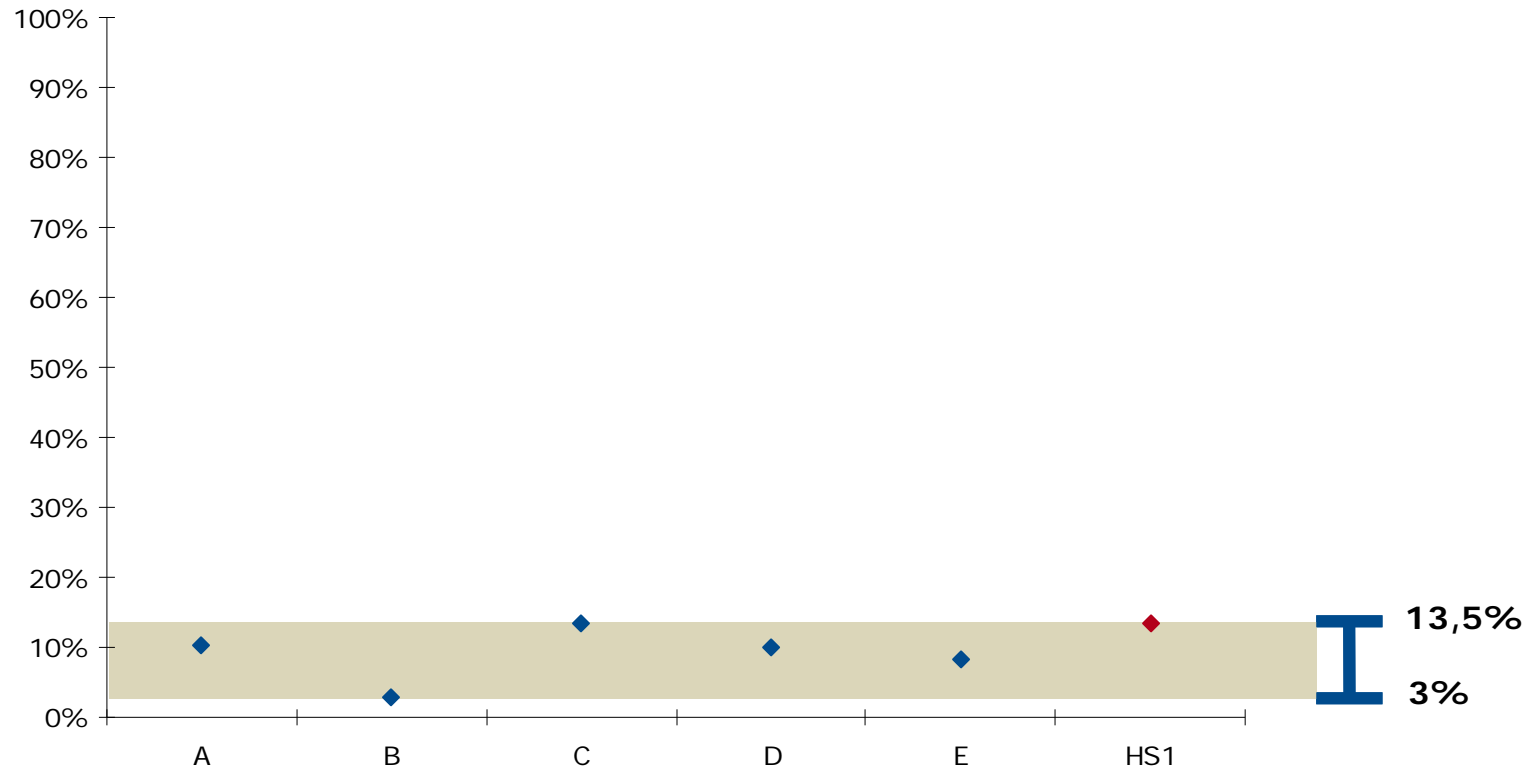
## Breakdown of total project costs



The "red rhomb" represents HS1 data, that was not included in the data sample to produce the spreads of each cost position

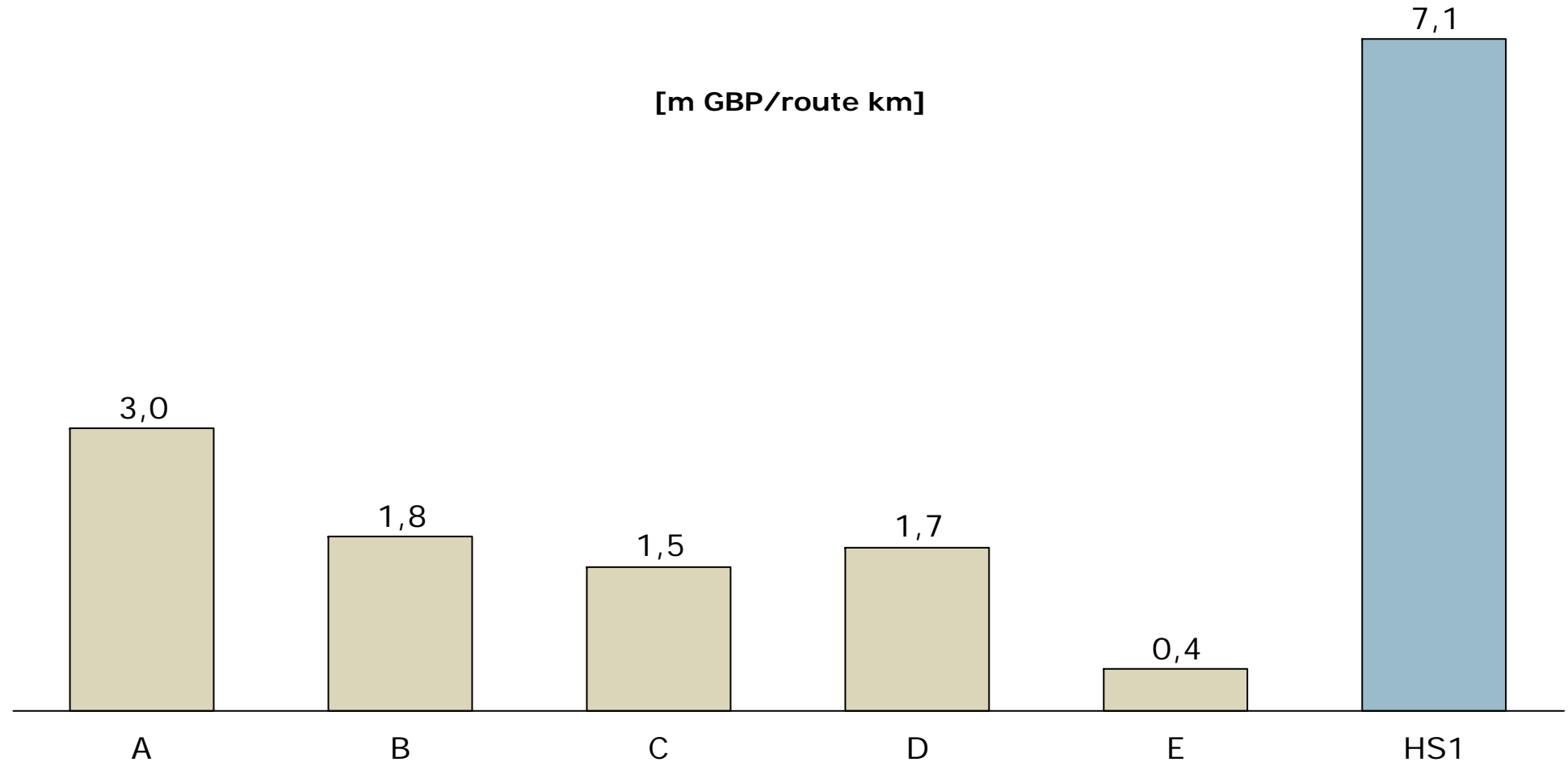
# Most of the railways show pre-phase costs near the upper limit of the range with one outlier revealing significantly lower costs

## Distribution of Pre-phase costs [% of total costs]



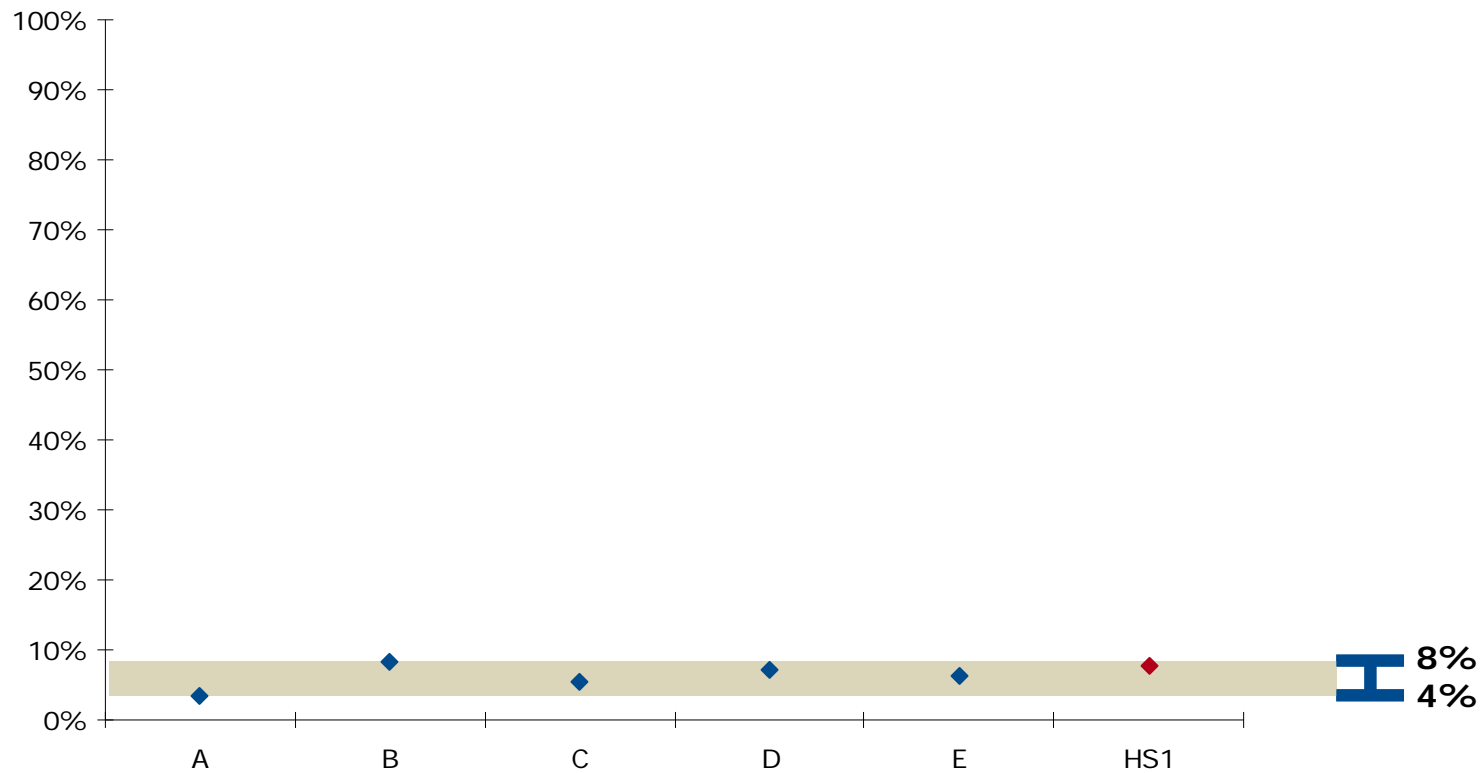
# The Pre-Phase total costs per route-km of HS 1 exceed the level of spending for any other comparator by far

Distribution of Pre-phase costs (price level 2008), normalised by PPP



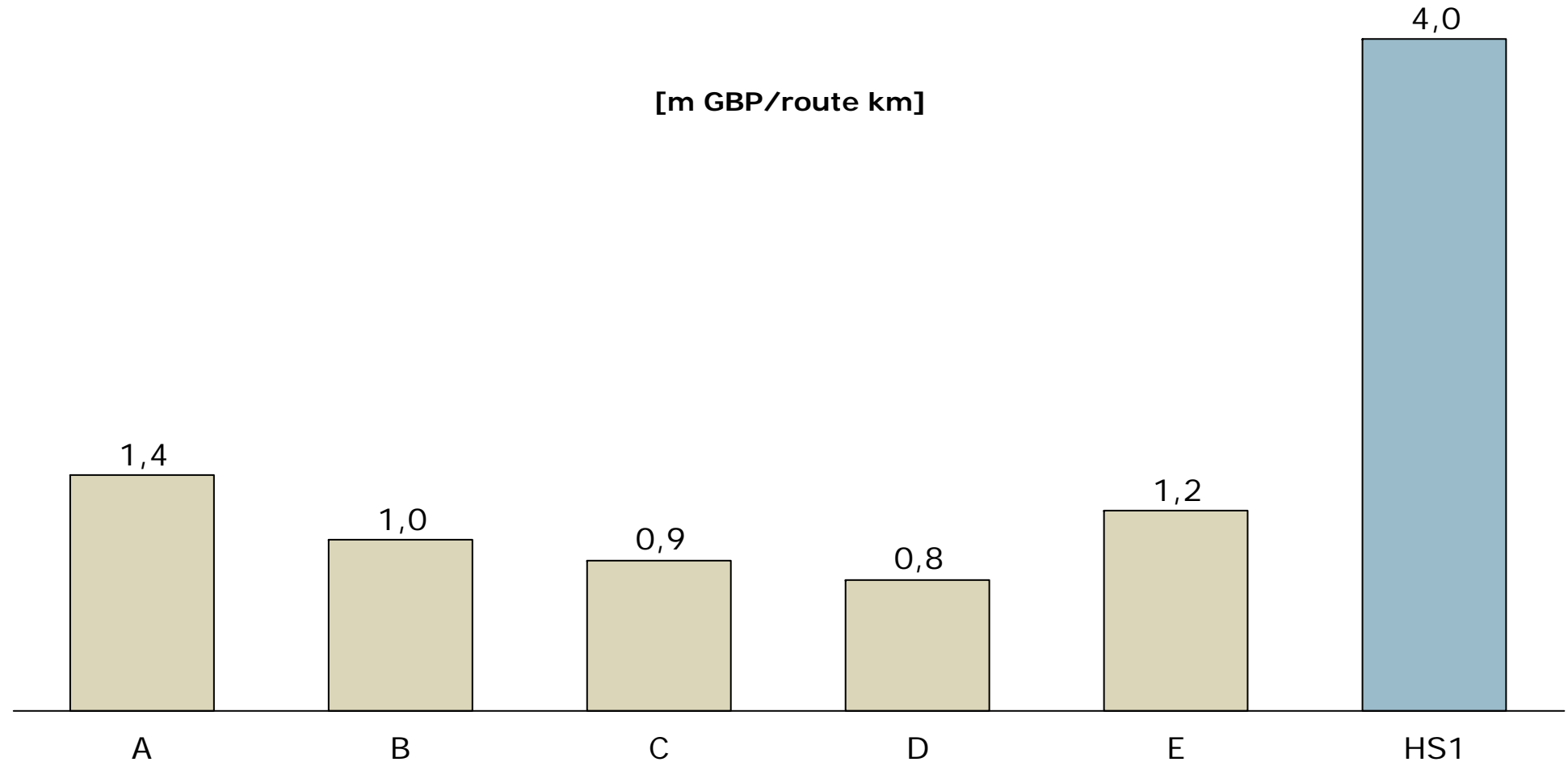
# Costs of planning and design are low overall and fluctuate within a small cost range without any outliers

## Distribution of Planning/Design costs [% of total costs]



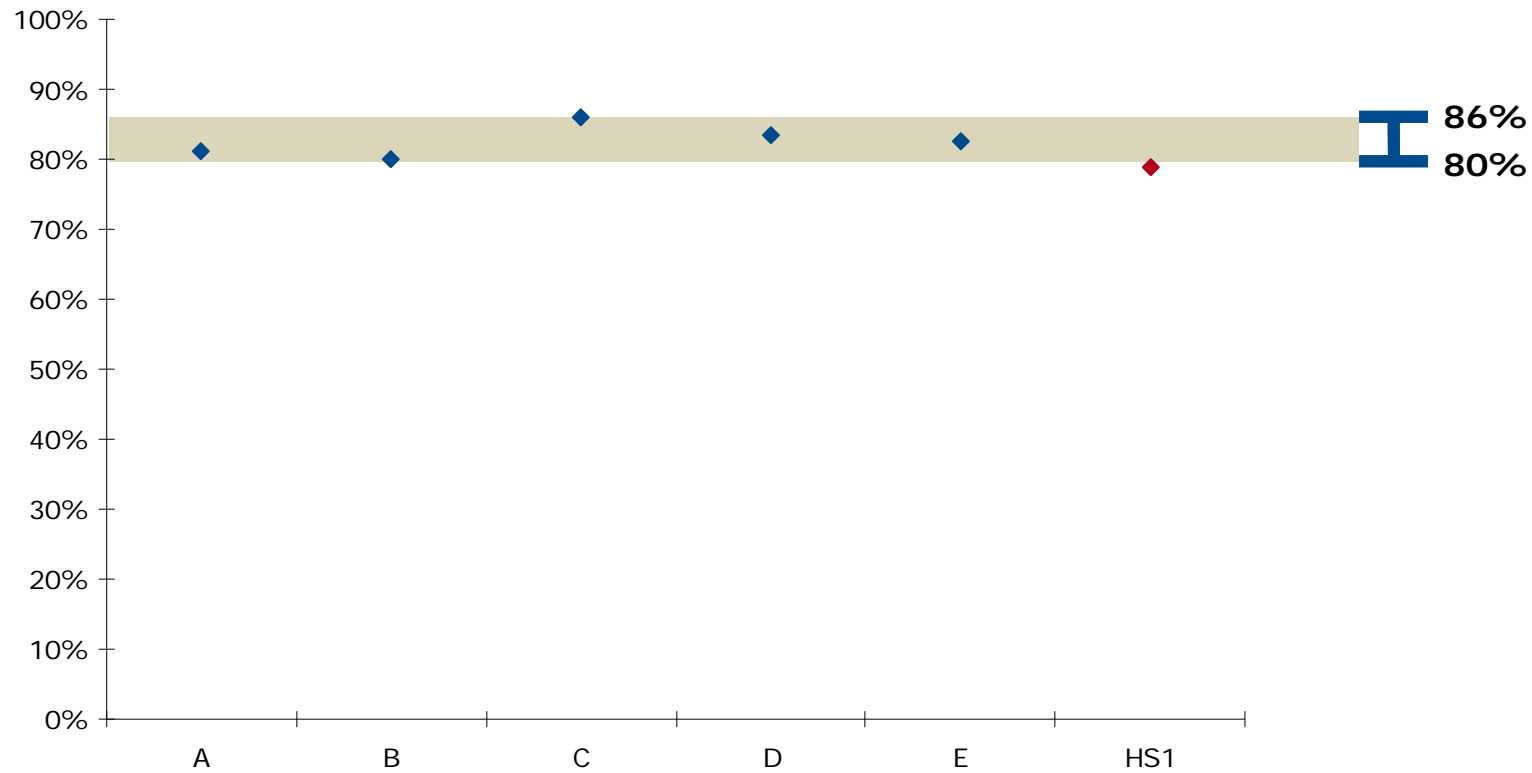
# Also in planning and design, HS1 has very high costs by comparison

Distribution of Planning/Design costs (price level 2008), normalised by PPP



# Construction costs are uniformly distributed within the cost range with HS1 slightly beneath the lower limit of the range

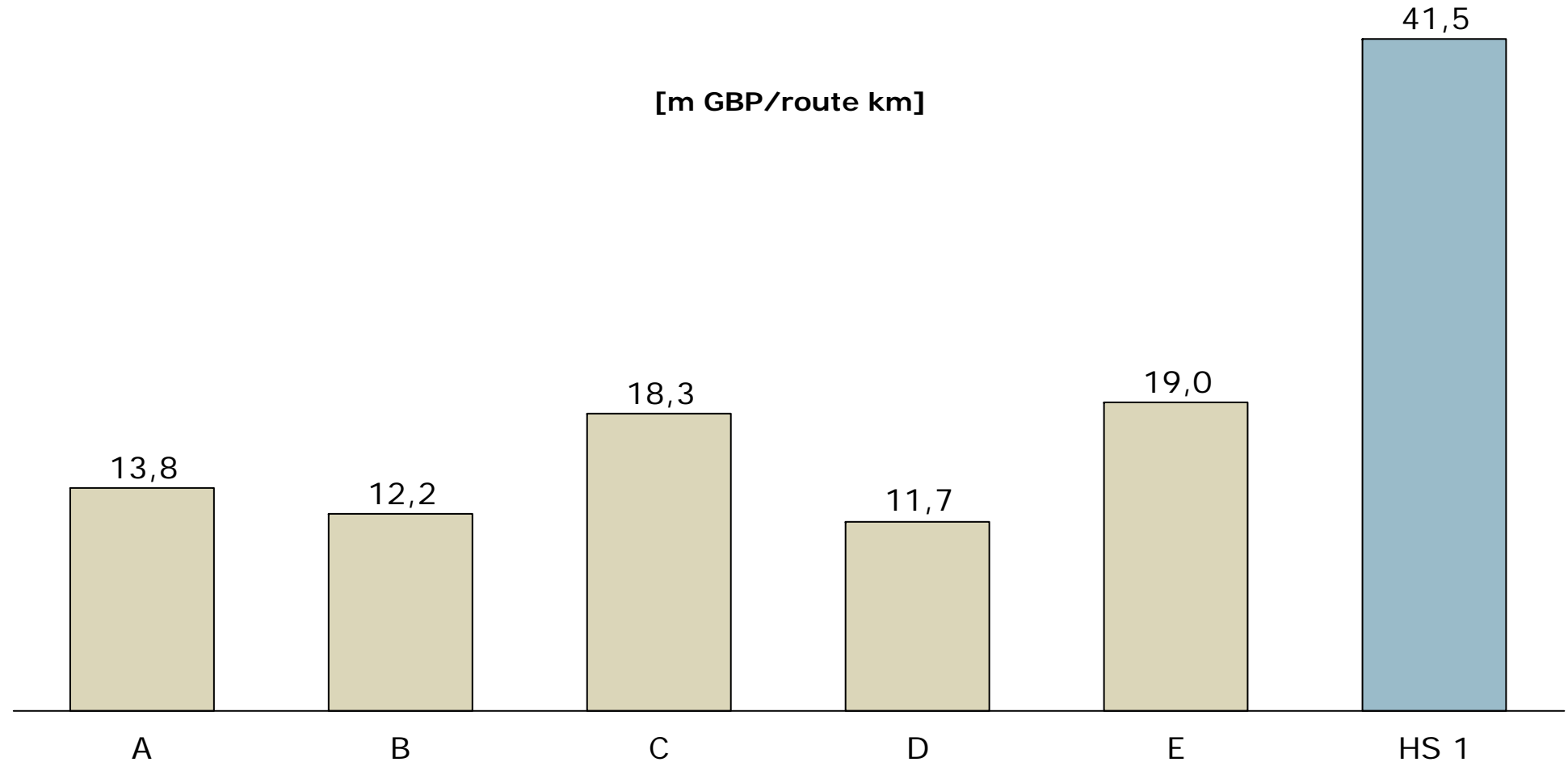
## Distribution of Construction costs [%of total costs]



Large share of construction costs are most likely driven by share of complex civil works such as tunnels and of stations/termini

# Construction costs vary significantly between the comparators with a large gap to HS 1 with more than double the costs

Distribution of Construction costs (price level 2008), normalised by PPP



# The focus of further analysis is on cost positions representing a larger share of total project costs

## Overview

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Project phases	Cost driving positions/activities	Share of total costs
Pre-phase and cross function	<ul style="list-style-type: none"> <li>Land acquisitions and land development</li> <li>Environmental issues (without construction costs)</li> <li>Legal and political aspects</li> </ul>	~ 10%
Design/planning	<ul style="list-style-type: none"> <li>Design regarding redesign as consequences of political decisions</li> </ul>	~ 6% <sup>1)</sup>
Construction	<ul style="list-style-type: none"> <li>Detailed view on construction costs: Asset groups and cost influencing line characteristics (next chapter)</li> </ul>	~ 80%
Commissioning	<ul style="list-style-type: none"> <li>Testing including trial sites</li> </ul>	~ 4% <sup>1)</sup>

1) Low contribution to total CAPEX and therefore so far no detailed analyses of particular cost positions


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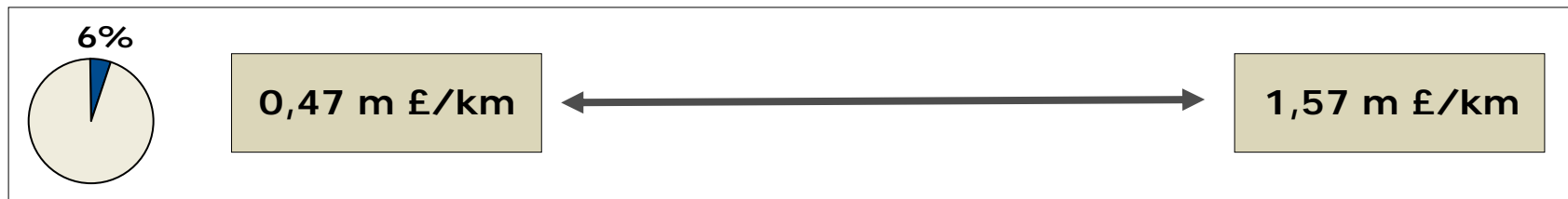
# The analysis of individual cost positions includes the spread of costs per route-km and the identification of main cost drivers

## Preliminary remarks

- The following charts shows maximum and minimum costs by relevant cost positions per route-km for the six lines studied (**no unit costs**)
- In the peer interviews relevant direct and indirect cost drivers for each position were identified
- Not all participants were able to break down costs to the specified levels. Sometimes spreads are based on as little as two or three values
- A pie chart  shows the average share of the specific cost position in the overall total CAPEX (regarding data of the lines that provided information on that cost position)

# Different alignments and property values cause major variations in costs for land acquisition

## Costs of land acquisition and cost drivers



- Line routing**
- Municipalities crossed (max. more than 60)
  - Distance of populated areas to the line (acquisition zone < 40 m)
  - Influence of people in municipalities
  - Parallelism to existing rail- or highway-lines (less legal cases)

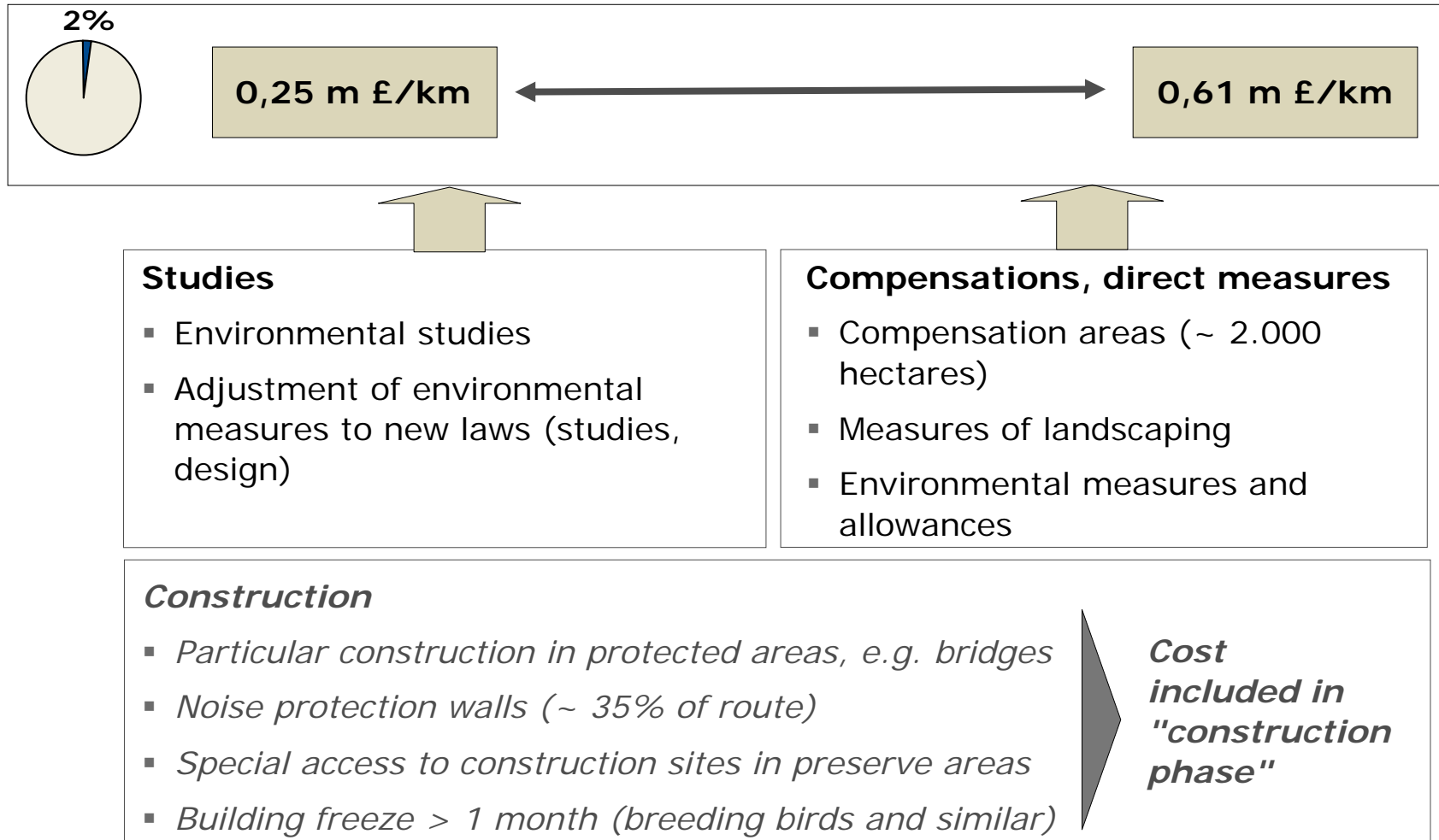
- Direct costs/m<sup>2</sup>**
- Number of real estate to be bought (up to 14.000 pieces of land)
  - Value of real estates (price per m<sup>2</sup> between ~ 1,35 £ and 28,00 £)
  - Legal costs; particular in cases of "unfriendly" processes (max. 5%)

- Compensations**
- Money paid for noise protection (double-glass windows)
  - Compensation for decreasing values of real estate and houses

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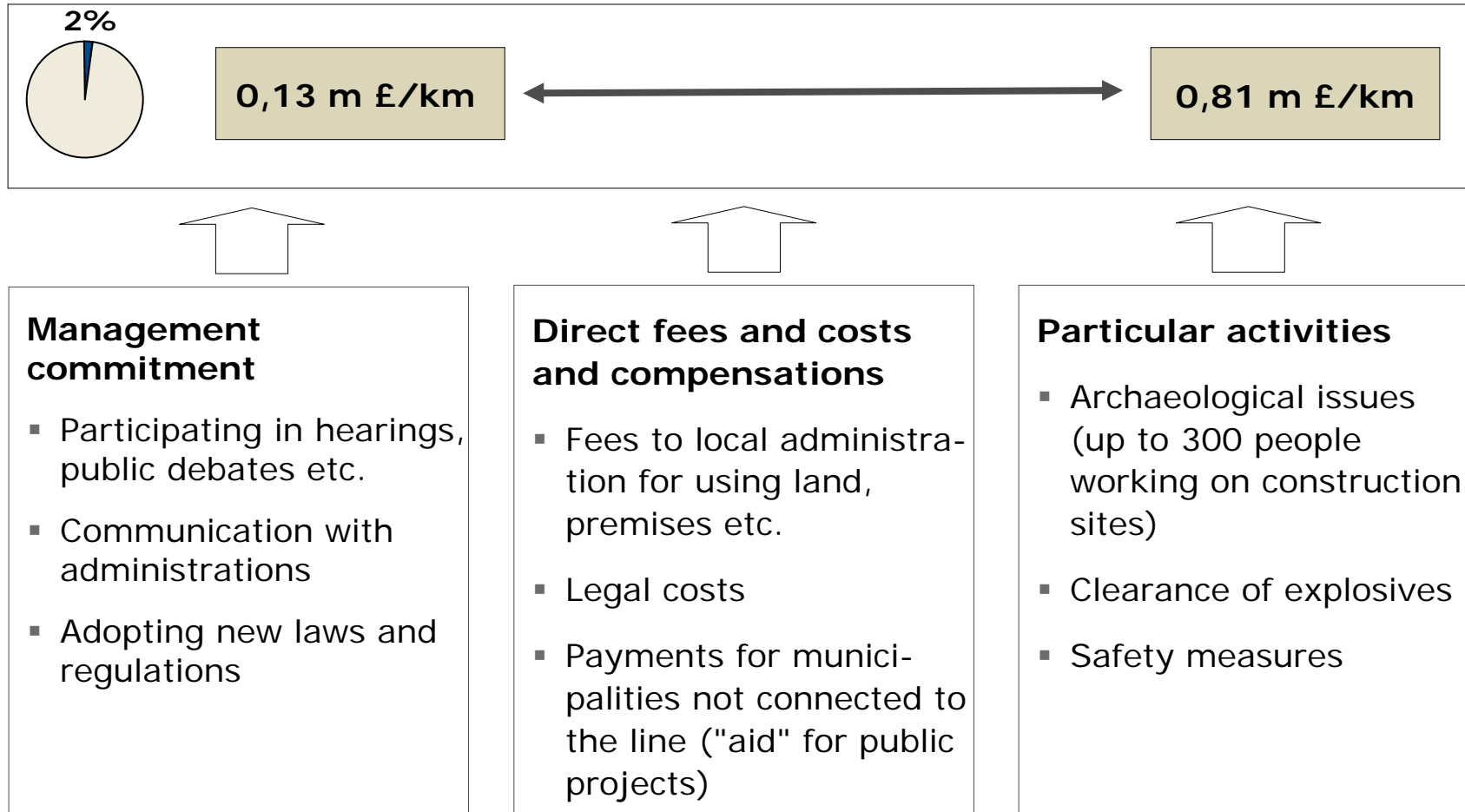
# Expenditures for environmental issues are driven through legal requirements which vary widely

## Costs of environment protection



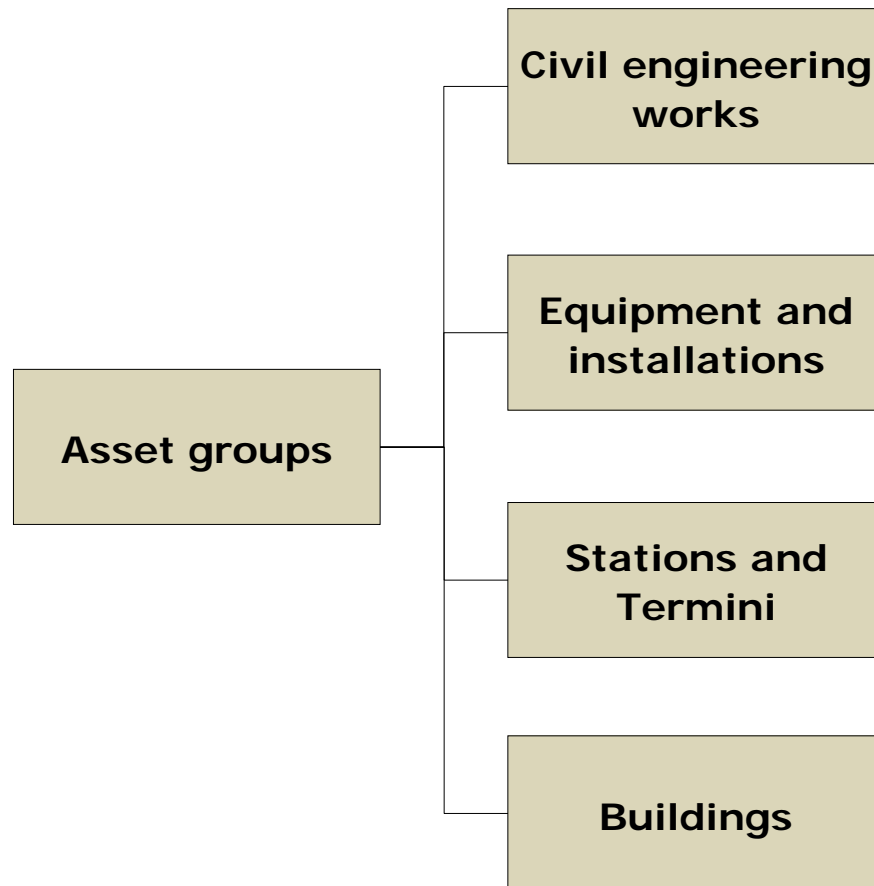
# All projects highly depend on the political and legal environment

## Costs of political/legal aspects and cost drivers



# The main assets are comprised in four major categories

## Asset groups and elements



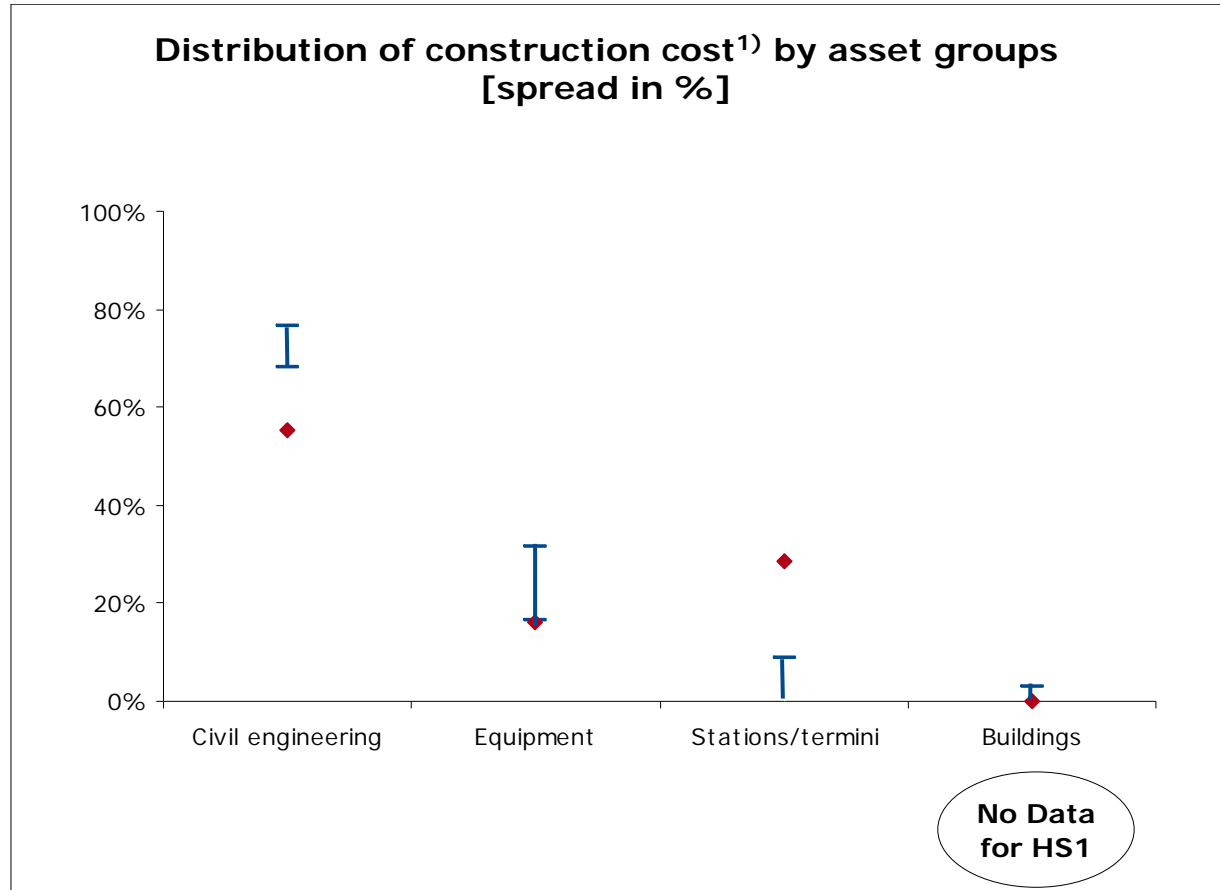
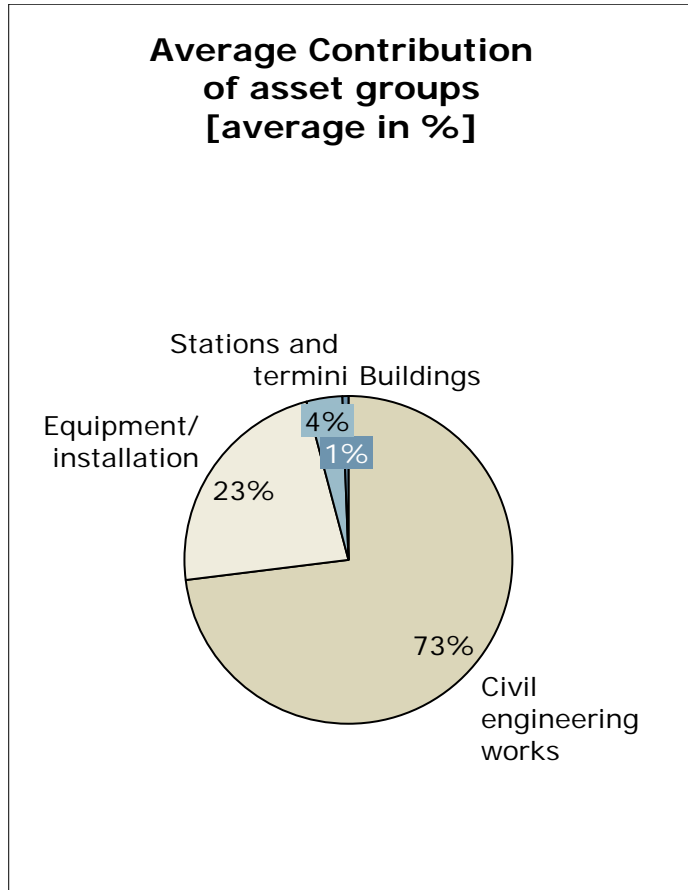
## Cost relevant elements

- Substructure (embankments, cuttings, ground level)
- Tunnels (natural single-/twin-bored, cut & cover)
- Bridges/overpasses
- Noise barriers
- Superstructure (Ballasted/slab track, points)
- Power supply (catenary, substations)
- Signalling equipment incl. line-side installations<sup>1)</sup>
- Telecommunications
- Platforms incl. roofing constructions
- Buildings, engineering and service rooms
- Surroundings, access
- Workshops infrastructure
- Depots (fleet), fleet serving facilities
- Administration

1) Control command centre, interlockings incl. interior control (e.g. circuit-breaker), point machines, axle counters, track circuits, train control systems/ATO (e.g. antennas, loops)

# Representing up to 80% of the cost civil engineering works are the driving cost factor in construction

## Cost breakdown by asset groups

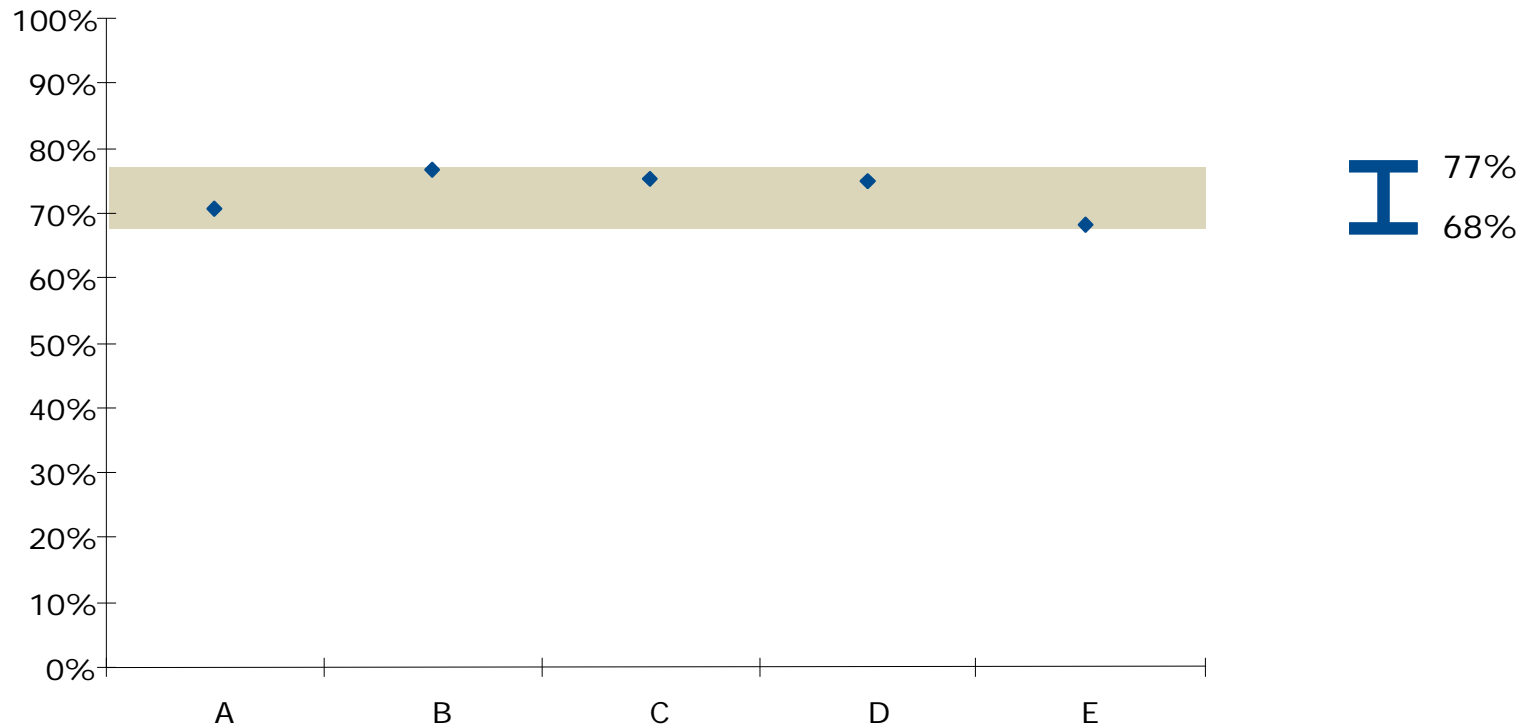


The "red rhomb" represents H1 data, that was not included in the data sample to produce the spreads of each cost position

1) Construction cost here only represent costs that could be allocated to defined asset categories; non-asset related miscellaneous costs and project management are excluded

# Cost driving civil engineering works do not show outliers on the one or the other end of the cost range

## Distribution of Civil Engineering Works costs [% construction costs<sup>1)</sup>]

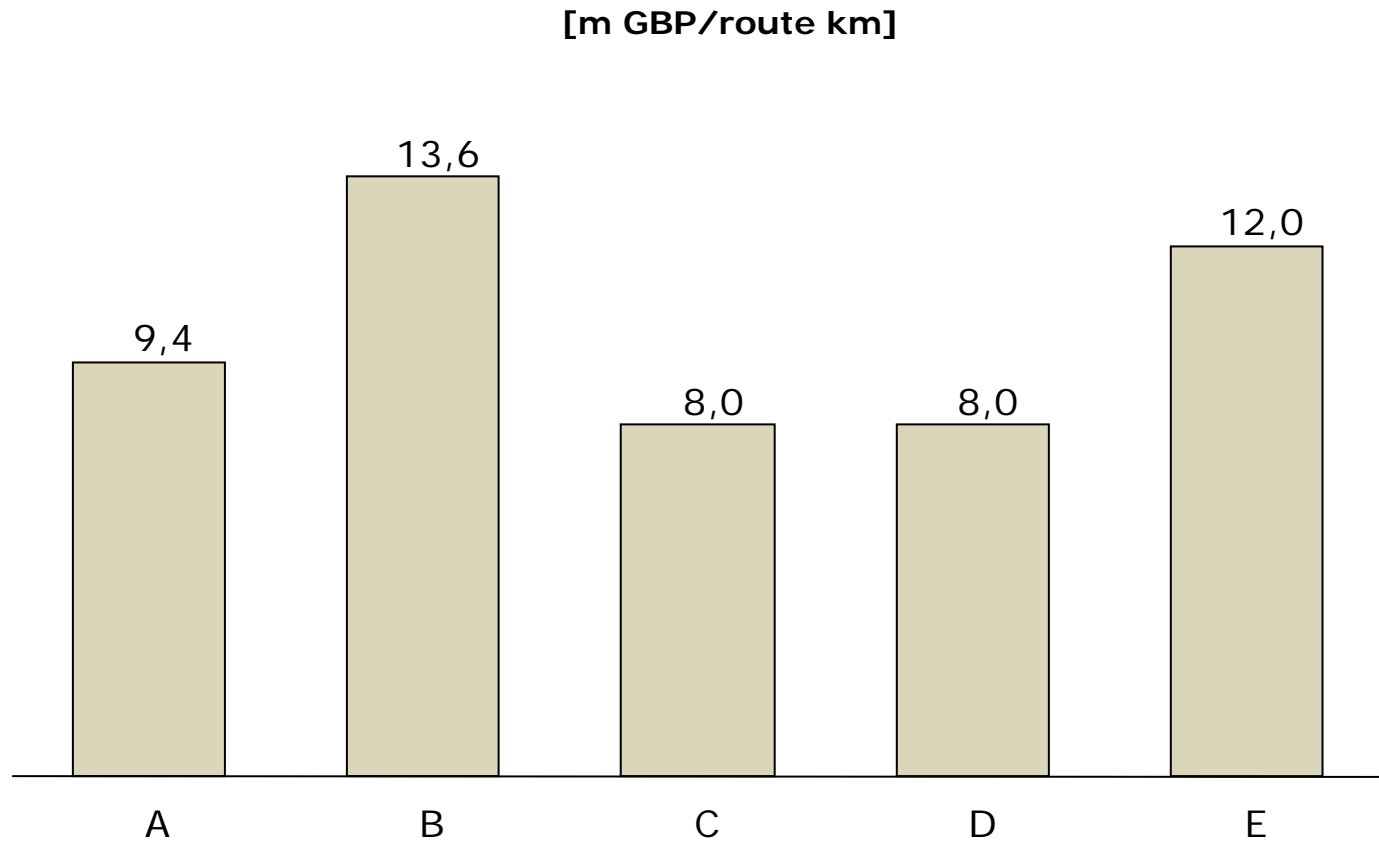


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1) Construction cost here only represent costs that could be allocated to defined asset categories; non-asset related miscellaneous costs and project management are excluded

# Distribution of Civil Engineering Works costs

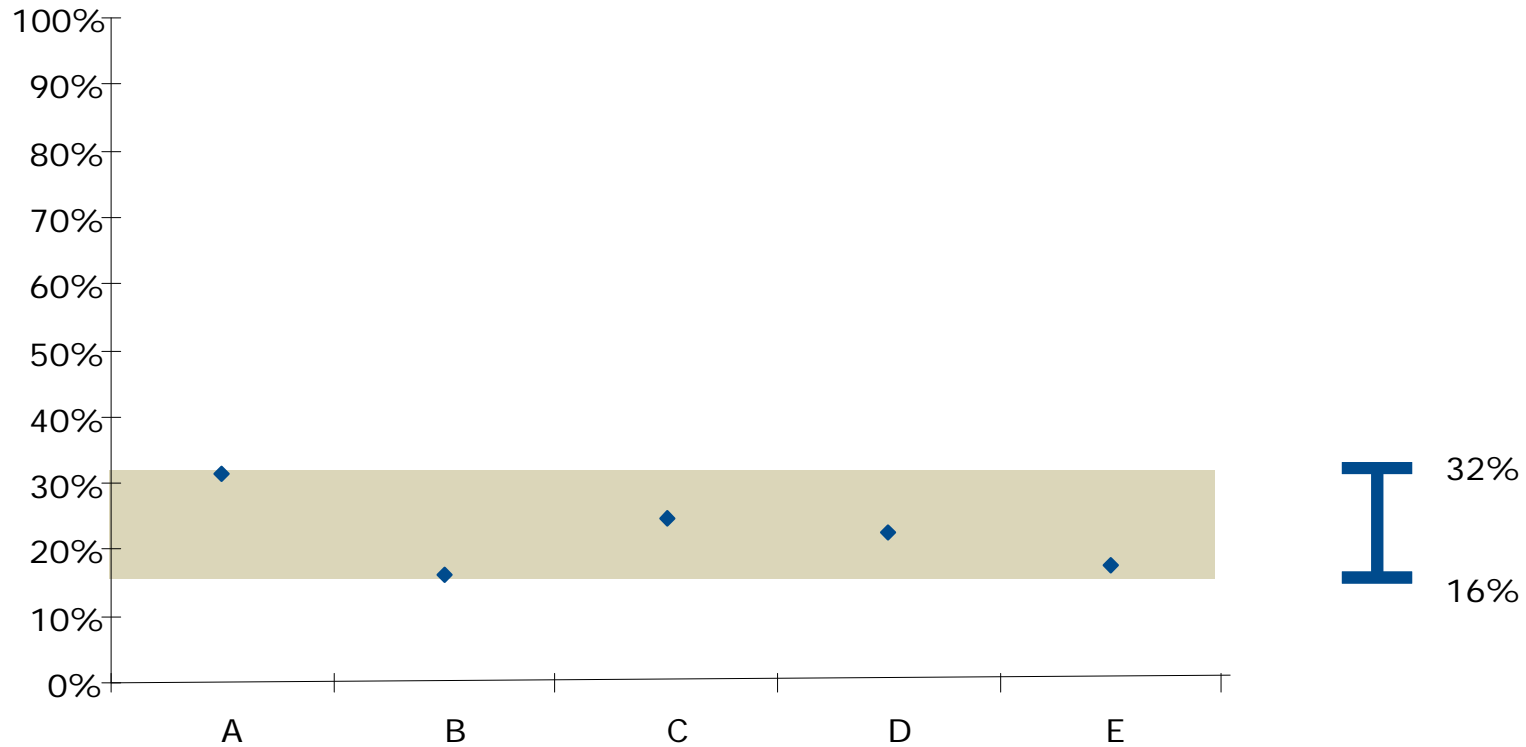
Price level 2008, normalised by PPP



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# The costs of equipment reveal one outlier on the upper limit of the range

## Distribution of Equipment/Installation costs [% construction costs<sup>1)</sup>]



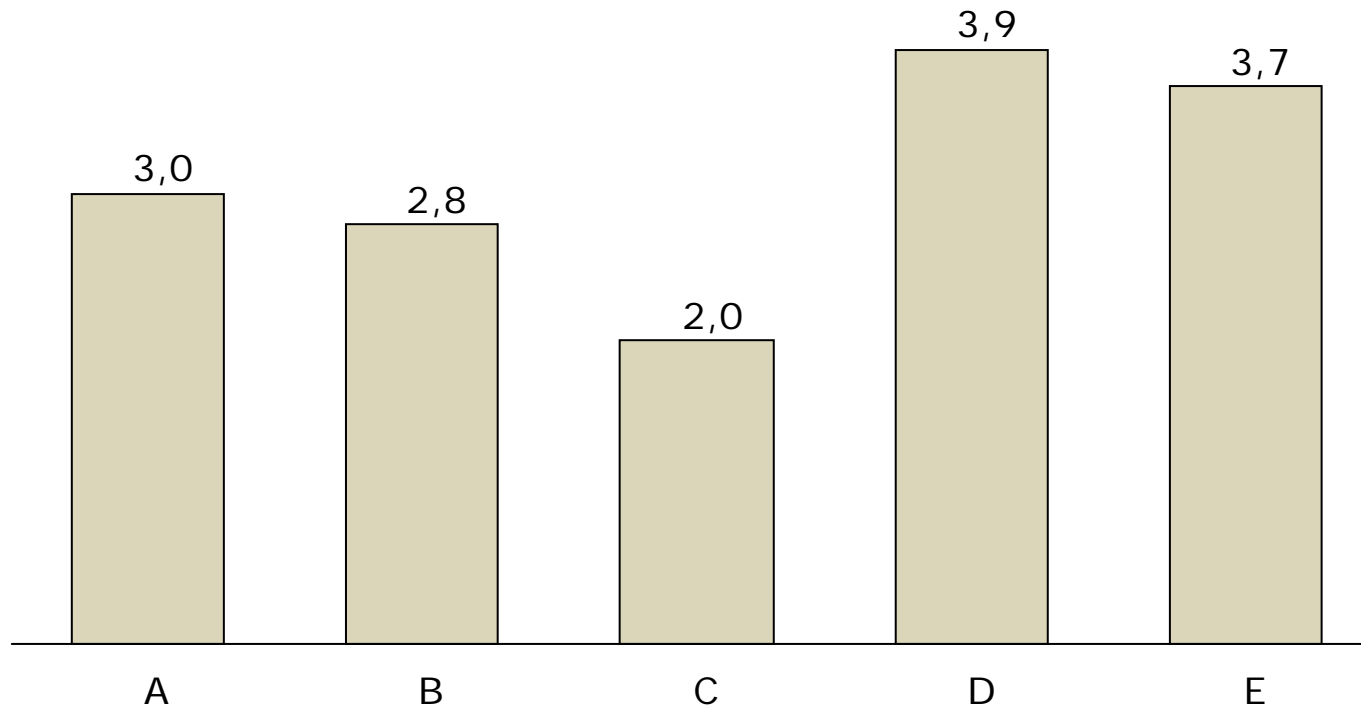
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1) Construction cost here only represent costs that could be allocated to defined asset categories; non-asset related miscellaneous costs and project management are excluded

# Distribution of Equipment/Installation costs

Price level 2008, normalised by PPP

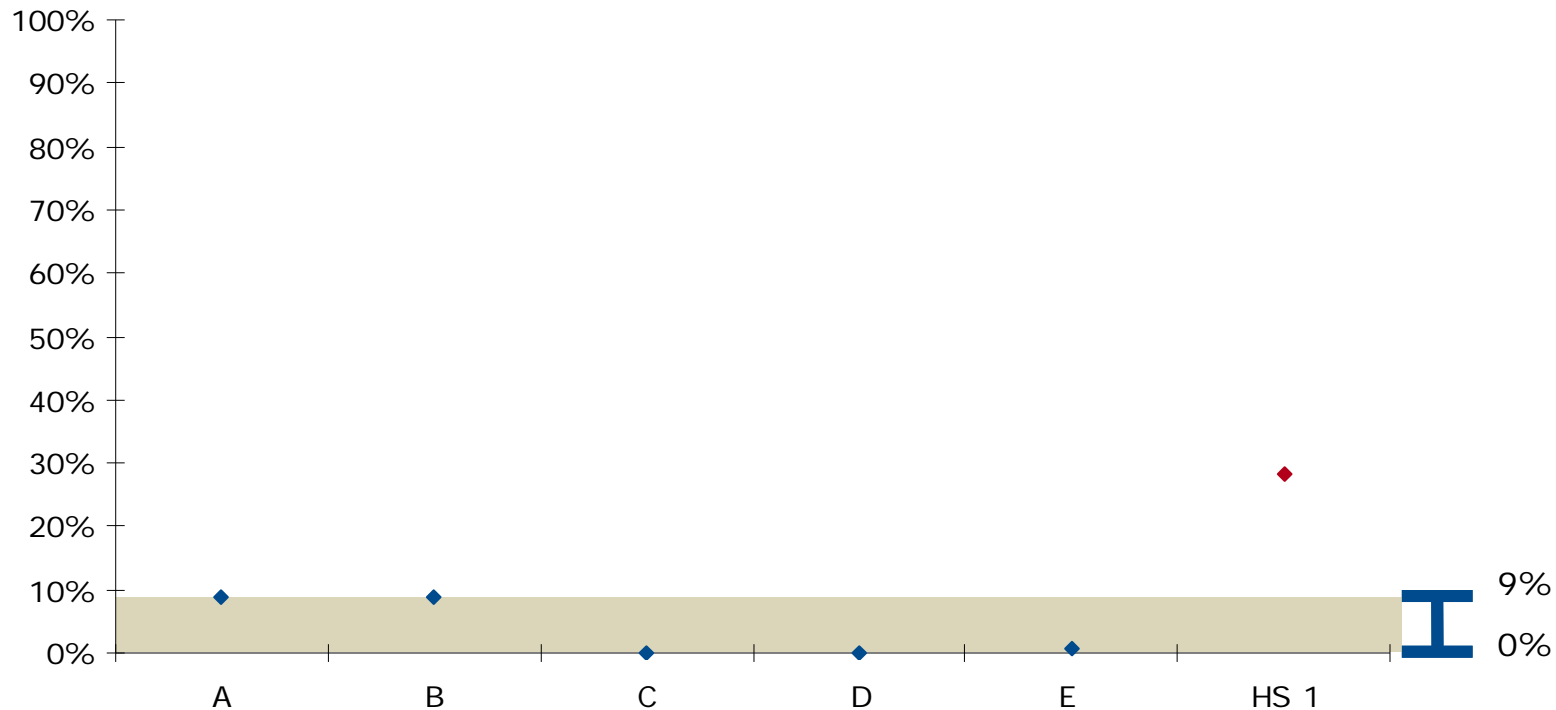
[m GBP/route km]



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# Station costs fluctuate, but can be explained by the number and extent of new built or refurbished stations

## Distribution of Stations/Termini costs [% construction costs<sup>1)</sup>]



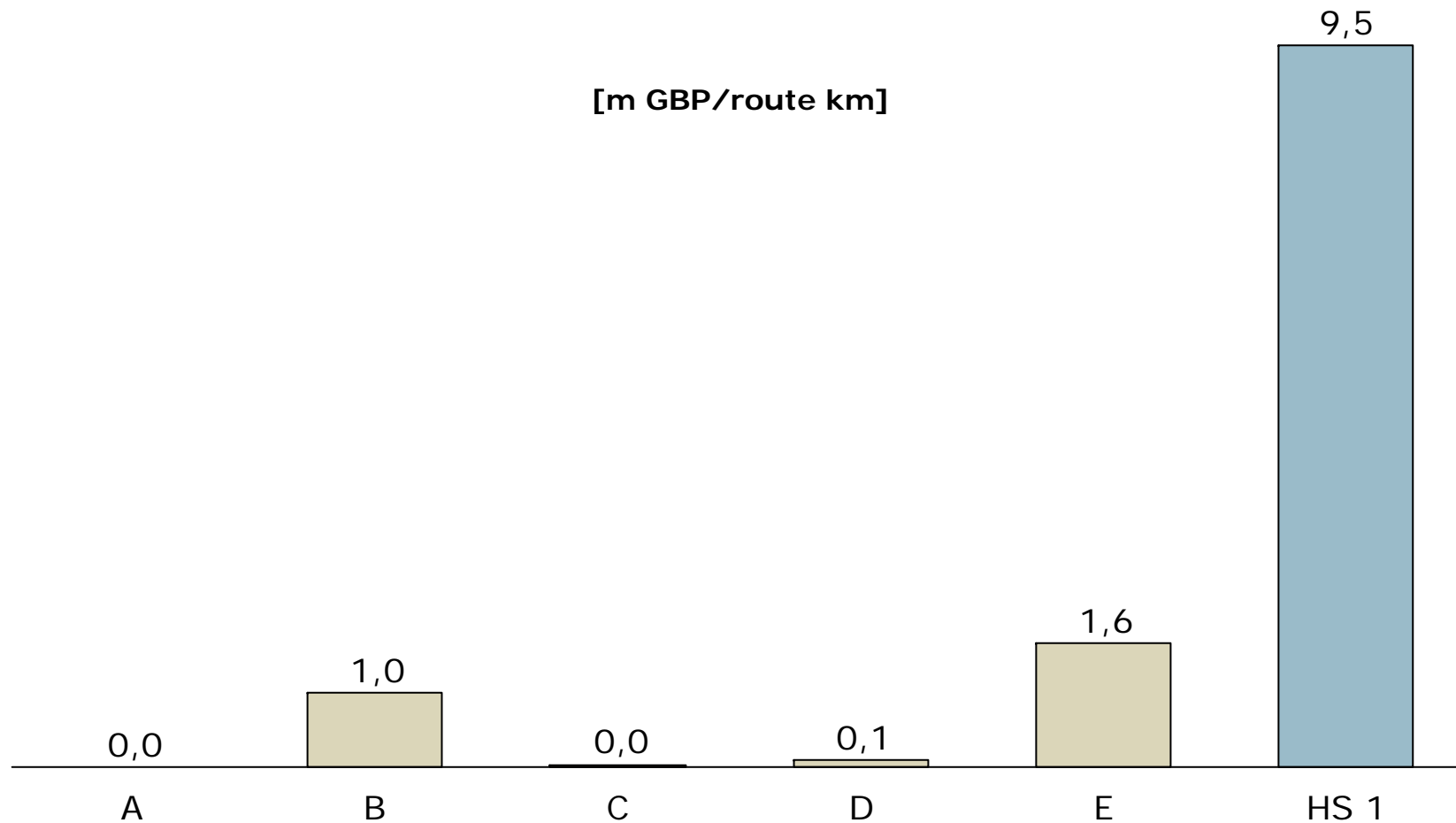
Lines with larger amounts of new/refurbished and dedicated stations obviously have higher cost shares, especially true for HS1 with the most extensive stations and termini

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1) Construction cost here only represent costs that could be allocated to defined asset categories; non-asset related miscellaneous costs and project management are excluded

Since the high complexity of stations and termini HS1's costs exceed the costs of the comparators by far

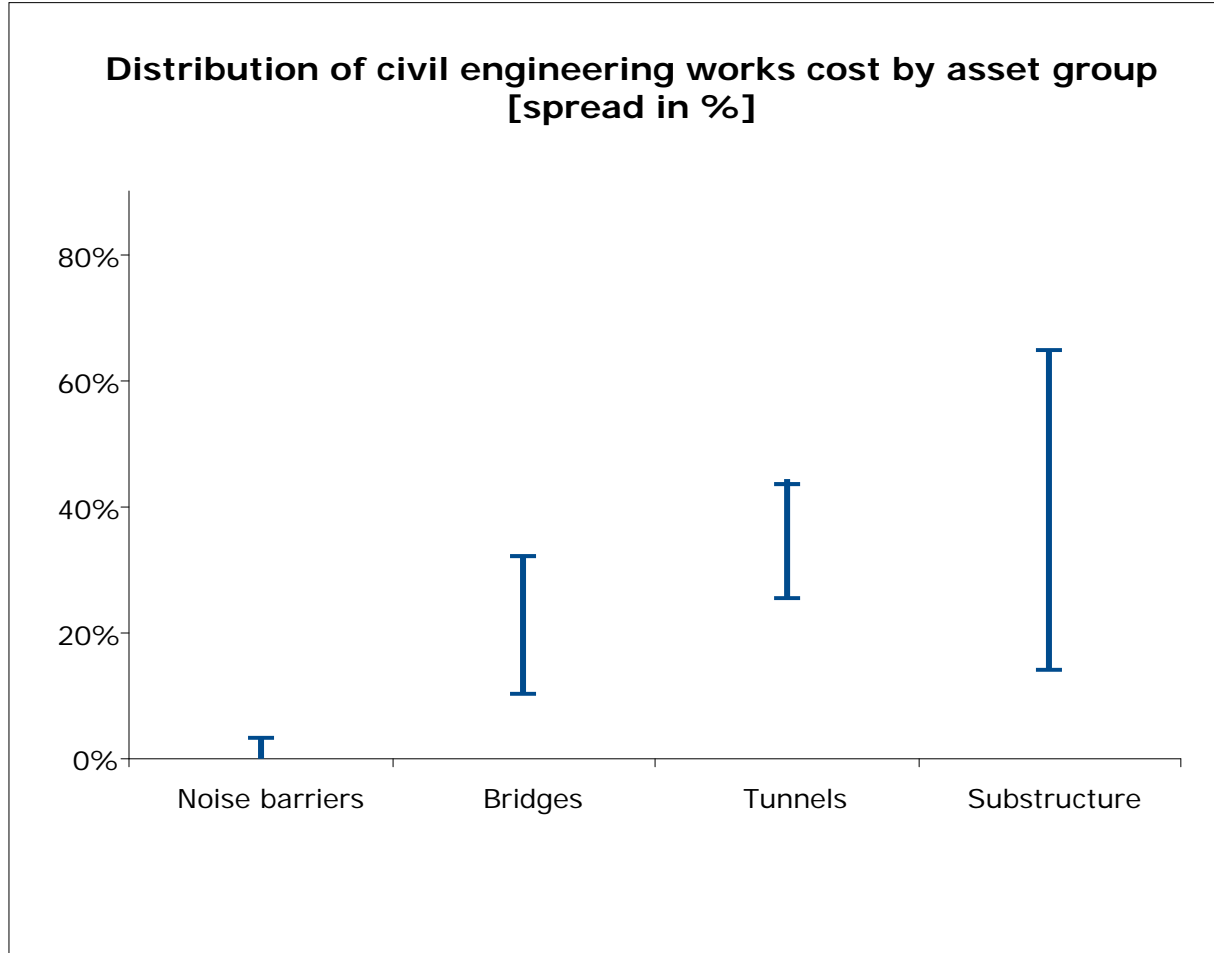
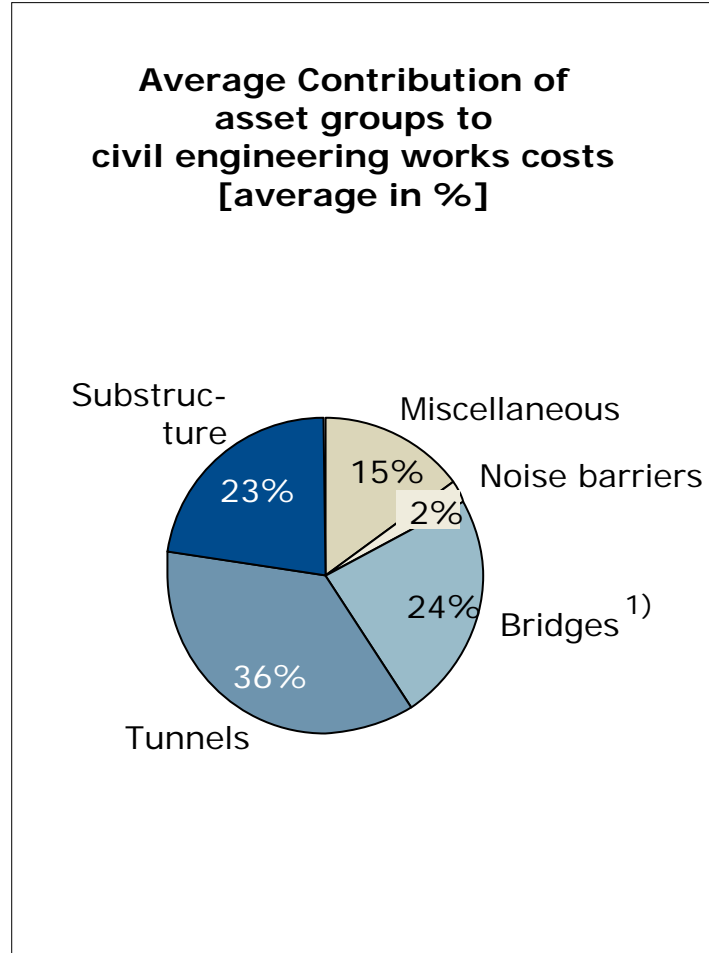
Distribution of Stations/termini costs (price level 2008), normalised by PPP



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# Tunnels and bridges account for more than 50% of civil engineering's total costs and vary widely

## Cost breakdown of "civil engineering"

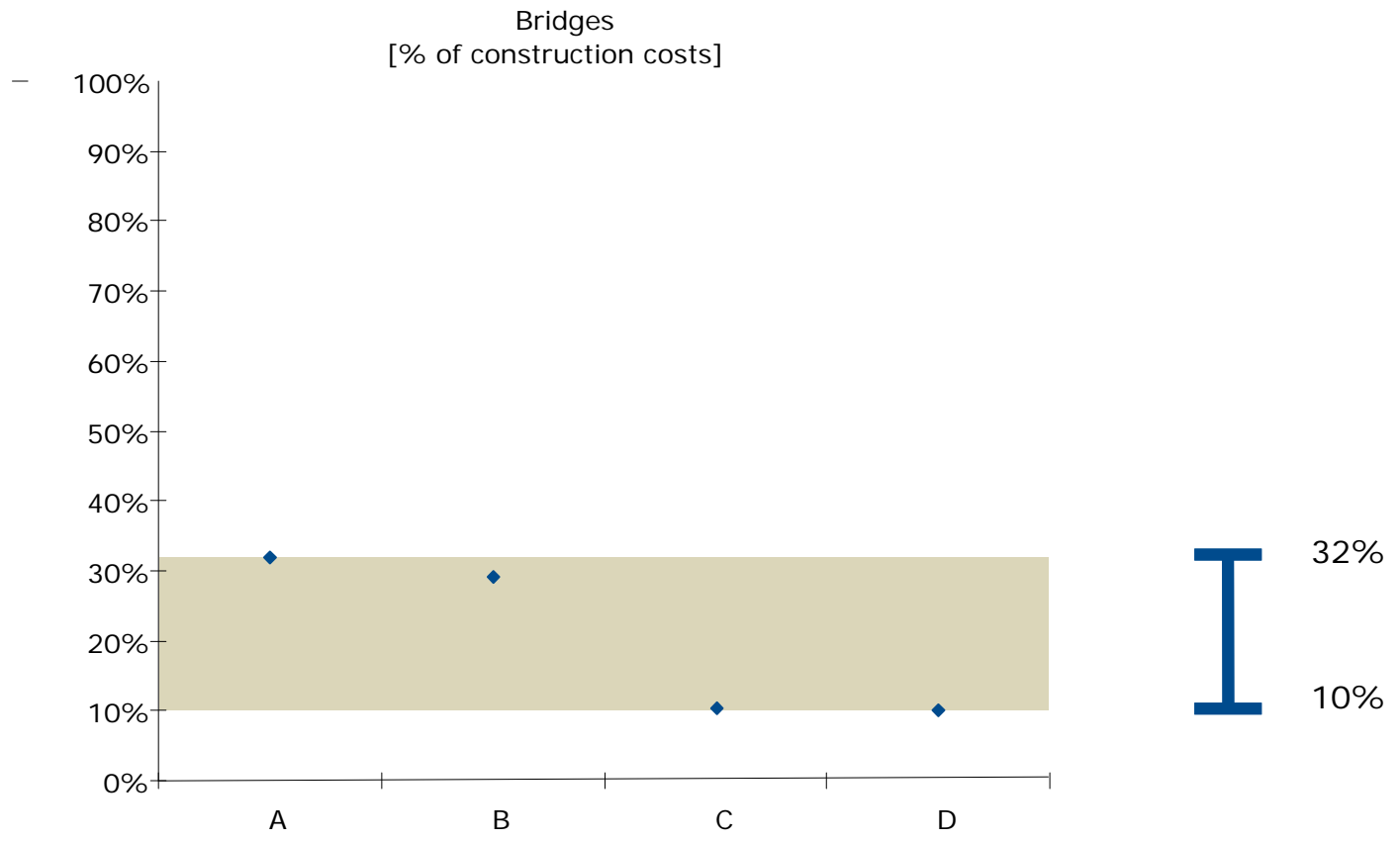


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1) Viaducts, railway overpasses, road bridges and similar

# The spread in costs for viaducts, railway overpasses and road bridges is significant

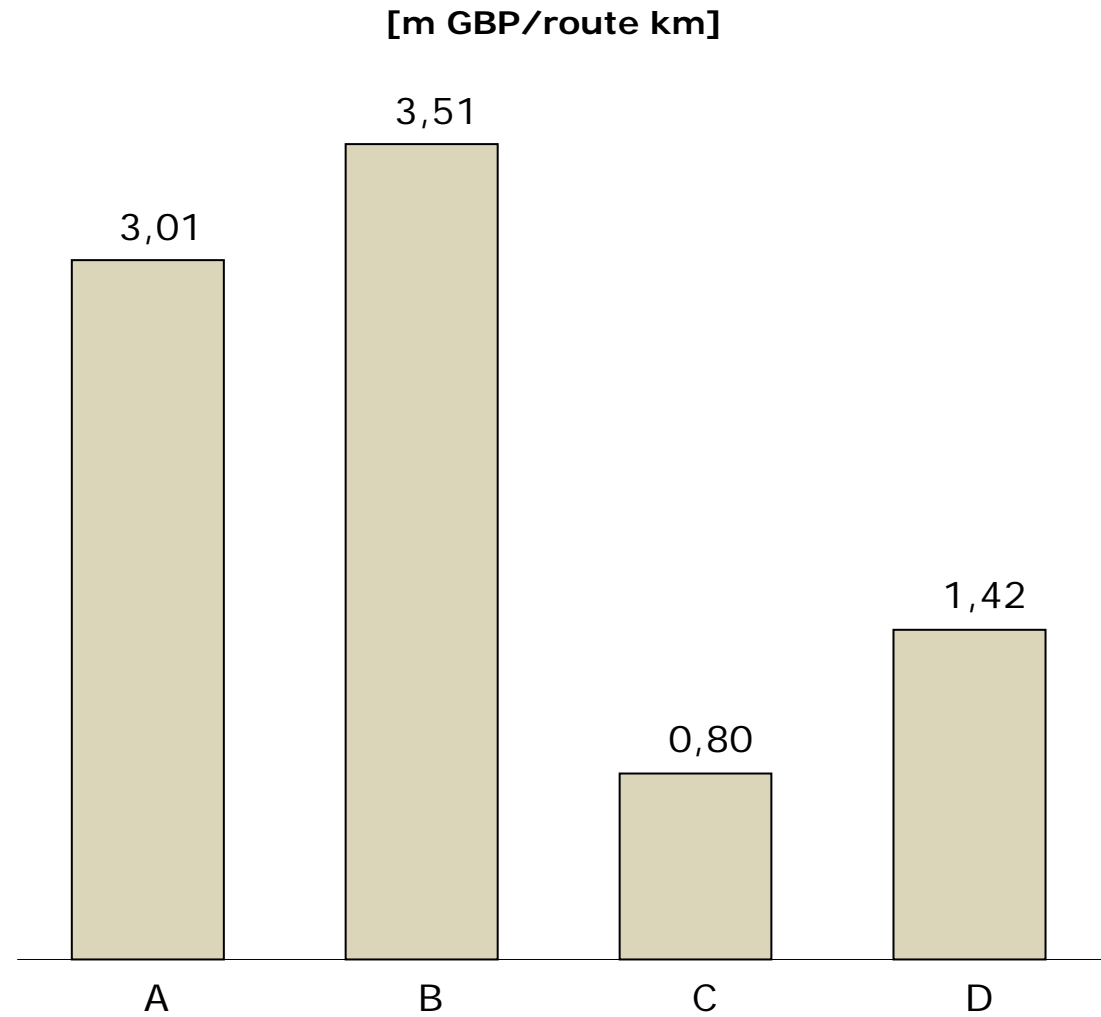
## Distribution of costs of Bridges [% of civil engineering works costs]



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# The cost per route km of viaduct costs varies

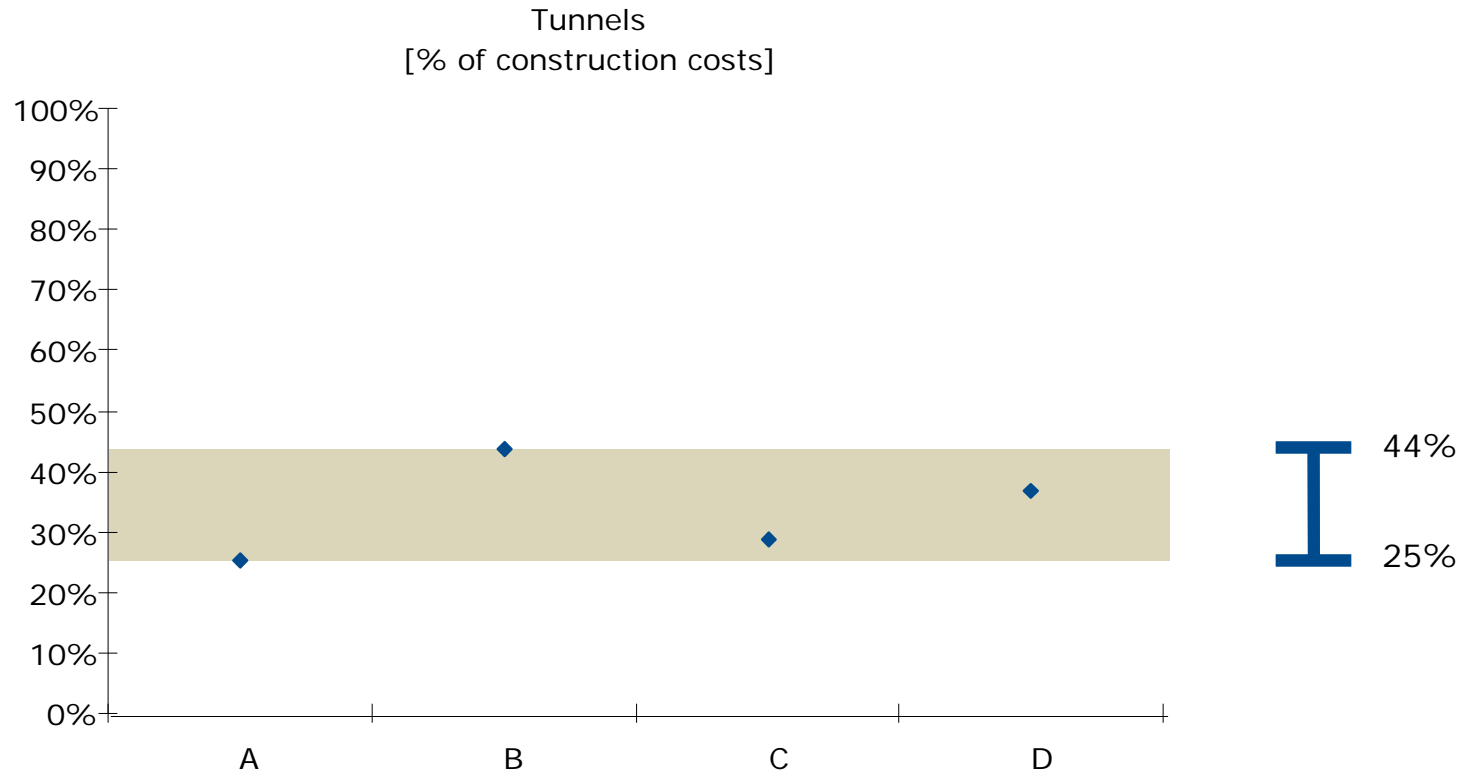
## Distribution of costs of Bridges (price level 2008), normalised by PPP



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# Also the spread in costs for tunnels is significant

## Distribution of costs of tunnels [% of civil engineering works costs]

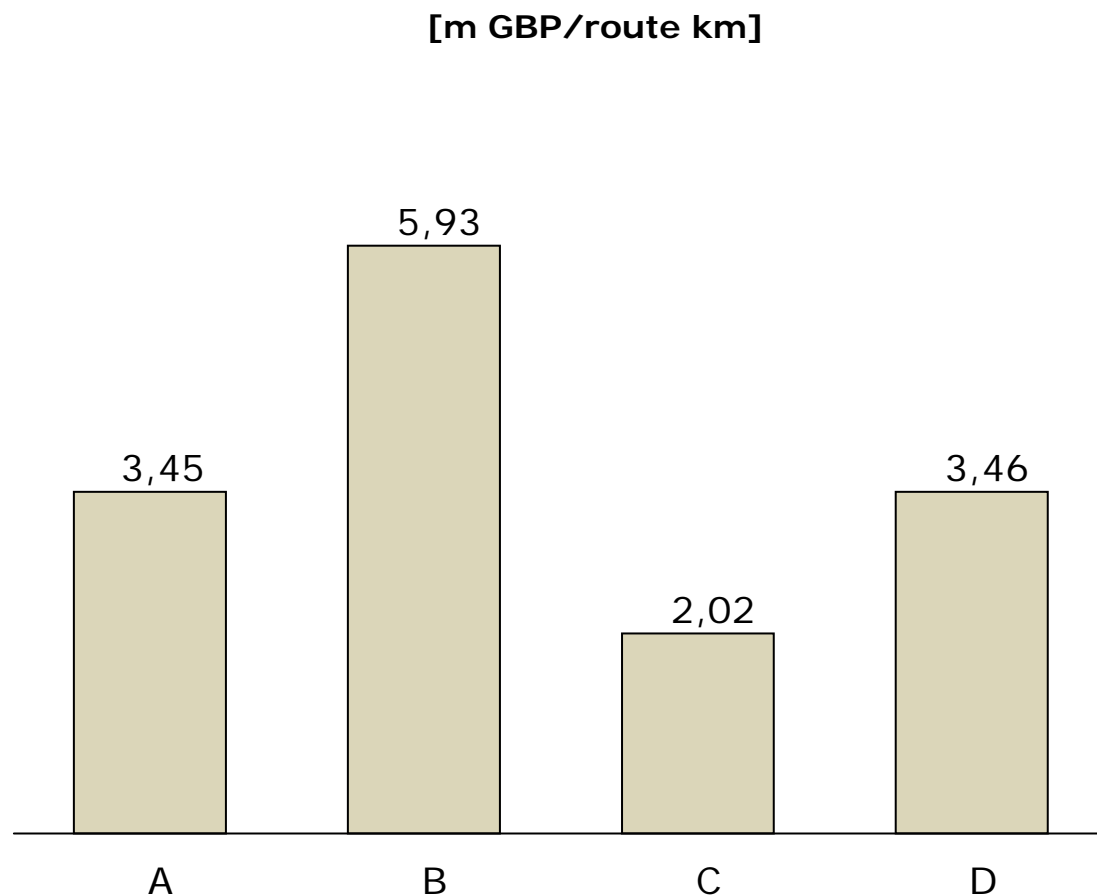


The share of tunnels on route drives the share of costs spent per km, independent of the kind and unit costs of tunnels

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# Distribution of costs of Tunnels

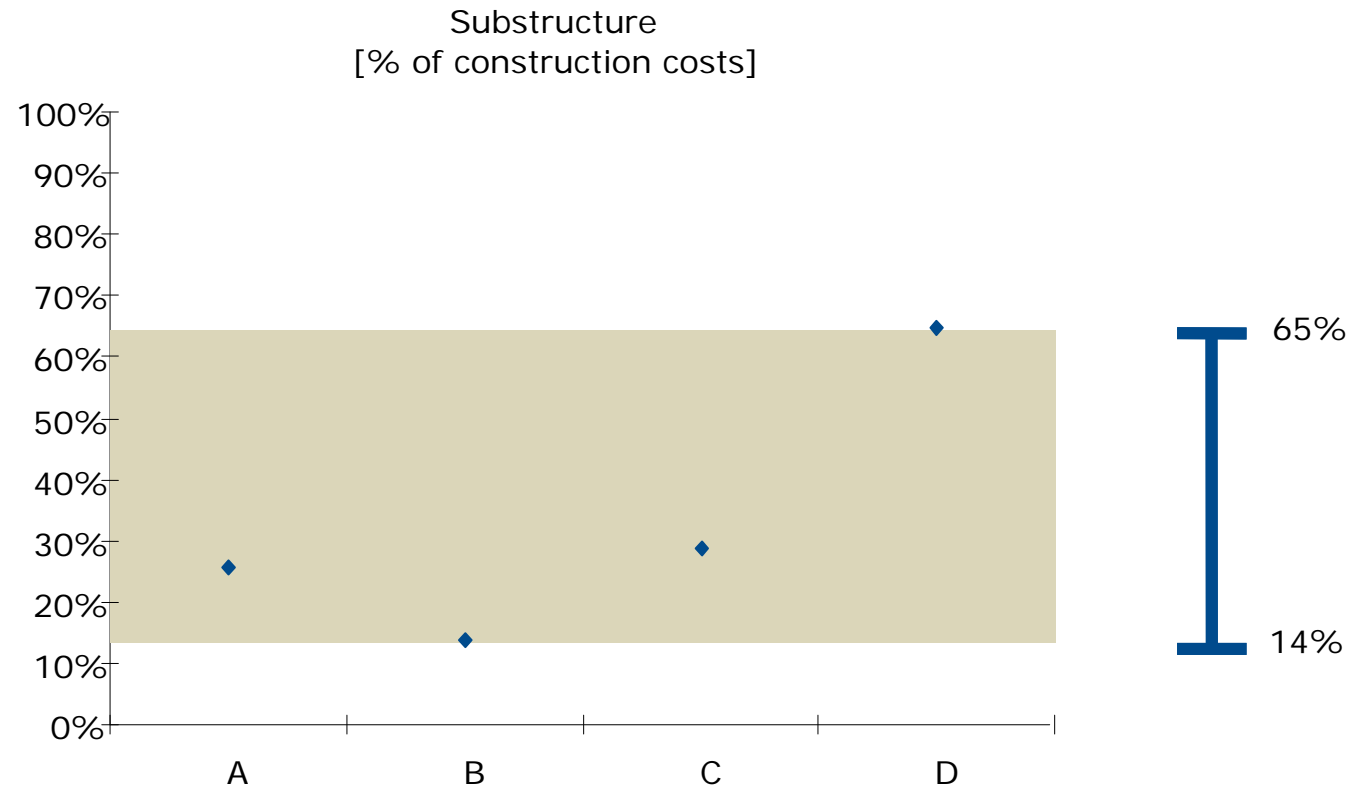
Price level 2008, normalised by PPP



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# The largest spread is found on substructures' cost shares with one outlier on the upper limit of the range

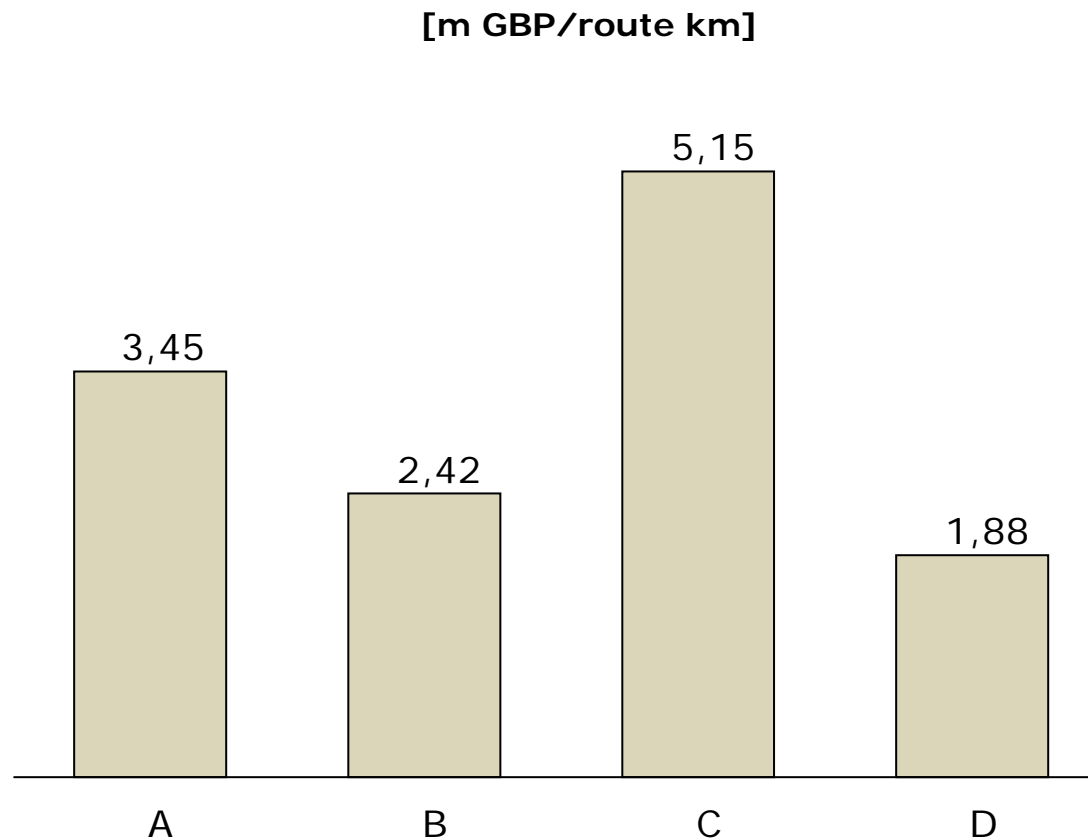
## Distribution of Costs of Substructure [% of civil engineering works costs]



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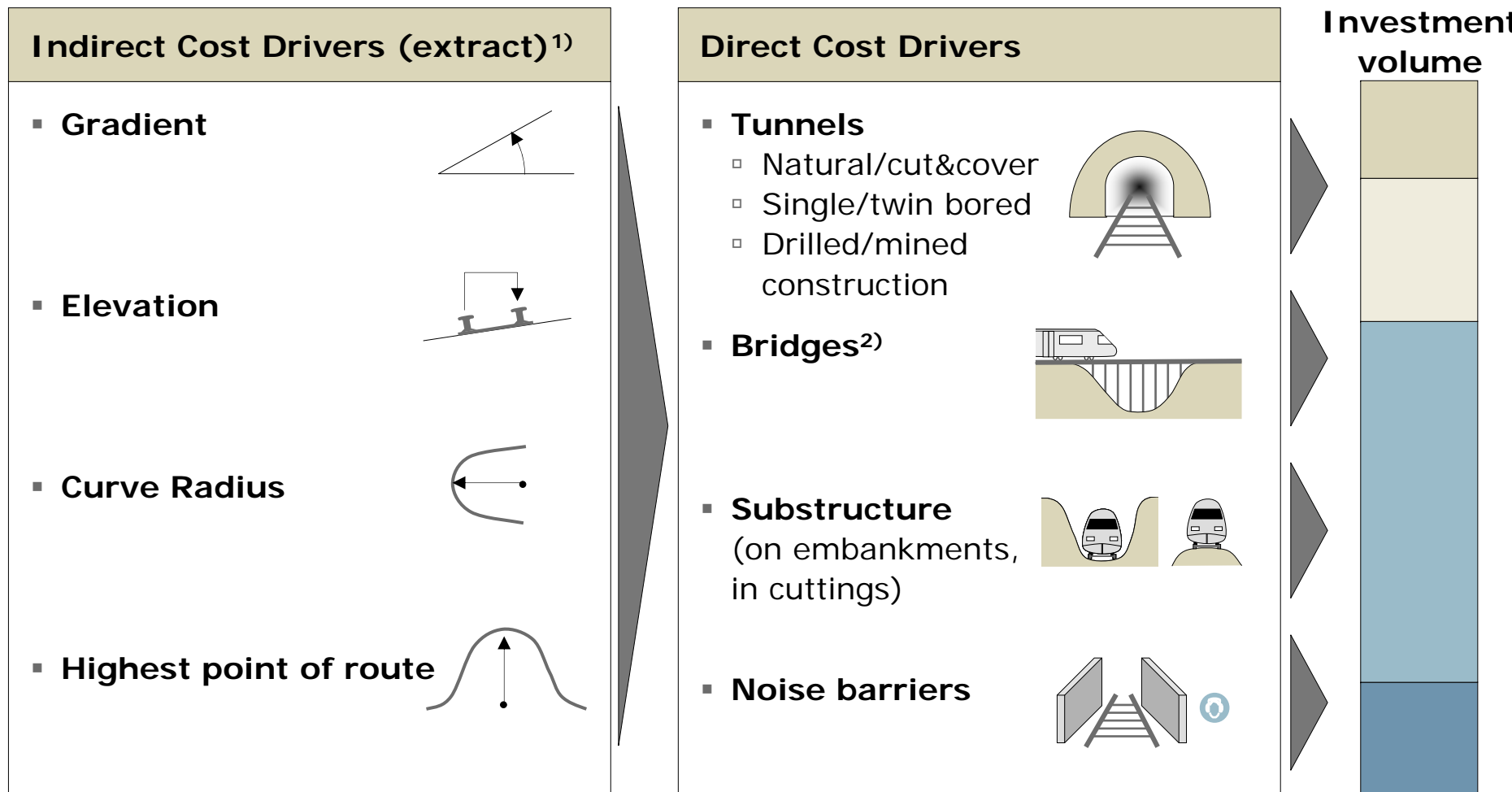
# Distribution of costs of Substructure

Price level 2008, normalised by PPP



# The investment volume of "Civil Engineering Works" is driven by the structural characteristics of the lines

## Overview Cost Drivers

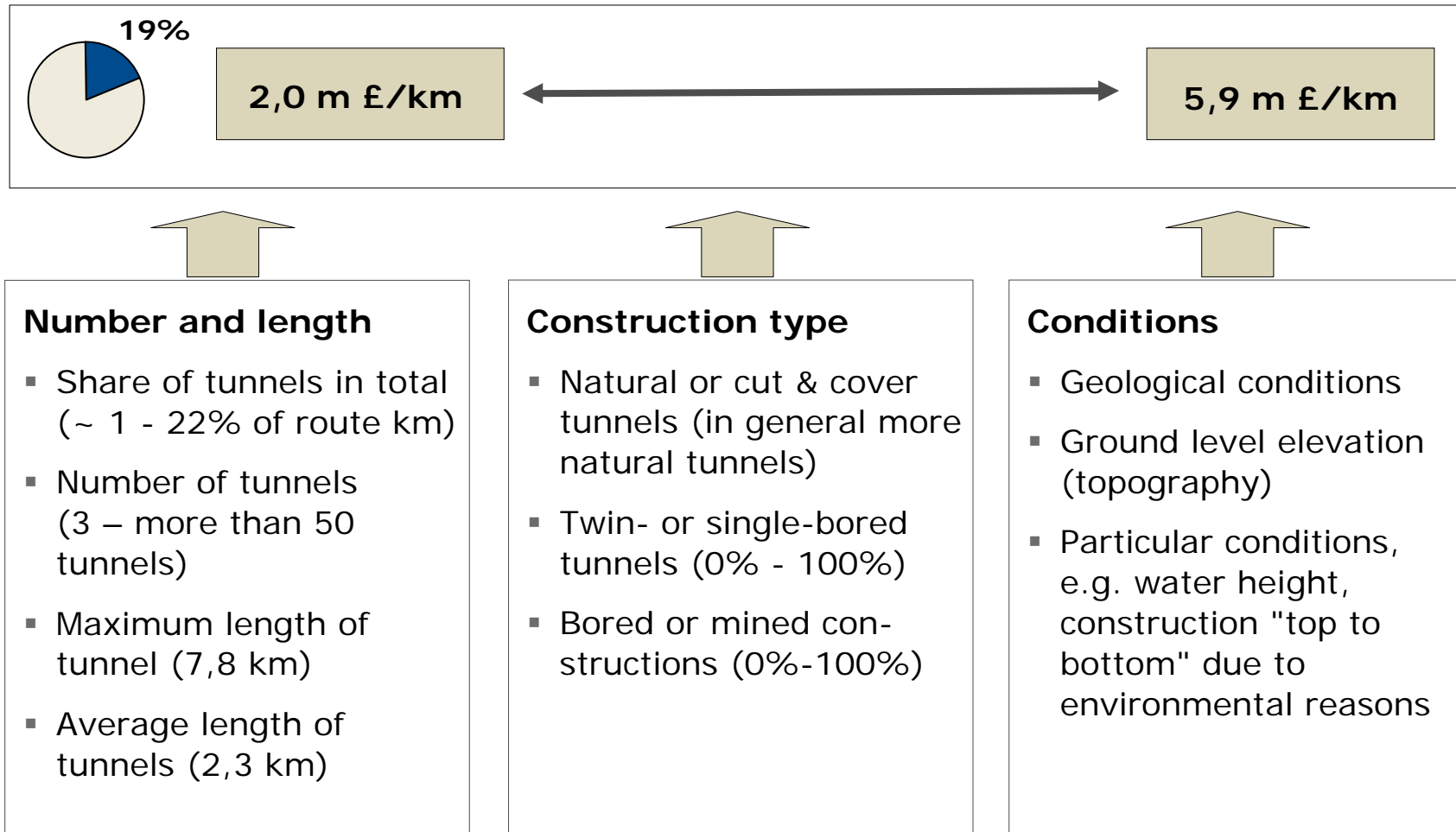


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1) Influencing the elements of net structure  
2) Including overpasses, road bridges and similar

# Cost driving aspects of tunnels are particularly the construction types and geological conditions

## Costs of tunnels related to total route-km<sup>1)</sup> and cost drivers



# Cost drivers of viaducts and overpasses are of course their specific lengths and designs

## Costs of viaducts and bridges related to total route-km<sup>1)</sup> and cost drivers



### Number and length of viaducts

- Share of viaducts (~ 1-20% of route-km)
- Number of viaducts (~ 5 – 95)
- Maximum length of viaduct (5,2 km)

### Construction type and elements of viaducts

- Concrete or steel viaducts with their unit costs
- Particular constructions ("urban requirements", environmental framework)
- Number of pillars (track on one or two pillars) and elements

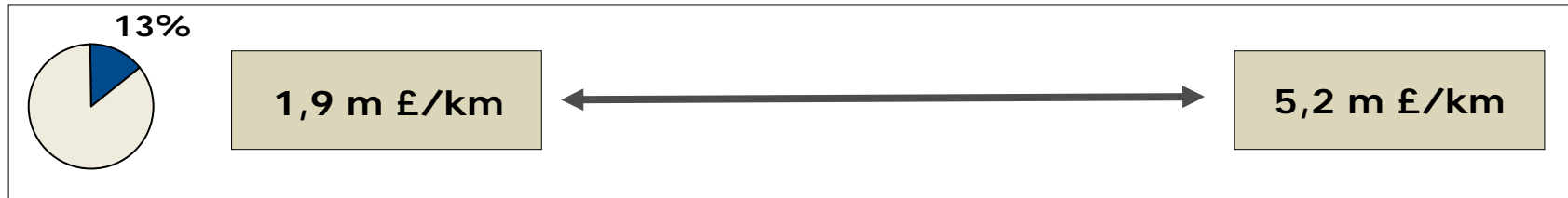
### Overpasses/bridges

- Number of overpasses (up to almost two overpasses/route-km)
- Number of bridges (up to almost one bridge/route-km)

1) Here no unit costs, but viaducts'/bridges' share of total CAPEX related to one route-km

# Costs of substructure are mainly influenced by its design

## Costs of route-km outside of tunnels/viaducts and cost drivers



### Length and "types" of substructure

- Share of route on embankments
- Share of route in cuttings
- Share of route at ground-level
- Cost-ratio of substructure types (embankment most cost-driving)

### Noise barriers

- Share of route-km with noise barriers (up to 34% of route-km)
- Characteristics of noise barriers (height up to 5 m)

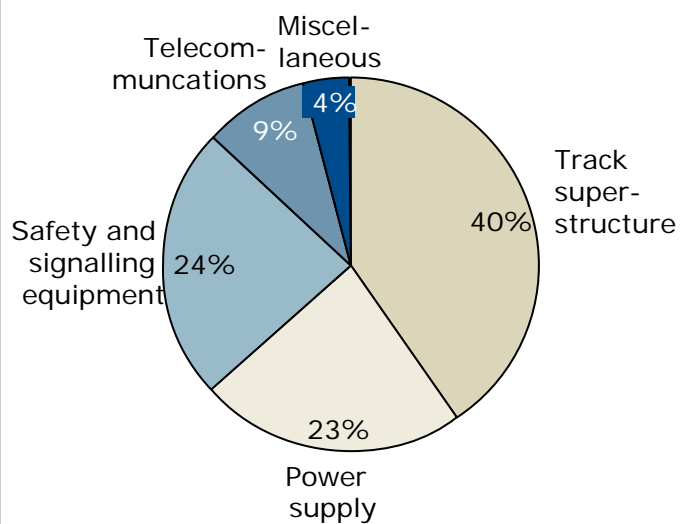
### Miscellaneous

- Share of costs for services diversions / utility pipes (water, gas, electricity etc.)
- Starting points of new or upgraded route (mostly outside of cities)

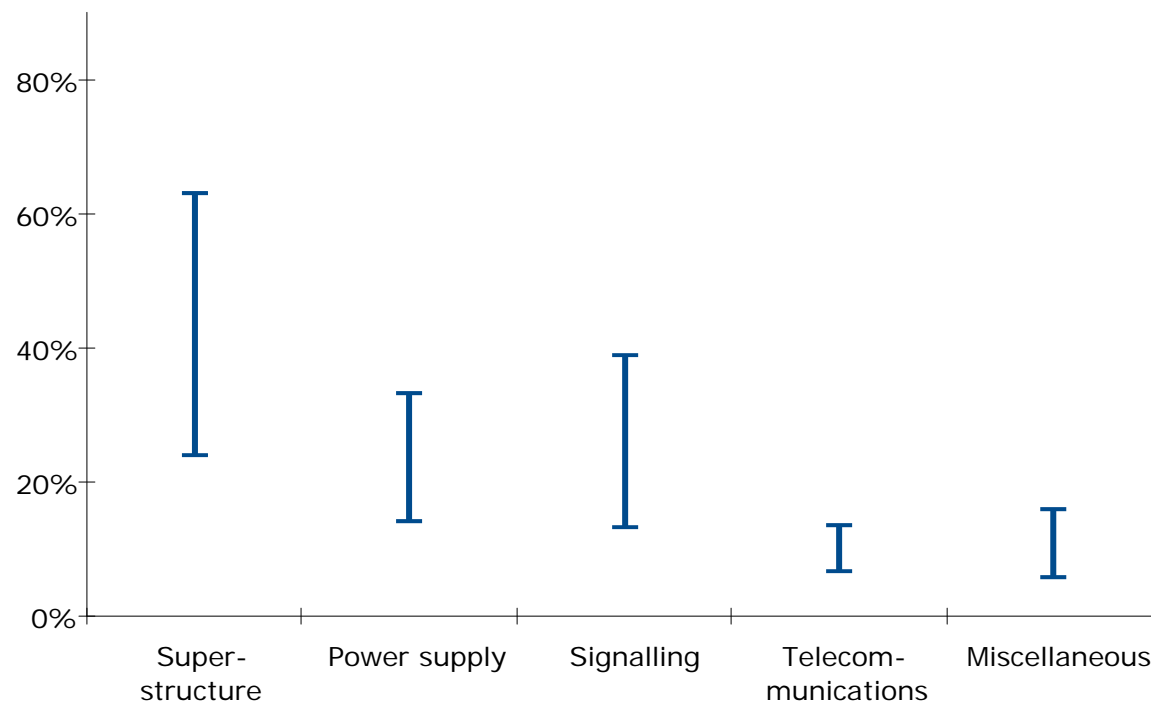
# Track superstructure is representing 40% of the equipment costs and varies widely

## Breakdown of railway equipments costs

Average Contribution of asset groups to total equipment costs [average in %]

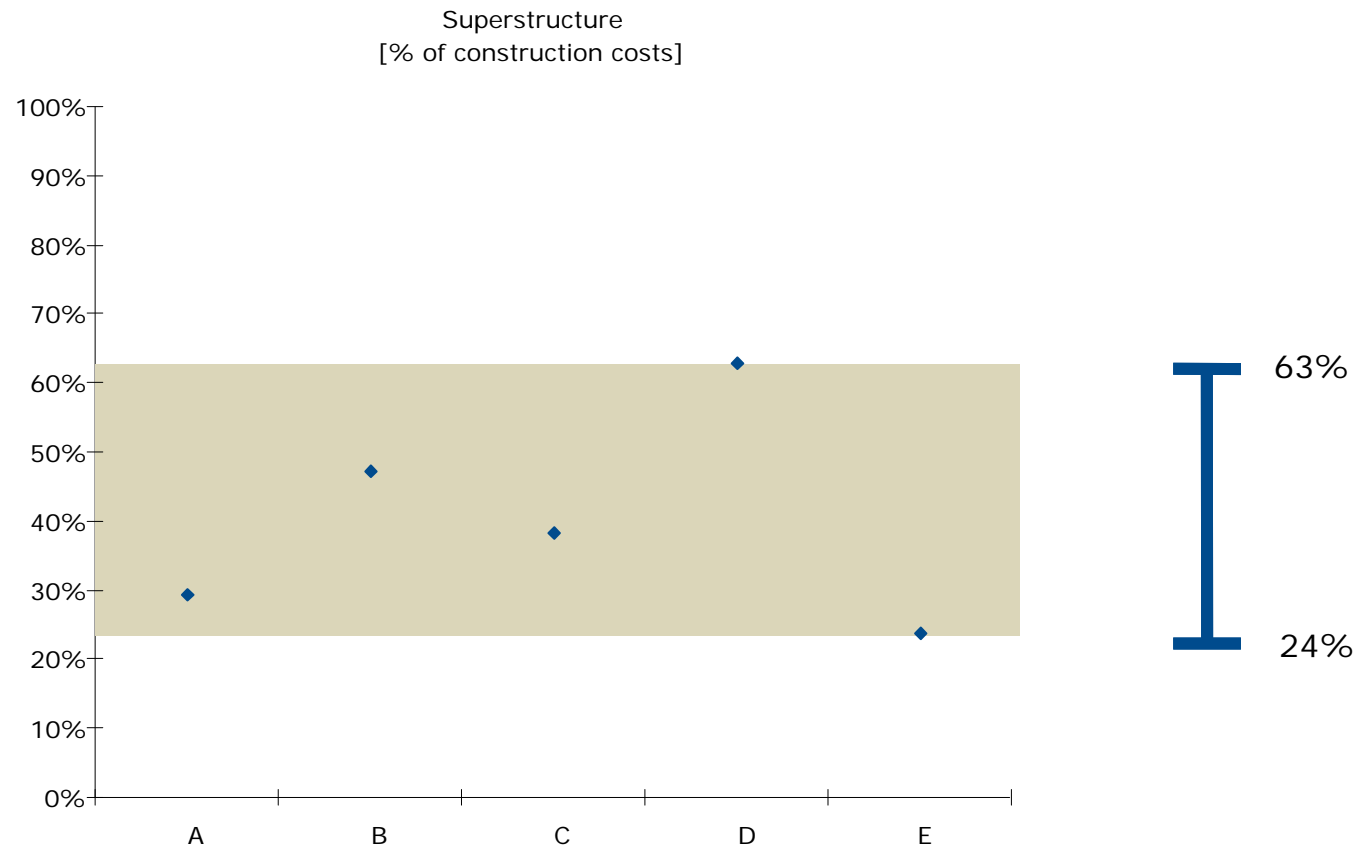


Distribution of equipment cost by asset group [spread in %]



# As in mostly all equipment asset categories costs of track superstructure disclose a very large spread

## Distribution of Costs of Track Superstructure [% of equipment costs]

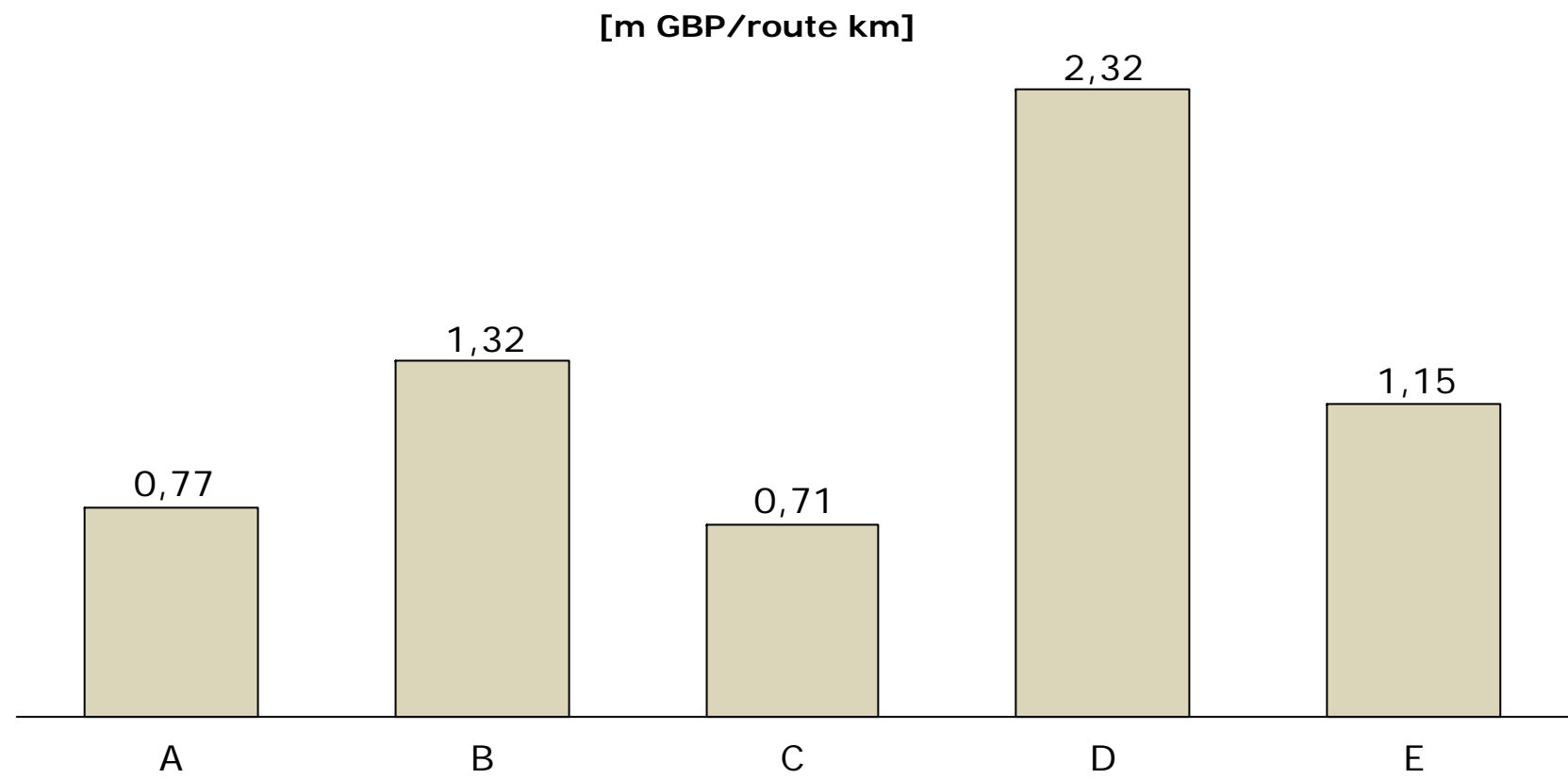


Lines with mostly either exclusively slab or ballast track were not pooled on the upper and lower limit of the cost range respectively

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# Superstructure costs per route-km show a large spread correlating with the different cost shares

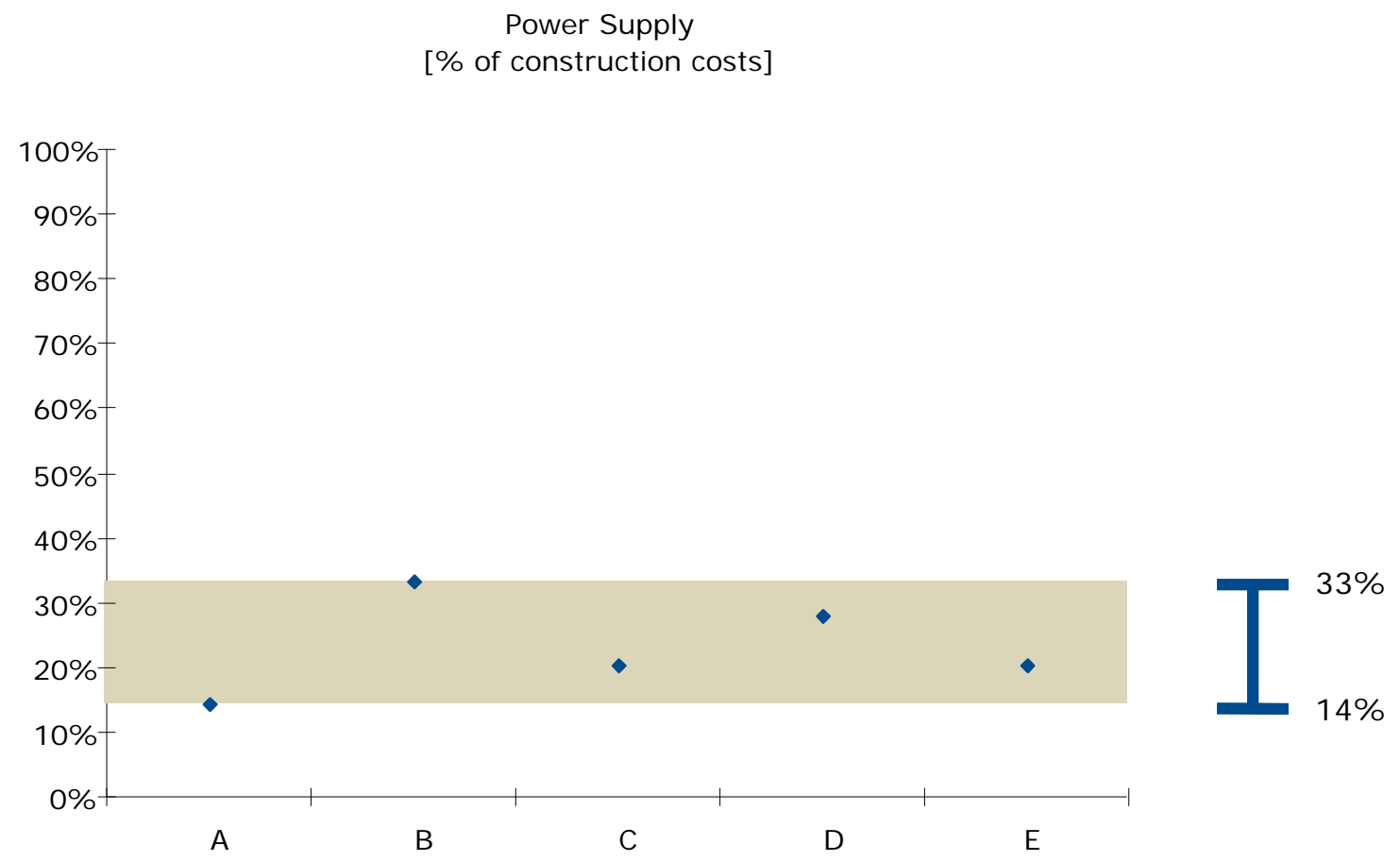
Distribution of costs of Track Superstructure (price level 2008), normalised by PPP



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# The costs of power supply are varying equally within a broad range

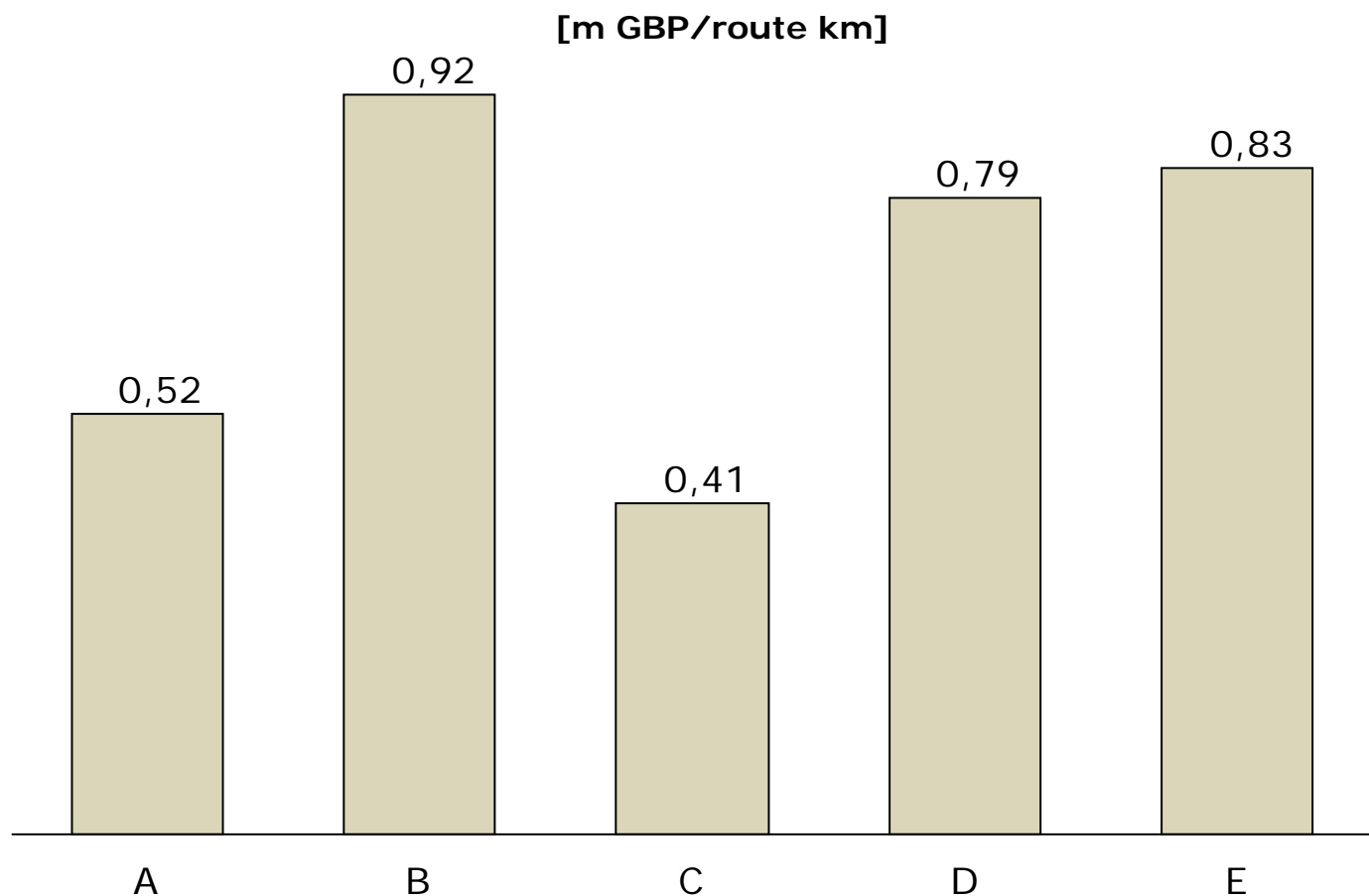
## Distribution of Costs of Power Supply, [% of equipment costs]



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# Distribution of costs of Power Supply

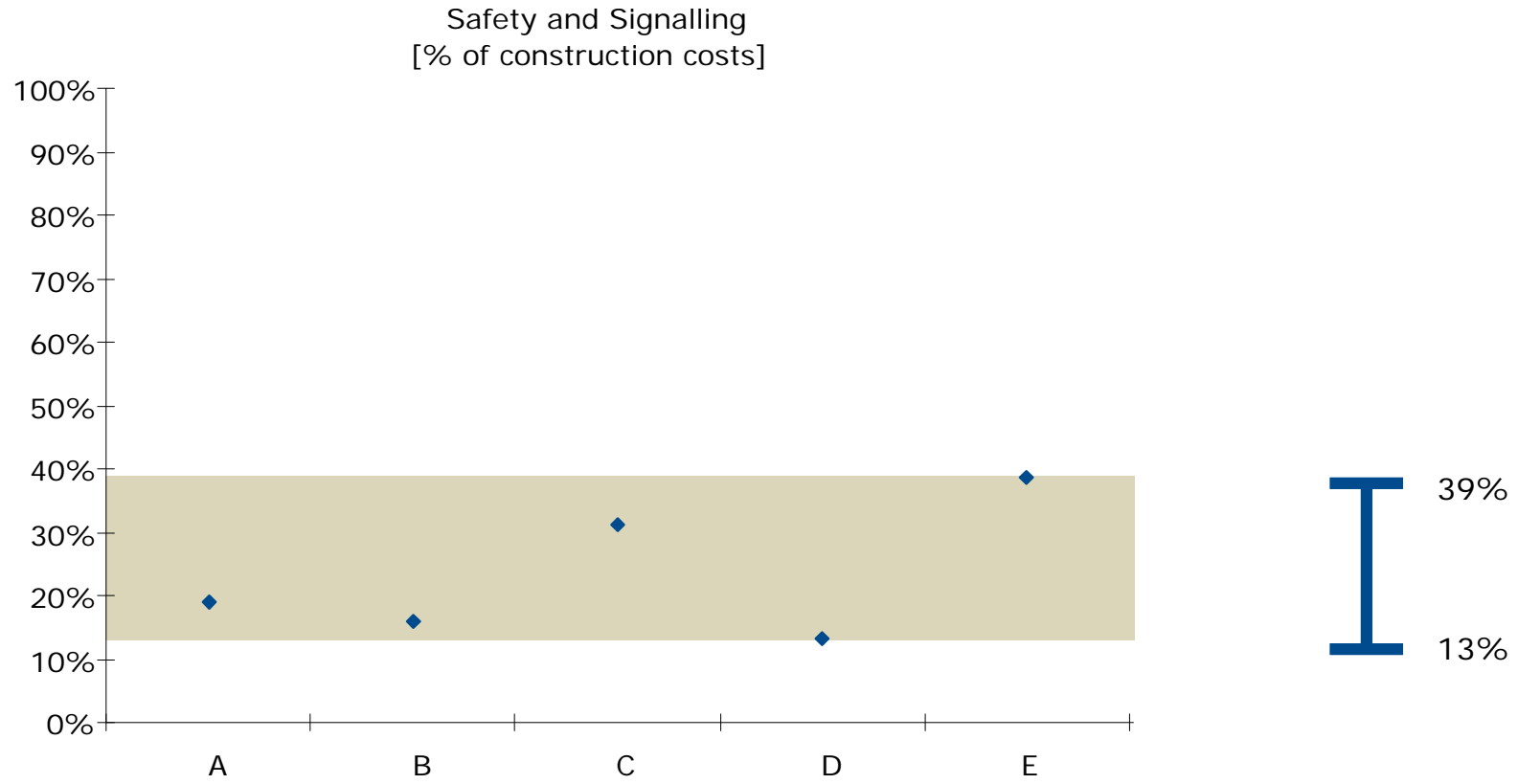
Price level 2008, normalised by PPP



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# Also signalling demonstrates significant cost spreads with one outlier representing 40% of total costs

## Distribution of Costs of Safety/Signalling [% of equipment costs]

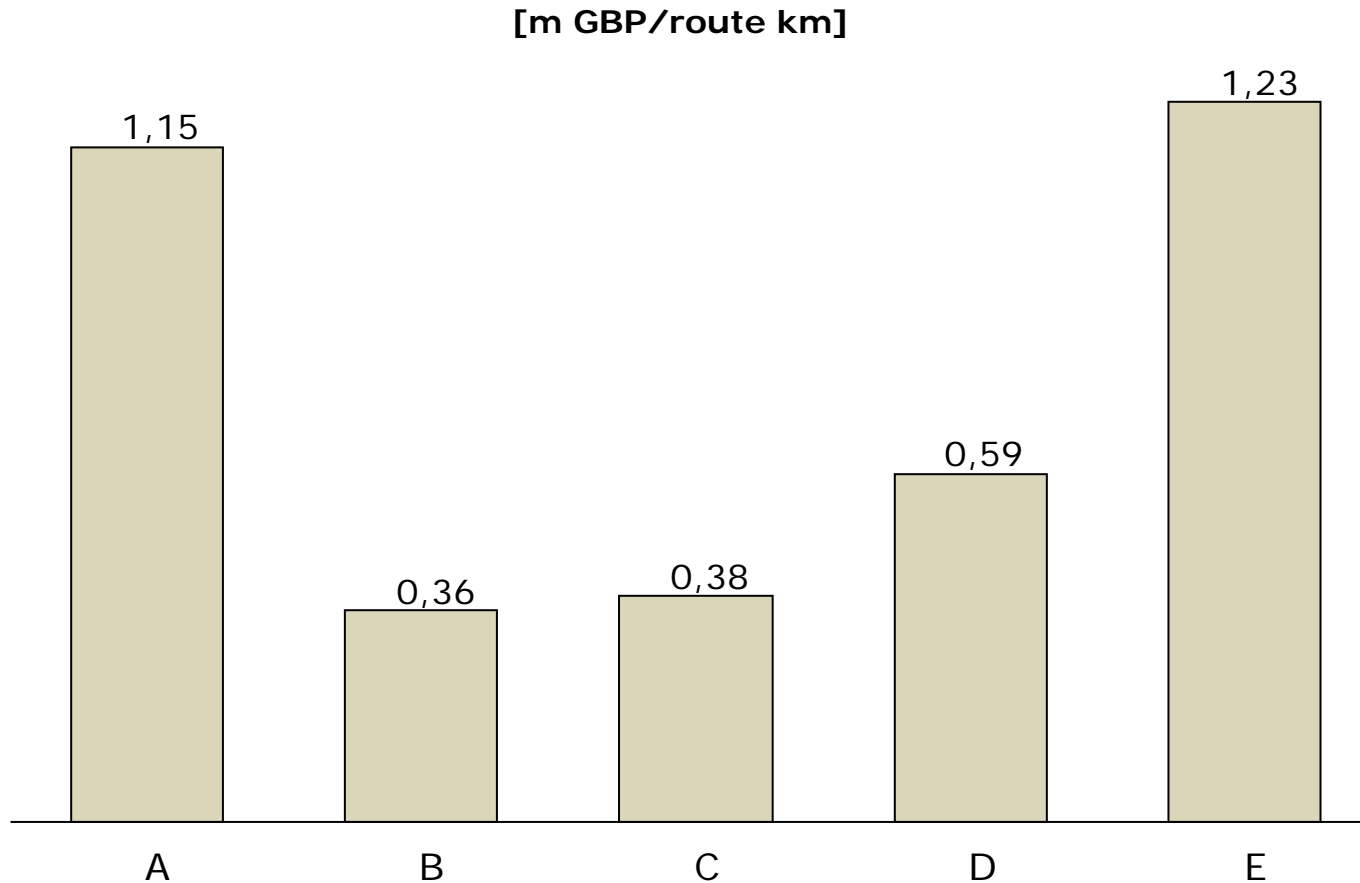


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# Signalling costs per route-km vary widely

Construction:  
Equipment

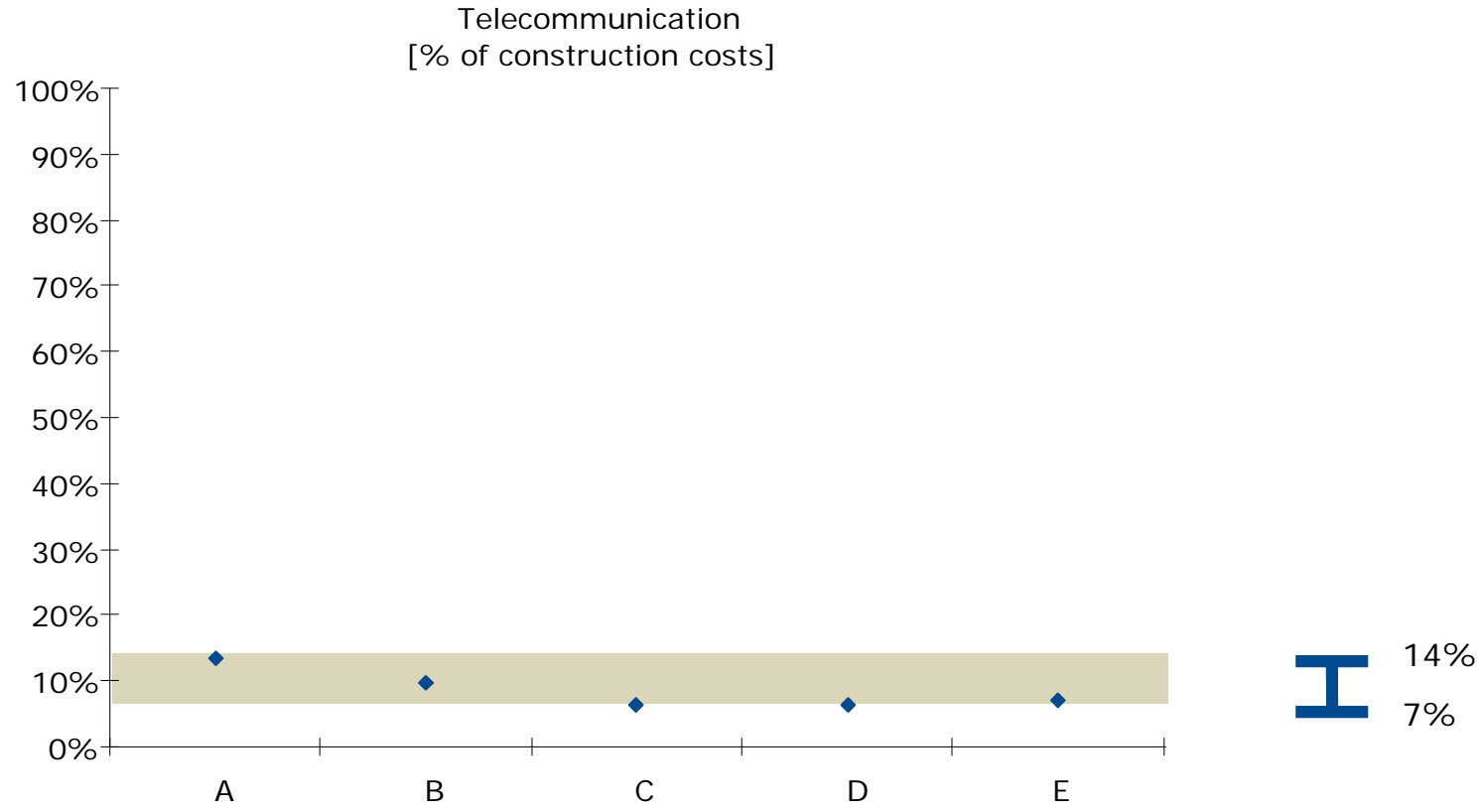
Distribution of costs of Safety/Signalling (price level 2008), normalised by PPP



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# Shares of telecommunication costs show the lowest spread of all equipment assets

## Distribution of Costs of Telecommunication [% of equipment costs]

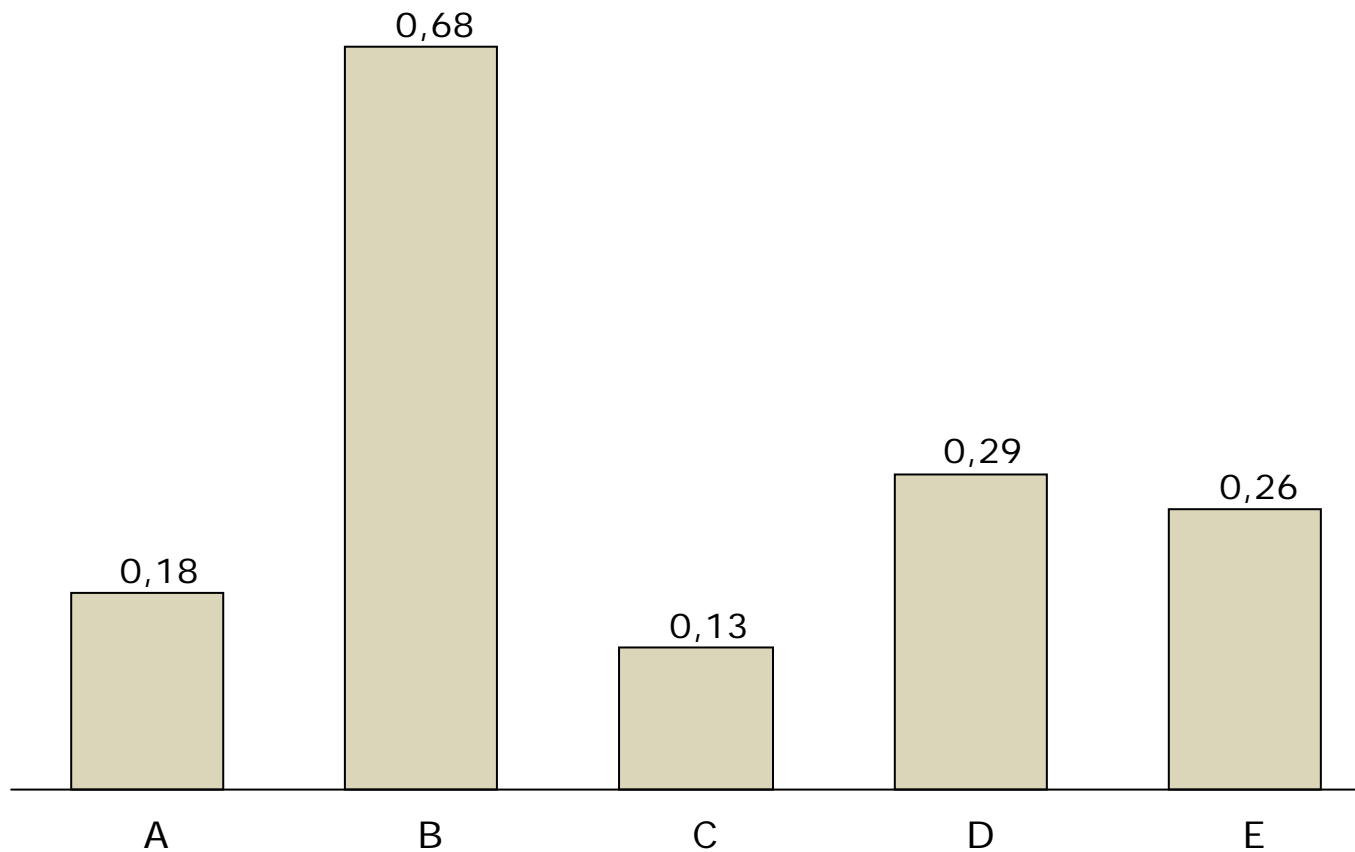


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# Distribution of costs of Telecommunications

Price level 2008, normalised by PPP

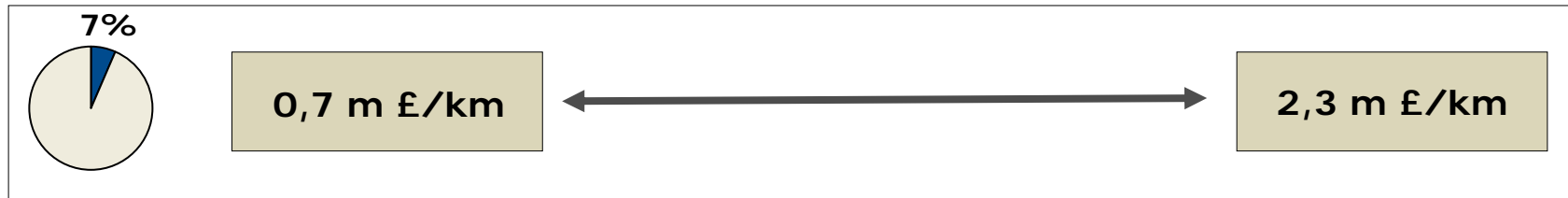
[m GBP/route km]



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# Costs of superstructure are largely influenced by the line length and less by the type of track installed

## Costs of superstructure per route-km and cost drivers



### Slab versus ballasted track

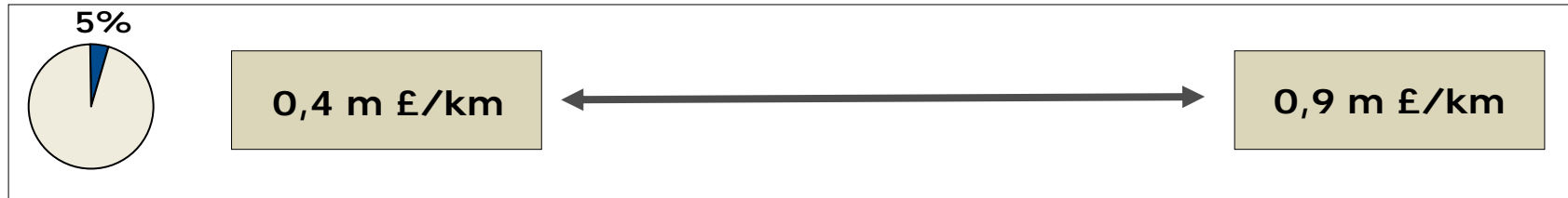
- Ratio of slab track and ballasted track could not be confirmed as cost driving structural factor
- Slab track as new type of superstructure with "trial and error" costs, but also on contractors side (e.g. several contractors to find the best solution)

### Points & crossings

- Number of points & crossings (0,2 – 0,7 points/route-km)
- Particular length of points
- Number of interconnections

# The length of catenary and among the number of substations the installed power was analysed regarding costs

## Costs of power supply per route-km and cost drivers



### Catenary

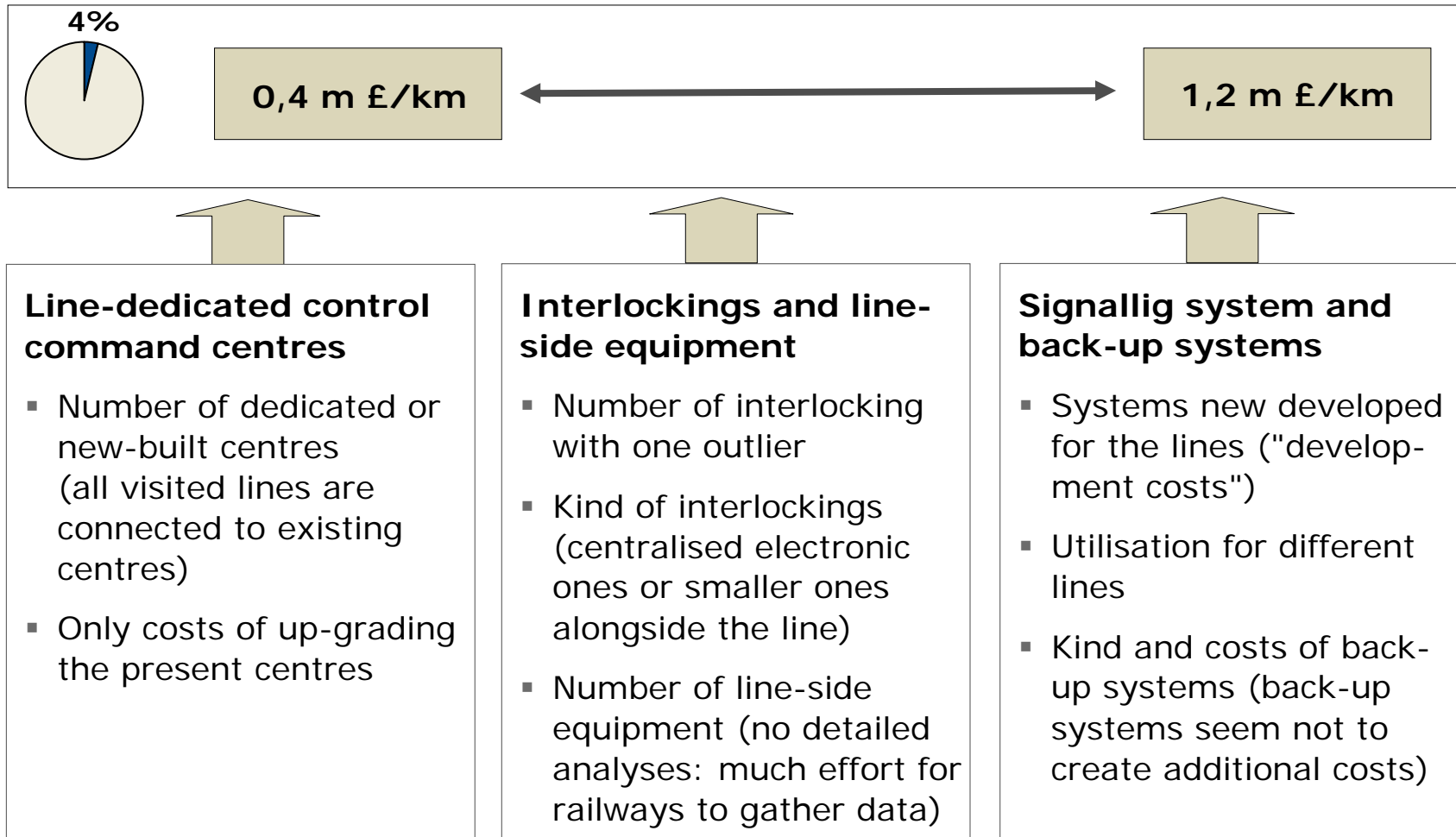
- All lines built as double track lines with catenary (no differences between lines)
- Type of catenary seems not to be a relevant cost driver
- Catenary in tunnels with particular construction forms and costs

### Substations

- Number of substations (1,7 -3,2 per route-km)
- Installed power per substation and number of transformers seem not be cost driving

# Signalling costs are driven by the kind of signalling system and its development costs and line-side equipment

## Costs of signalling per route-km and cost drivers



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- Objectives and preliminary remarks
- Selection of comparators
- **HSL CAPEX in comparison**
  - 1. Step: Total investment costs PPP-normalised
  - 2. Step: Breakdown of cost positions
  - 3. Step: Analyses by cost position
  - **4. Step: Unit costs of cost-driving assets**
- Conclusions

# In particular the unit costs for substructure and noise barriers vary greatly

## Unit costs (1)

Year	Units	Minimum Costs <sup>1)</sup>	Maximum Costs <sup>1)</sup>	Deviation in %	Considered lines <sup>2)</sup>
All tunnels	m £/tunnel-km	19,41	27,93	43,9%	4
Natural/bored tunnels	m £/tunnel-km	16,40	27,93	70,2%	5
Single-bored	m £/tunnel-km	16,40	24,66	50,4%	4
Twin-bored	m £/tunnel-km	27,42	29,00	5,8%	2
Boring machine	m £/tunnel-km	28,38	28,38	0,00%	1
Mined construction	m £/tunnel-km	16,40	26,78	63,3%	3
Cut & cover tunnels	m £/tunnel-km	27,34	32,97	20,6%	2
Viaducts	m £/viaduct-km	15,51	20,57	32,6%	5
Overpasses/bridges	m £/part	1,16	1,67	43,2%	3
Substructure	m £/km substructure	3,20	7,62	138,0%	4
On embankments	m £/km embankment	4,06	5,99	47,5%	2
In cuttings	m £/km cutting	2,87	4,61	60,5%	2
Noise barriers	m £/km barriers	0,85	2,21	161,0%	3

- 1) PPP-adjusted 2008 and based on costs per asset group related to its specific units (e.g. costs of – single or twin bored – tunnels divided by particular length of -single or twin bored - tunnels)  
 2) Number of lines, where data availability allows for a cost breakdown by units

# The unit costs of telecommunication, superstructure and signalling show very large spreads

## Unit costs (2)

Year	Units	Minimum Costs <sup>1)</sup>	Maximum Costs <sup>1)</sup>	Deviation in %	Considered lines <sup>2)</sup>
Superstructure track	m £/track-km	0,37	1,16	210,7%	4
Slab track	m £/track-km	0,37	0,54	44,2%	2
Ballasted track	m £/route-km	0,46	1,16	154,4%	3
Points	m £/part	0,22	0,71	219,4%	4
Signalling	m £/route-km	0,36	1,23	238,7%	4
Power supply	m £/route-km	0,41	0,92	139,5%	4
Telecommunications	m £/route-km	0,13	0,68	453,5%	4

- Possible explanations of the large spreads in units costs might be:
  - Technical and construction standards, e.g. bridges' pillar constructions
  - Innovation of systems (e.g. depending on year of opening) with effort on developing and testing
  - Regulatory standards, e.g. environmental requirements, with impact on construction types
  - Differences in allocation of construction costs to asset categories and single assets
- Explanations of higher costs of ballasted than of slab track could not be derived from the collected data, but it is might be well worth further examination

# Contents

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- Objectives and preliminary remarks
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- **Conclusions**

# Overview on cost driving issues for HS1 whilst considering the uncertainties on HS1's data

- Land acquisition (more than double the costs/route-km than the next following cost driving line within this comparison)
- Environmental issues (more than double the costs of the next following line, but less significant than land acquisition since total amount is much lower)
- Largest share of inner-urban route-km with effects on construction types
- Share of tunnels (largest share in the whole sample with around 25%)
- Share of twin-bored tunnels combined with the large amount of tunnels in total and tunnels' unit costs on the upper limit of the range
- Extensive intermediate stations and termini with the highest costs in the comparison (St. Pancras with 15 new or major refurbished platforms, termini construction for buses etc.)
- Unit costs very likely to be cost drivers, but not sufficient comparable data provided for HS1
- Others factors, such as commissioning, could not be sufficiently analysed due to lack of data availability

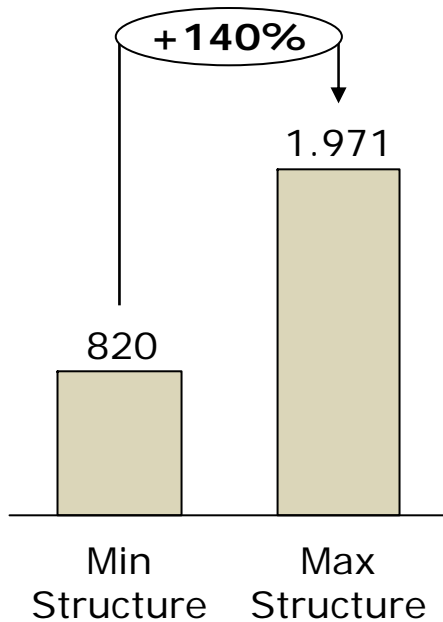
# In general there are enormous cost deviations depending on line characteristics and unit costs

## Cost Scenario Analysis (1)

### Scenario 1: Variation of structures

What would 100 route-km cost based on minimum/maximum structures and average unit costs?

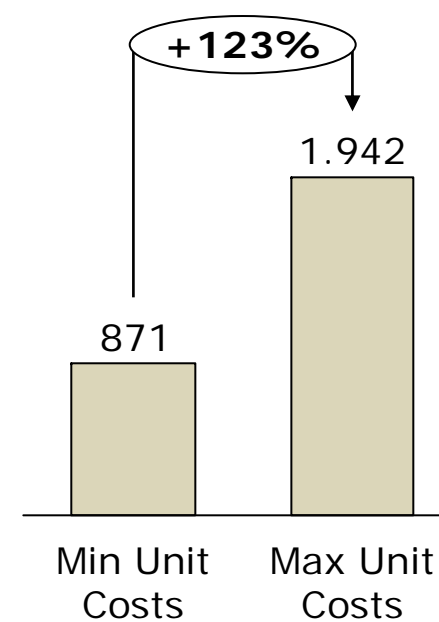
Total Cost in m £ per 100 km



### Scenario 2: Variation of unit costs

What would 100 route-km cost based on minimum/maximum unit costs and average structures?

Total Cost in m £ per 100 km



# This scenario analysis – considering asset-related construction costs only – gives an idea on cost spreads of high speed lines

## Cost Scenario Analysis (2)

**Scenario 1: variation of structures**

Net Structure	Min Structure per 100 km	Average costs [m £ per km or #]	Max Structure per 100 km
Natural tunnels	0,0%	23,1	17,1%
Cut & cover tunnels	0,0%	30,2	5,2%
Viaducts	1,9%	17,8	18,6%
Embankments/cuttings	98,1%	4,9	59,1%
Overpasses/Bridges	72,6	1,3	203,2
Ballasted track <sup>1)</sup>	0%	0,9	100%
Slab track <sup>1)</sup>	100%	0,5	0%
Points	20,1	0,3	70,4
Power supply	100%	0,7	100%
Signalling	100%	0,8	100%
Telecommunications	100%	0,3	100%
Intermediate stations <sup>2)</sup>	0	29,9	5
Termini <sup>2)</sup>	0	29,9	2
Buildings	0	1,7	2

**Scenario 2: variation of unit costs**

Net Structure	Unit Costs min [m £ per km or #]	Average structure [% or #]	Unit Costs max [m £ per km or #]
Natural Tunnels	16,4	9,4%	27,9
Cut & cover Tunnels	27,3	2,0%	33,0
Viaducts	15,5	7,8%	20,6
Embankments/cuttings	3,2	81%	7,6
Overpasses/Bridges	1,2	110,3	1,7
Ballasted track <sup>1)</sup>	0,5	71%	1,2
Slab track <sup>1)</sup>	0,4	29%	0,5
Points	0,0	51,7	0,7
Power supply	0,4	100%	0,9
Signalling	0,4	100%	1,2
Telecommunications	0,1	100%	0,7
Intermediate stations <sup>2)</sup>	5,3	3	72,5
Termini <sup>2)</sup>	5,3	1	72,5
Buildings	1,7	1	1,7

1) Related to track-km

2) Stations/termini: Mixture of new built and (major) refurbishment, one unit cost price for both stations/termini

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*Director*

Katja Gieseke  
*Senior Project Manager*

Anna Lutterbach  
*Senior Consultant*

Klaus Wittmeier  
*Senior Consultant*

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