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Feasibility of Strait Crossings Solutions

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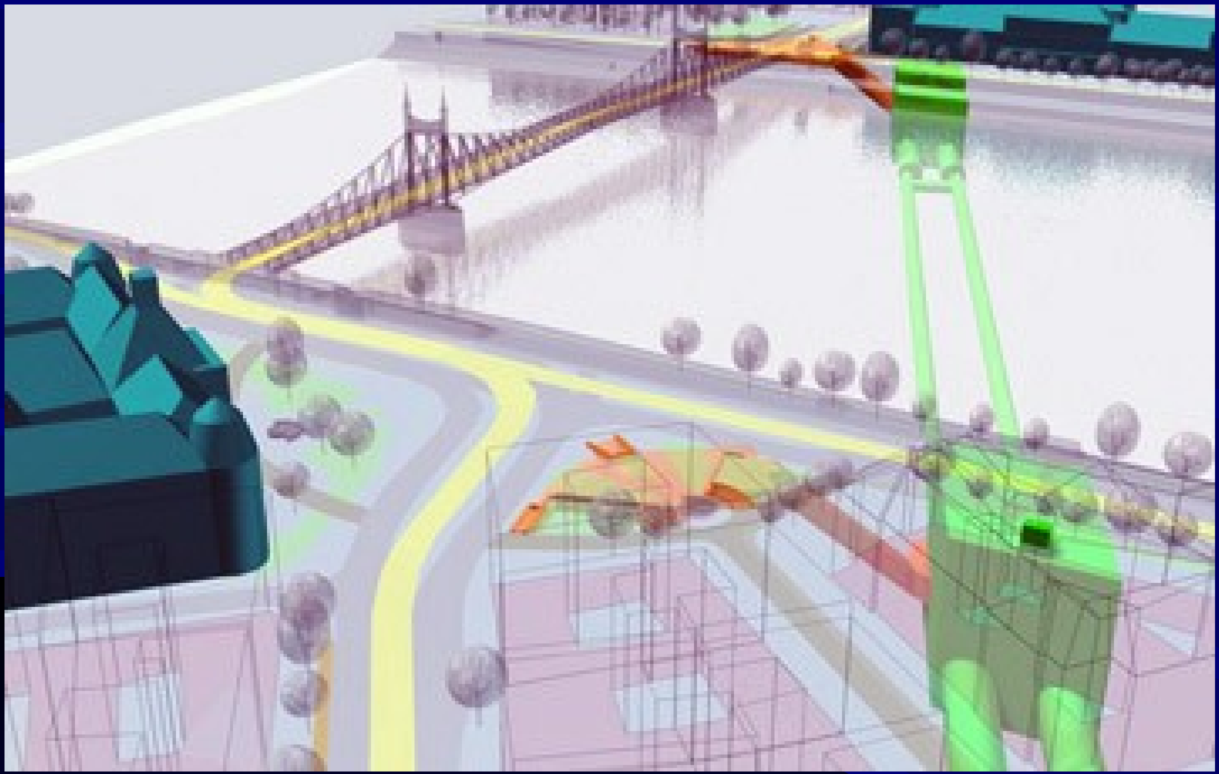
1.Introduction: Concepts of Strait Crossings



Metro 4 Line Budapest :

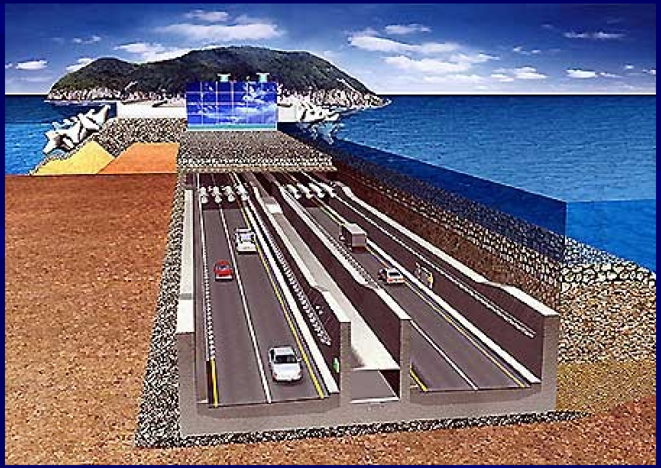
- undercrossing Danube
- bored tunnel option

  between stations Gellert and Fovam

- vicinity of old bridge
- mineral and thermal water wells in Danube
- length of about 500 m between stations

Aesthetic reasons when choosing tunnel option vs. bridge.

1.Introduction: Concepts of Strait Crossings

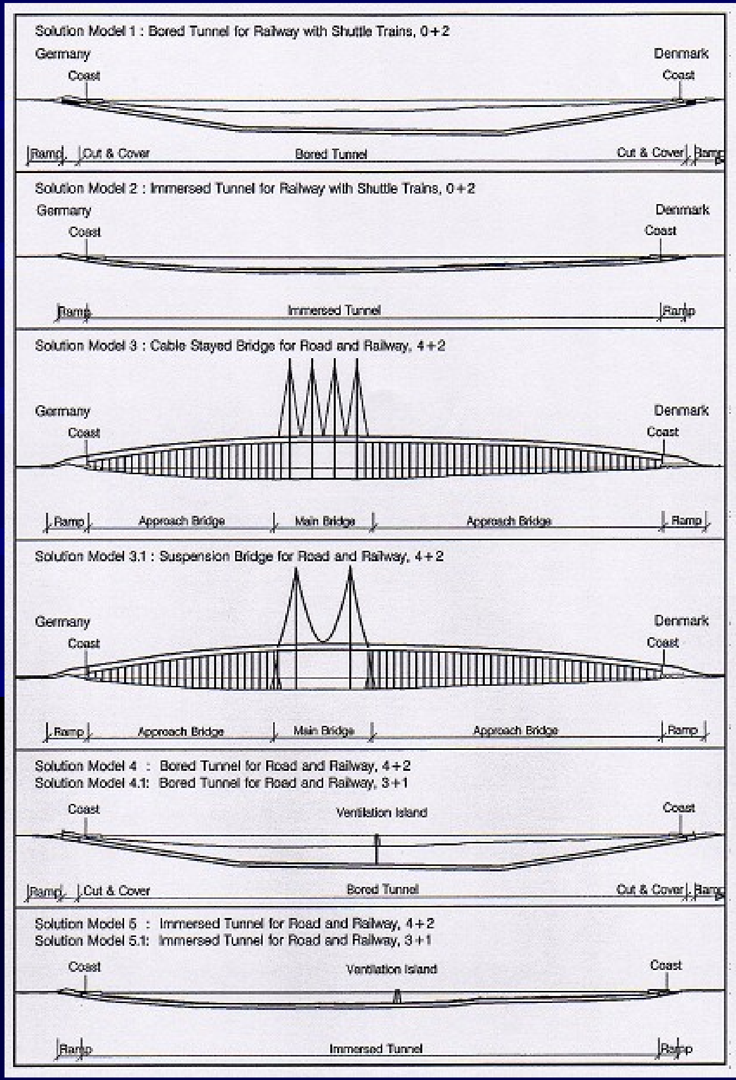


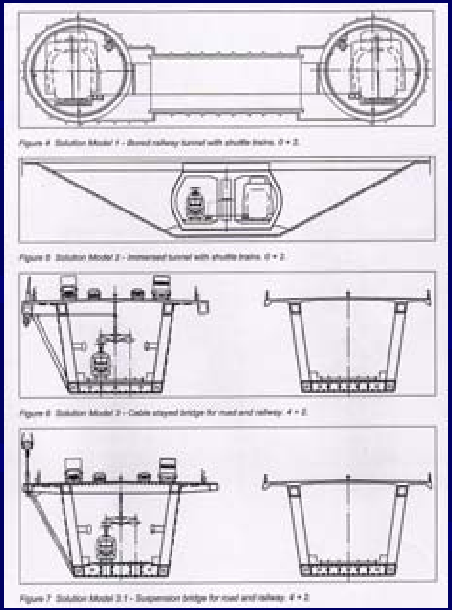
Project Busan – Island Geoje, 8.2 km

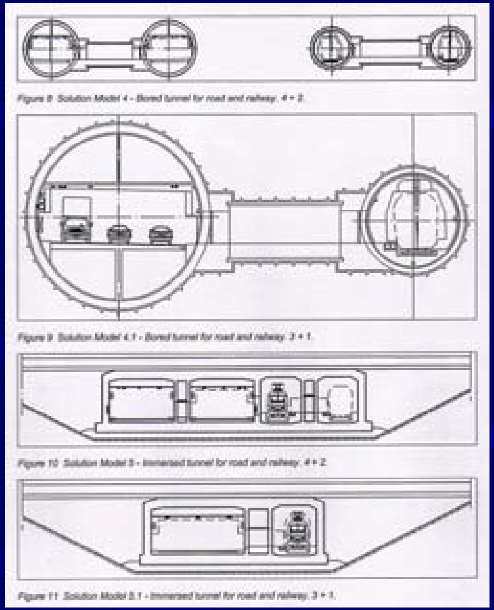
- Cable stayed bridges over 2 km
- Immersed tube 3.8 km long, 50 m deep
- on crowded ship route
- vicinity of a new port near Busan

- double tube, double lane
- safety and ventilation channel

1.Introduction: Concepts of Strait Crossings







- Fehmarn Belt, Denmark-Germany : 19 km
- Options :
- bridge, immersed tube, bored tunnel
- traffic capacity of the crossing vs. costs

1.Introduction: Concepts of Strait Crossings

		Total	Relat.	No.	Width	No.	Width	Length	Costs per m²
model	Crossing type	costs	costs	lanes	lane	rail track	rail track	L	Traffic area
	Road lanes + rail tracks	Mill [€]	[%]	[-]	[m]	[-]	[m]	[m]	[€ / m²]
1	Bored tunnel 0+2	3.391	118	0	3,75	2	5,50	23.015	13.394
2	Immersed tube 0+2	3.545	123	0	3,75	2	5,50	20.210	15.946
3	Cable stayed bridge 4+2	3.040	106	4	3,75	2	5,50	21.318	5.485
3.1	Suspension bridge 4+2	3.573	124	4	3,75	2	5,50	21.278	6.458
4	Bored tunnel 4+2	4.420	154	4	3,75	2	5,50	22.815	7.451
5	Immersed tube 4+2	3.780	132	4	3,75	2	5,50	20.380	7.134
4.1	Bored tunnel 3+1	2.992	104	3	3,75	1	5,50	22.815	7.829
5.1	Immersed tube 3+1	2.874	100	3	3,75	1	5,50	20.380	8.419

Fehmarn Belt, Denmark-Germany : 19 km

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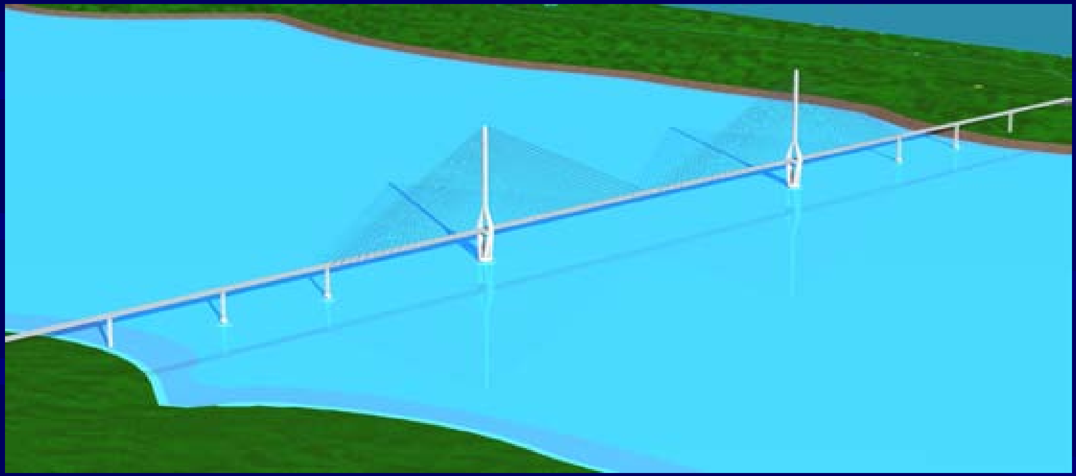
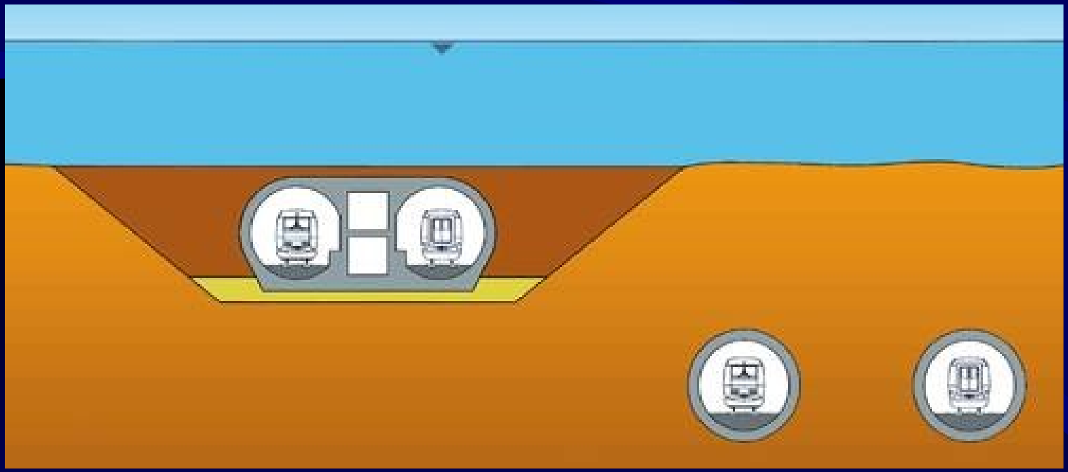




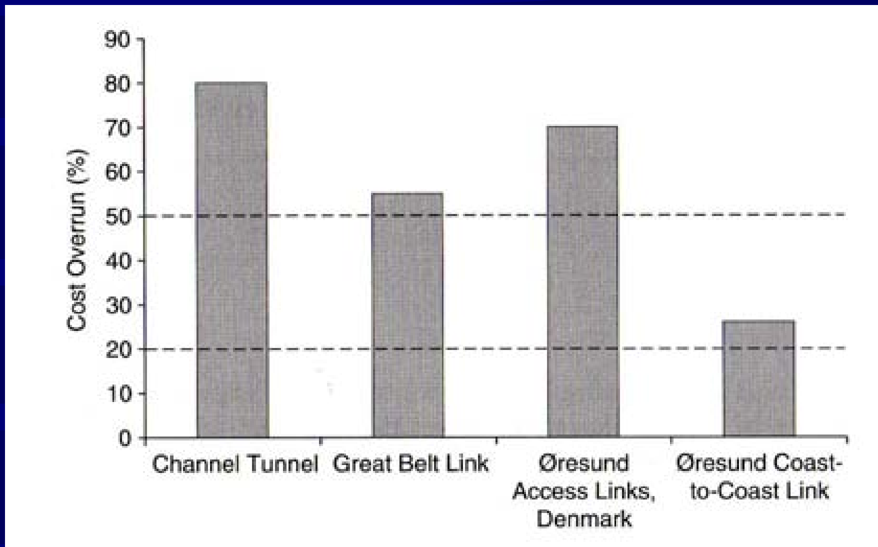
Feasible solutions among :

- Bridge solution
- usually as a combination of a
- one big opening and several continuous spans

- Immersed tube
- up to 3 km length
- not deeper than 50 m

- Bored tunnel
- deeper elevation
- lenghts longer than 2 km

2. Strait Crossings and Cost Overruns



Serious cost overruns by megaprojects:

- Rail tunnel crossing
- Rail-Road bridge-tunnel crossing

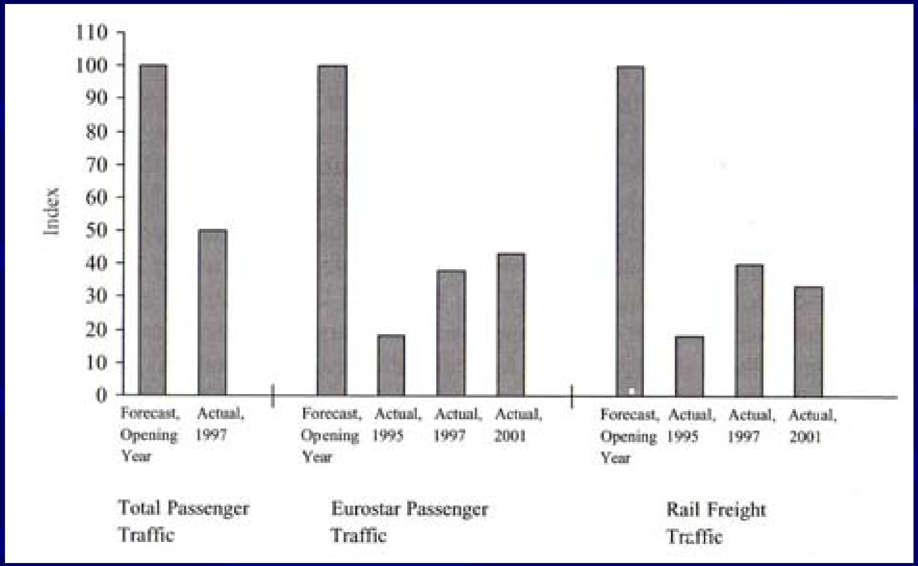
- Prof. Flyvbjerg,
- University Aarlborg, Danemark

Transportation infrastructure project overruns by feasibility studies:

- Rail lines
- Highways
- Bridge crossings
- Tunnel road connections
- Metro lines

Project	Cost overrun (%)
Boston's artery/tunnel project	196
Humber bridge, UK	175
Boston–Washington–New York rail, USA	130
Great Belt rail tunnel, Denmark	110
A6 Motorway Chapel-en-le-Frith/Whaley bypass, UK	100
Shinkansen Joetsu rail line, Japan	100
Washington metro, USA	85
Channel tunnel, UK, France	80
Karlsruhe–Bretten light rail, Germany	80
Øresund access links, Denmark	70
Mexico City metro line	60
Paris–Auber–Nanterre rail line	60
Tyne and Wear metro, UK	55
Great Belt link, Denmark	54
Øresund coast-to-coast link	26

2. Strait Crossings and Cost Overruns



Traffic forecasts :

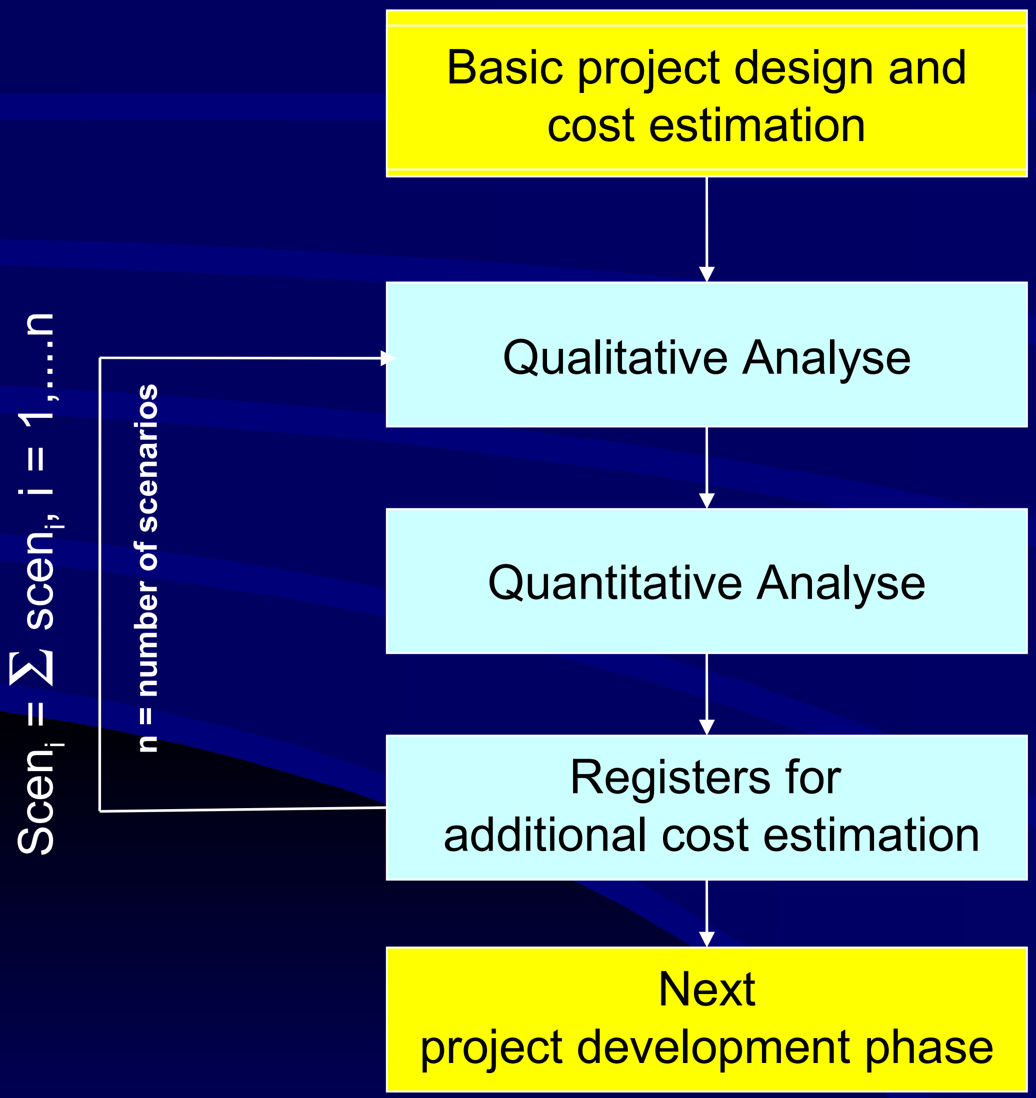
- overestimated opening year
- traffic development through time
- investment back-up through traffic development

Overestimation in the early project development phase :

- Making project more attractive
- Enabling investment
- Enabling start of works

Project	Actual traffic as percentage of forecast traffic, opening year
Calcutta metro, India	5
Channel tunnel, UK, France	18
Miami metro, USA	15
Paris Nord TGV line, France	25
Humber Bridge, UK	25
M65 Huncoat Junction to Burnley Section, UK	35
Tyne and Wear metro, UK	50
Mexico City metro	50
Denver International Airport	55

3. Methodology for Cost Optimisation



Evaluation of scenarios for additional :

* design decisions

and

*cost estimation

3. Methodology for Cost Optimisation

Registar scenarija _1

Kvalitativna analiza

br.	PODRUČJA		Potpodručja	Opis scenarija	Utjecaji TI	VG	ZO	SO	RS	Suma utjec.	Vjer. pojave	akcija	Aktivnost na rješavanju scenarija	Korek/ prom./ dopuna
1	Uvjeti lokaliteta	1.1	priključak na post. prometnice	dodatni radovi na priključenju na post. cestovnu mrežu	1	1	1	1	2	6	3	prihv.	proračun dodatnih troškova i radova	dop.
		1.2	dubina na plov. puta ispod mosta	produbljivanje i proširenje profila za plovila	1	1	4	1	1	8	2	prihv.	premjer podvodnog profila, pregled morskih strujanja i nanosa, zaštita od erozije pokrova temelja	dop.
		1.3	udar plovila u stup mosta	radovi na zaštiti od udara plovila u stup mosta	3	4	1	1	1	10	2	prihv.	izvedba zaštitnih nasipa plutajućih odbojnika	dop.
		1.4	vjetar	utjecaj vjetra na gradnju mosta	4	4	3	2	2	15	4	krit.	promjena poprečnog presjeka, zaštita od vjetra na mostu	kor.
		1.5	potres	utjecaj potresa na gradnju mosta	4	2	3	2	2	13	,1	prihv.	provjera horizontalnih i vertikalnih pom. konstrukcije uvjetovanih potresom	dop.
2	Geološki uvjeti	2.1	meki slojevi	utjecaj mekih naslaga o kojima jos nema podataka geotehnickih istrazivanja	4	4	3	3	3	17	3	ozb.	temeljenje na krajnje mekim slojevima	kor.
		2.2	podzemne vode	pojava podzemnih voda i strujanja	3	3	1	2	2	11	0	zanem	0	0
		2.3	rasjedi temeljnog tla	pojava rasjeda u temeljnom tlu	3	3	1	2	2	11	1	zanem	0	0
3	Koncept konstrukcije mosta	3.1	podvodni i vanjski dio stupova	koncept izvedbe pod- i nadvodnog dijela stupa	2	3	1	2	2	10	2	prihv.	provjera na udar broda	dop.
		3.2	oslonci	pogreske u izvedbi niza oslonaca	1	2	1	1	1	6	2	prihv.	numer.provjera na izmjenu / slijeganje 1 oslonca	dop.
		3.3	poprečni presjek	osjetljivost otvorenih sandučastih presjeka	2	3	1	3	3	12	3	prihv.	provjera na dinamičke oscilacije i njihovu kombinaciju	dop.
4	Tehnologija izvedbe	4.1	klizna oplata stupova	izvedba stupova u kliznoj oplati	2	2	1	2	2	9	2	prihv.	provjera broja oplata u uporabi	dop.
		4.2	ovjesi kolničkog nosača	montaža ovjesa visećeg mosta	3	3	1	3	3	13	2	prihv.	provjera na ispadanje jedne zatege	dop.

Register 1 : scenarios for additionla cost estimation

3. Methodology for Cost Optimisation

Decision matrix

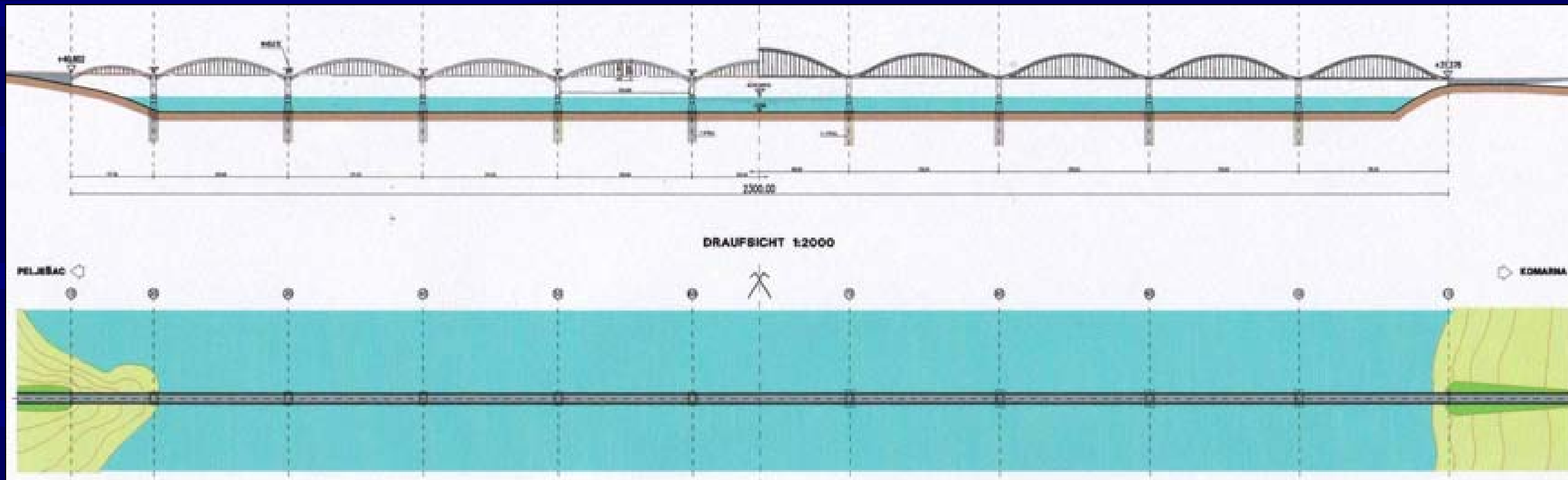
for the

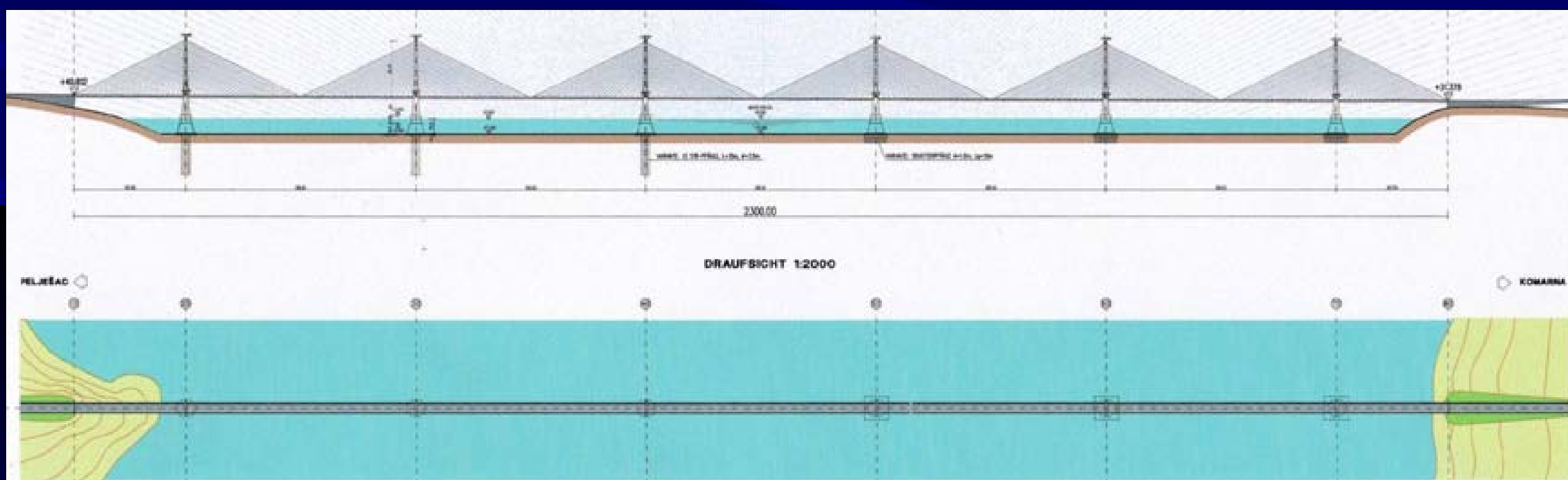
qualitative scenario evaluation

HS vs. PI	Pi = 1	Pi = 2	Pi = 3	Pi = 4	Pi = 5
0 –2.5	Neglig.	Neglig.	Neglig.	Neglig.	Accept.
2.5 – 5.0	Neglig.	Neglig.	Accept.	Accept.	Accept.
5.0 – 7.5	Neglig.	Accept.	Accept.	High	High
7.5 - 10.0	Neglig.	Accept.	Accept.	High	High
10.0 –12.5	Neglig.	Accept.	Accept.	High	Severe
12.5– 15.0	Accept.	Accept.	High	High	Severe
15.0-17.5	Accept.	Accept.	High	Severe	Severe
17.5-20.0	Accept.	High	High	Severe	Severe
20.0-22.5	Accept.	High	Severe	Severe	Severe
22.5-25.0	Accept.	High	Severe	Severe	Severe

4. Examples of Strait Crossings

Pelješac strait crossing

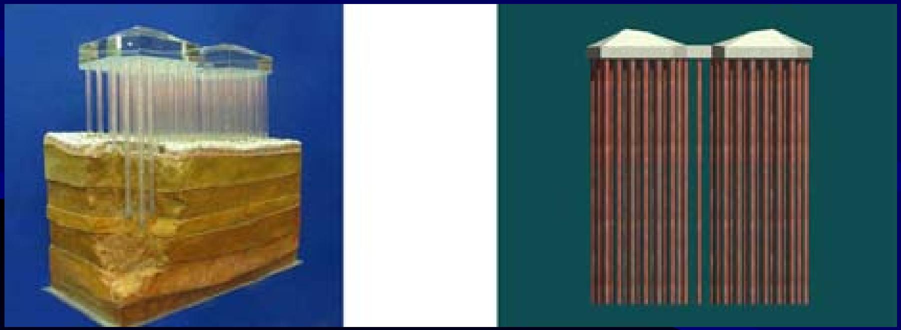


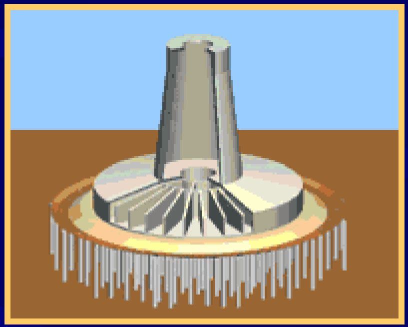


Longitudinal disposition and number of foundations/columns :
influence of structural parameters on economic feasibility of strait crossing

4. Examples of Strait Crossings

Pelješac strait crossing





- **<u>Sutong bridge, PR China</u>**

Foundation on group of 120 m deep RC bored piles

- **<u>Rion Antirion bridge,Greece</u>**

Foundation through soil improvement by steel casings

4. Examples of Strait Crossings

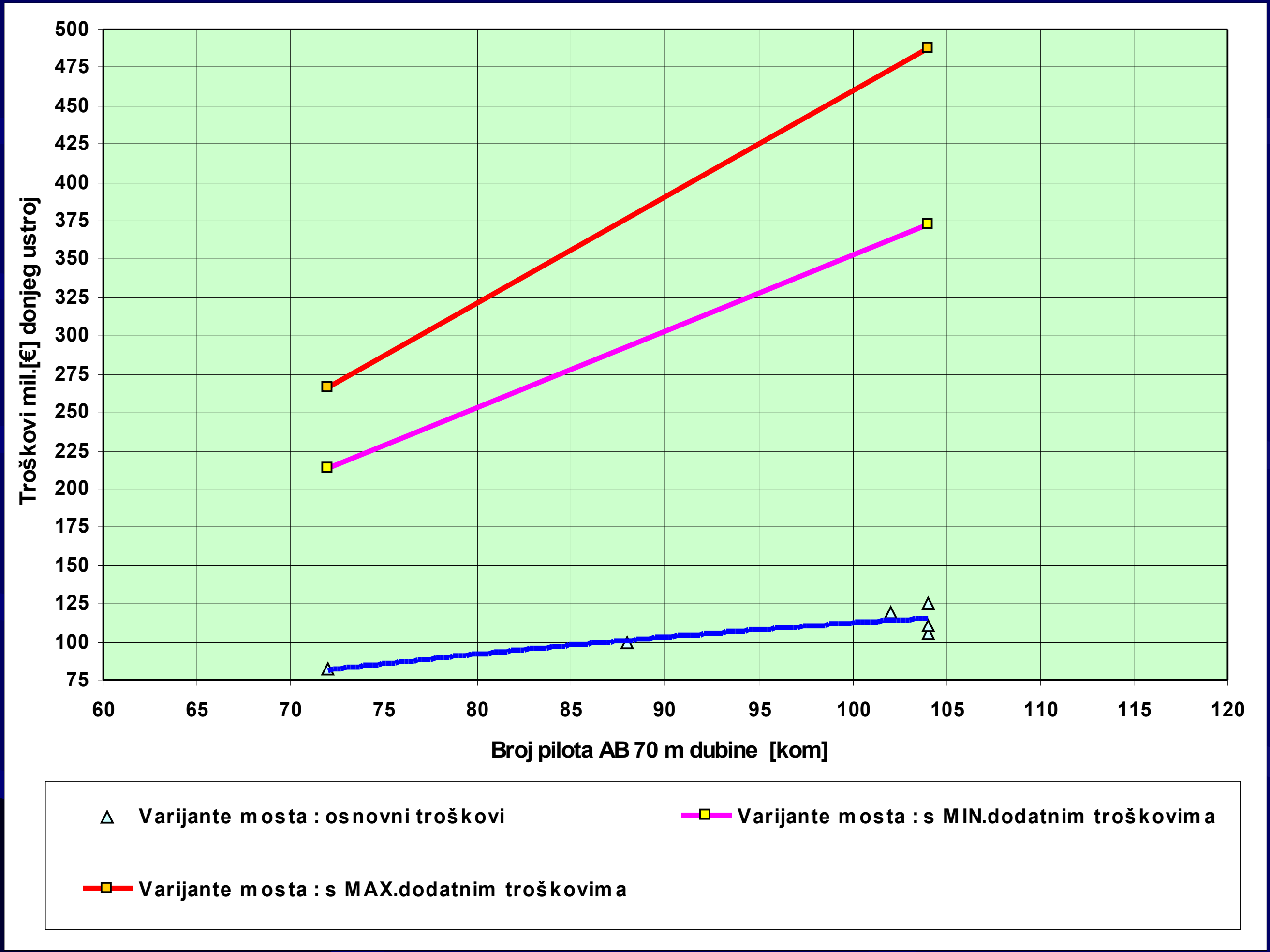
Pelješac strait crossing

costs of substructure parts

vs.

number of 70 m deep RC piles

Overall vs. Basic Costs = 2:1 to 3:1



Influence of a foundation design decision on the final cost estimation and overall project feasibility

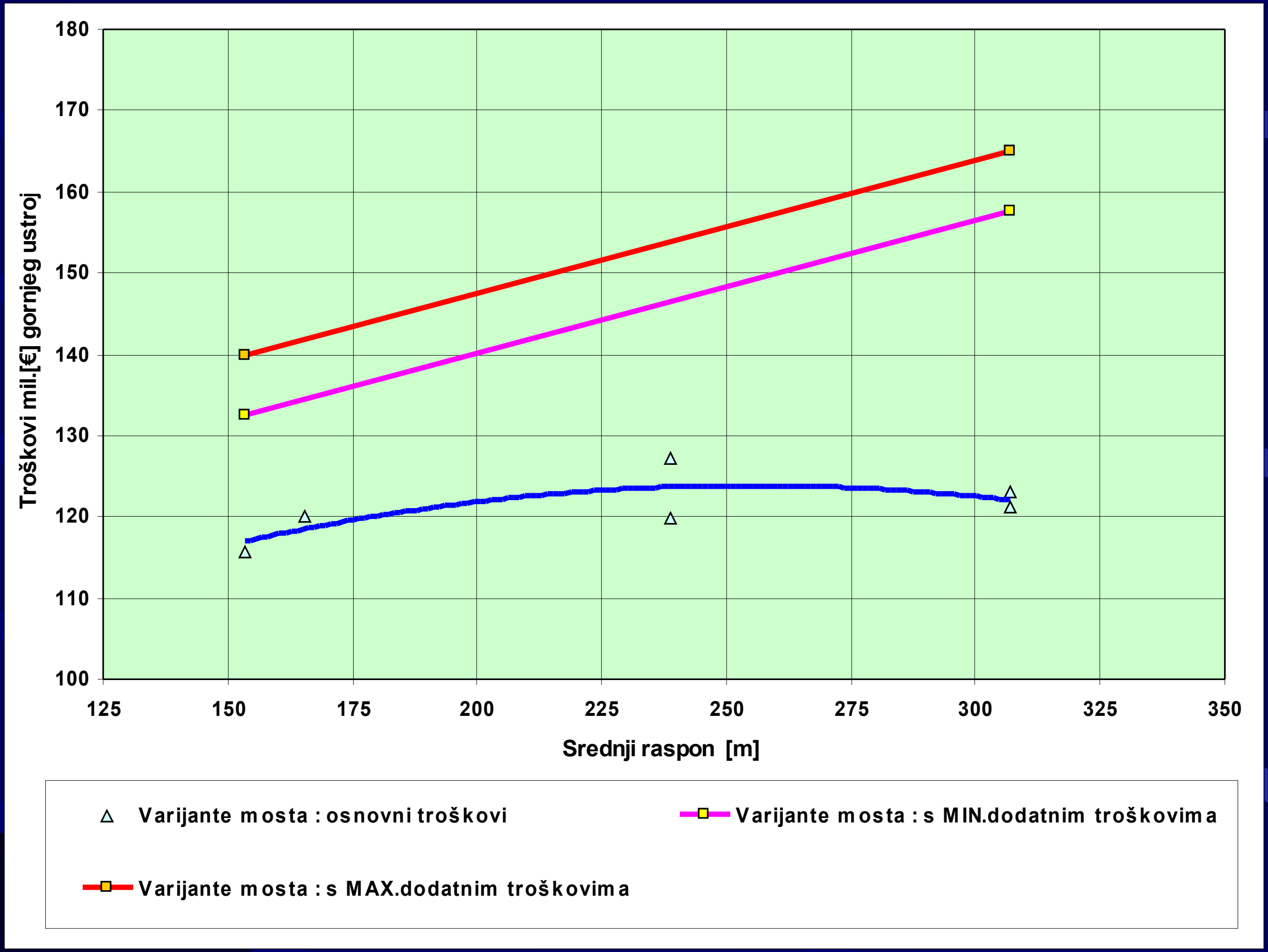
4. Examples of Strait Crossings

Pelješac strait crossing

costs of supertructure parts

vs.

medium bridge crossing span



Overall vs. Basic Costs = 1.15:1 to 1.25:1

Influence of a structural design decision on the final cost estimation and overall project feasibility

4. Examples of Strait Crossings

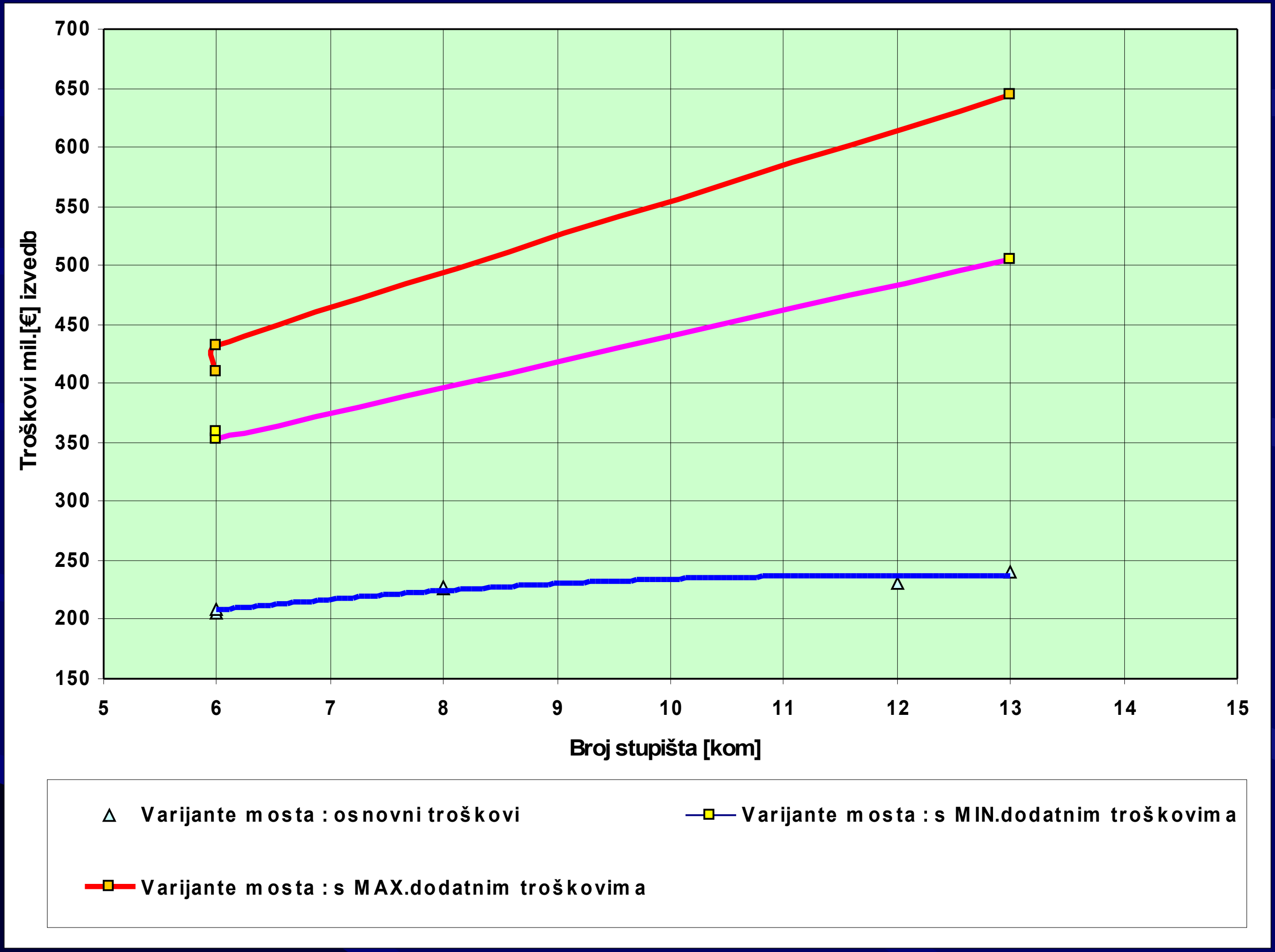
Pelješac strait crossing

overall costs of bridge construction

vs.

number of columns / foundations

Overall vs. Basic Costs = 1.75 : 1 to 2.15 : 1



Influence of a structural design decision on the final cost estimation and overall project feasibility

4. Examples of Strait Crossings

Danube crossing Vidin (BG) – Calafat (RO)

Project in development over 20 years :

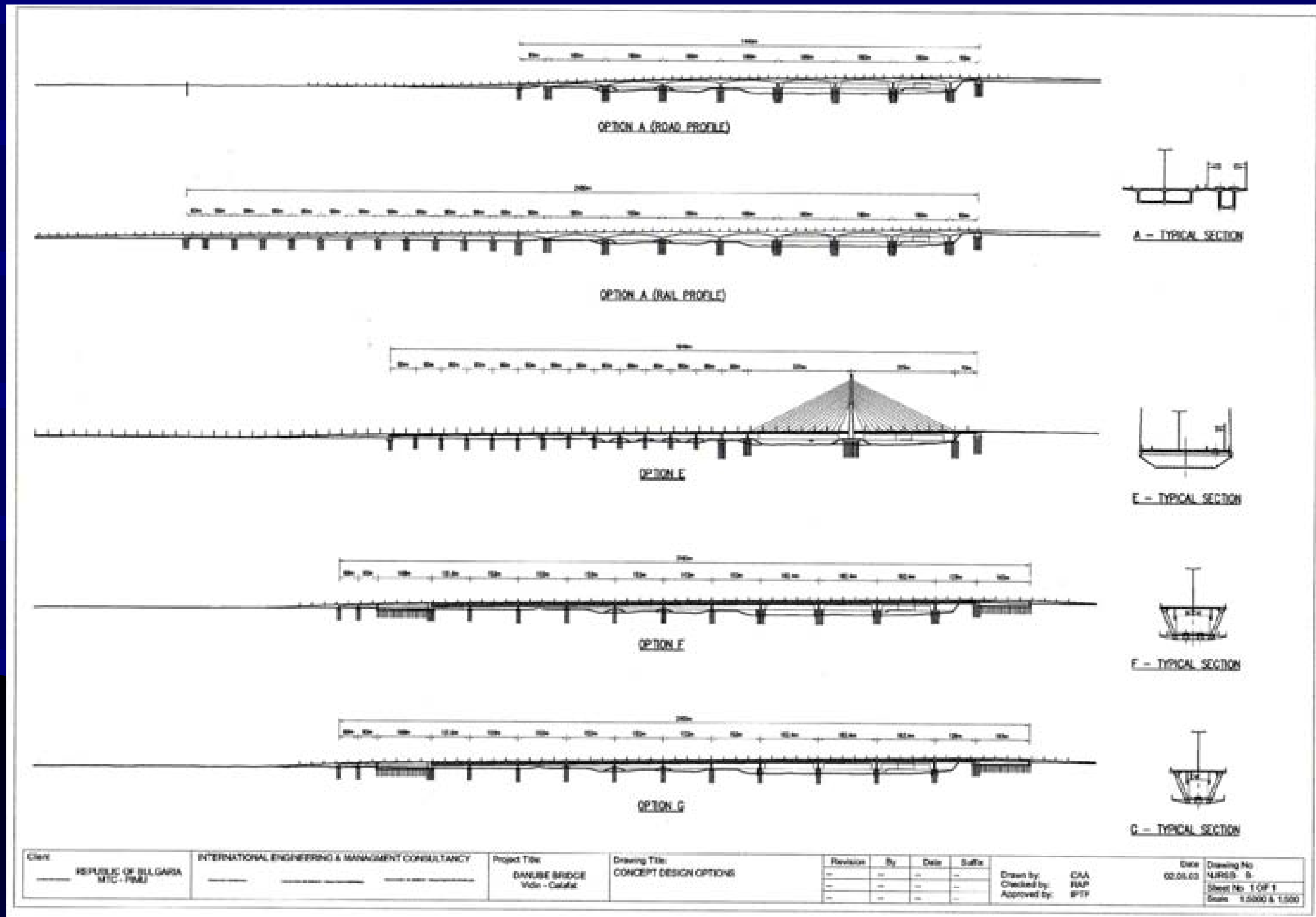
- strategical and traffic demand
- next bridge 350 km to east and 500km west

Last 10 years itensive development of technical options

Development as : design-build project,
Financing by : EU, banks , both countries
Estimated budget : 267 mill. EURo (addit.rail structures included)

4. Examples of Strait Crossings

Danube crossing Vidin (BG) – Calafat (RO)



Option "A" : continuous PC box girder as 2 parallel bridges
Road 4 lanes 1440m long, Rail 2 tracks 2480 m long, max.span 180 m

4. Examples of Strait Crossings

Danube crossing Vidin (BG) – Calafat (RO)

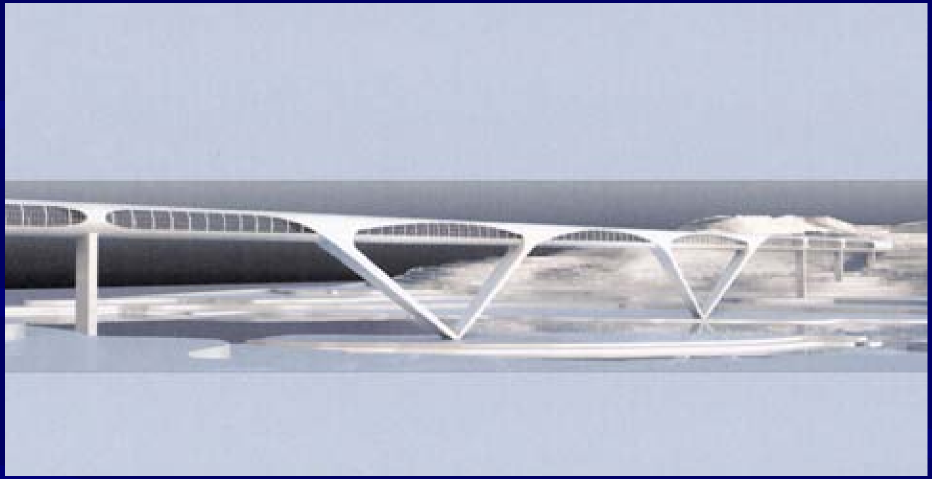
No. var.	Structure type	Max. Span [m]	No. Foundat. pcs.	Overall constr. costs [mil. €]	Unit price [€ / m²]	Sub-Structure costs [%]	Super-structurecosts [%]	Relation costs [%]
"A"	Continuous box girder Rail 2 tracksj. 2480m, width 9.75 m Road 2 lanes 1440m, width 19.75 m Fondation on piles	180 180	22 10	134.60	2558	43	57	100

No. var.	Structure type	Basic costs mil. EUR	Minimal additional costs mil. EUR	Maximal additional costs mil. EUR	Overall construction costs- MIN mil. EUR	Overall construction costs- MAX mil. EUR
„A"	Continuous box girder Rail 2 tracks. 2480m, w 9.75 m Road 2 lan.1440m,w 19.75 m Fondation on piles	134.60	19.62	33.85	154.22	168,45

Reduced cost overruns through : known type of project development, public presentation, involvement of expert consultanca for technical and economicla parts during 10 years

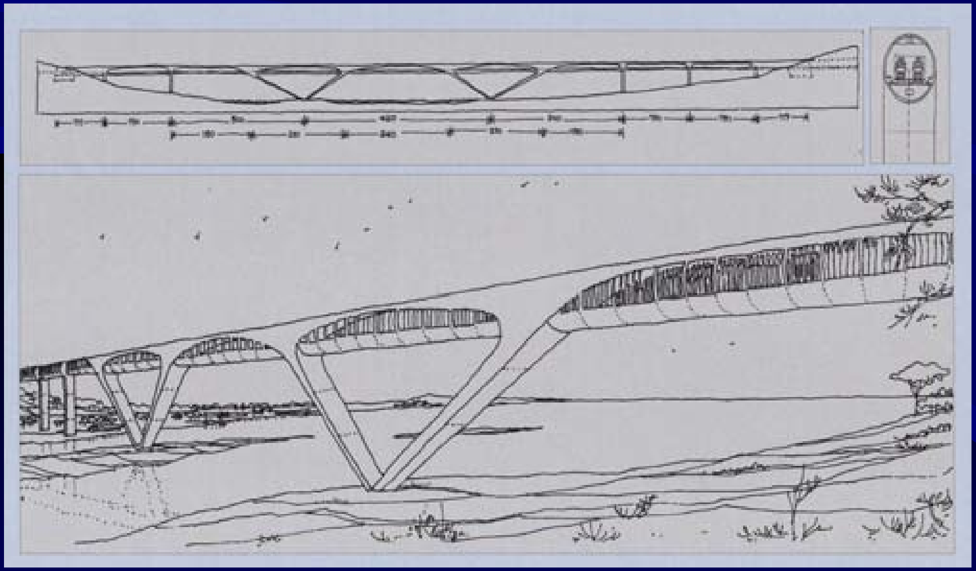
Best bid : 165 mill EURo for bridge (estimated 226 mill.EURo) ??

5. Future Structures



Ulla Bridge* design
for the new rail line in Spain

(*) design by
H.Corres Peiretti , Madrid



Substructure :

similar on high-speed rail lines in Germany on line Hannover-Wuerzburg (LAP)

Superstructure :

- tube cross section (stat .+ dynam.)
- for urban areas (noise)
- for strait crossings

5. Future Structures

Strait crossing Hong Kong –Macao , 32 km long over Pearl River estuary
Shipping channel over 1.4 km immersed tube with 2 artificial islands

6. Conclusions

- **Strait crossing solutions are based on location conditions and traffic requirements**
- Structural feasibility through simple and sound structural design solutions
- Economical feasibility through public evaluation of project demand and use