Neuron Zagreb doo

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Optimization of Bridges for Big Crossings

5th CCC

Baden ,
September 25,2009

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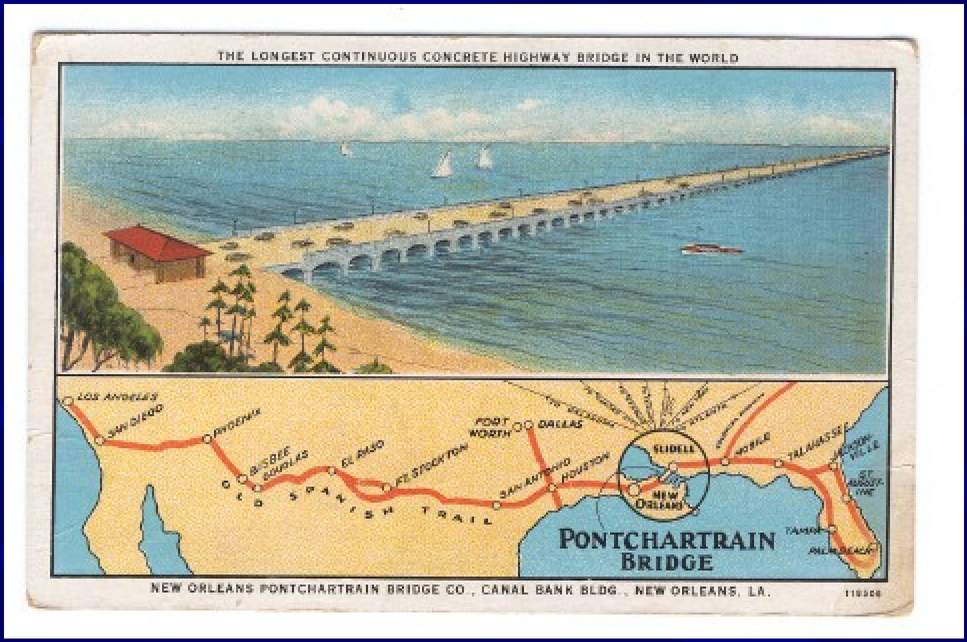
1. Introduction



Lake Pontchartrain Causeway Bridge

over lake near New Orleansa, USA

Length 38 km, with 4 lanes on 2 parallel bridges, pile foundation 6 m long, in construction 1955/56 i 1967/69

Traffic development: 3000 veh./day (1956)

3000 veh. / ho (1990)

Need for a big crossing :

- Traffic requirements
- Strategical reasons
- Economical reasons

Structural types :

- 1 bridge type in a row
- system of bridges
- hybrid type with bridges, tunnels and islands

1. Introduction

Red. br.	Ime prijelaza	objekt	Država	Duljina (km)	Godina Izvedbe
1	Lake Pontchartrain Causeway	most	SAD	38,422	1969
2	Hangzhou Bay Bridge	most	NR Kina	35,673	2008
3	Runyang Bridge	most	NR Kina	35,660	2005
4	Donghai (East China Sea Bridge)	most	NR Kina	32,500	2005
5	Cheasepeake Bay Bridge	most/tunel	SAD	24,140	1952/1973
6	King Fahd Causeway	most	Bahrain/S.Arabija	25,000	1986
7	Great Belt	most / tunel	Danska	21,401	1998
8	Vasco da Gama Lisabon	most	Portugal	17,185	1998
9	Oeresund	most / tunel	Danska/Švedska	16,380	2000
10	Penang 1st Bridge, Seberang Prai	most	Malezija	13,500	1985

Longest bridge crossings : one bridge type, bridge system or hybrid crossings bridge-island-tunnel.

1. Introduction

Red. br.	Ime prijelaza	objekt	Država	Duljina (km)	Godina Izvedbe
1	Penang 2nd Bridge	most	Malezija	24,000	u gradnji
2	Qingdao Haiway Jiazhou Bay Crossing	most	NR Kina	28,000	u gradnji
3	Qiong Zhou Strait Crossing	most/tunel	NR Kina	32,000	u planu
4	Pearl River Strait Crossing	most/tunnel	NR Kina	32,000	u planu
5	Rio de la Plata	most	Argent. / Urugvaj	42,000	u pripremi
6	Qatar –Bahrein Causeway	most	Katar/Bahrein	45,000	u pripremi
7	Gulf of Thailand Bridge, Bangkok SW	most	Tajland	47,000	u pripremi
8	Berring Strait	most	Rusija / SAD	80,000	u razmatr.
9	Bo Hai Bay Crossing	most	NR Kina	108,000	u planu
10	Taiwan	most	NR Kina/Taiwan	125-207,000	u planu

Longest planned bridge crossings as : bridge systems or hybrid bridge-island-tunnel type.

1. Introduction

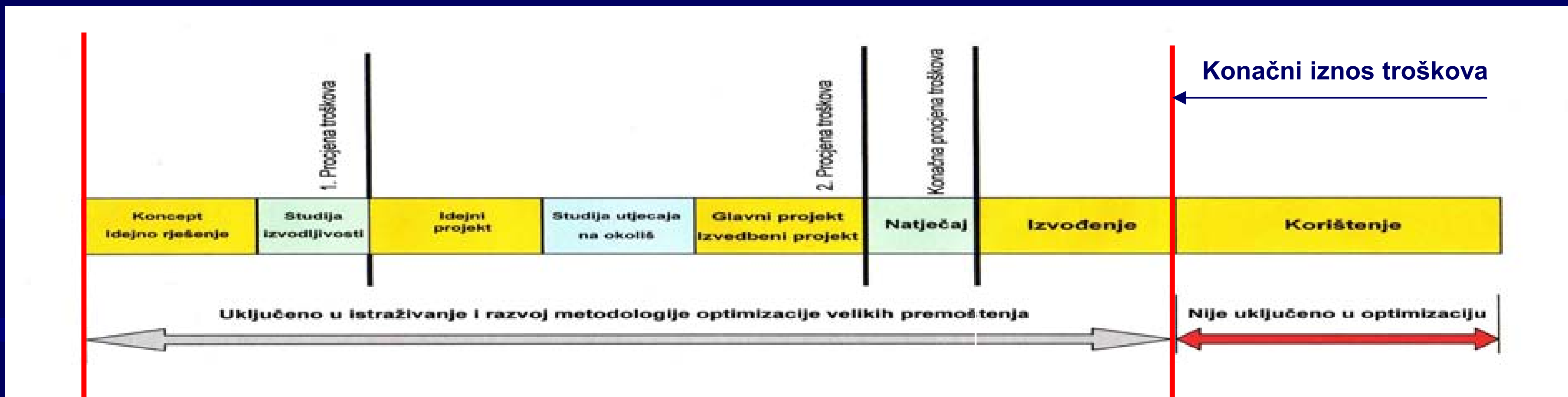
Hangzhou Bay Bridge 35.6 km

Qatar-Bahrain Causeway 45 km

2. Limits of „feasible span lenghts“

The need for optimization of big bride crossing

Project phases included in optimization :



Estimation of possible cost overrun 10-25 % | 10-200 %

Used project budget 2 - 10 % | 90-98 %

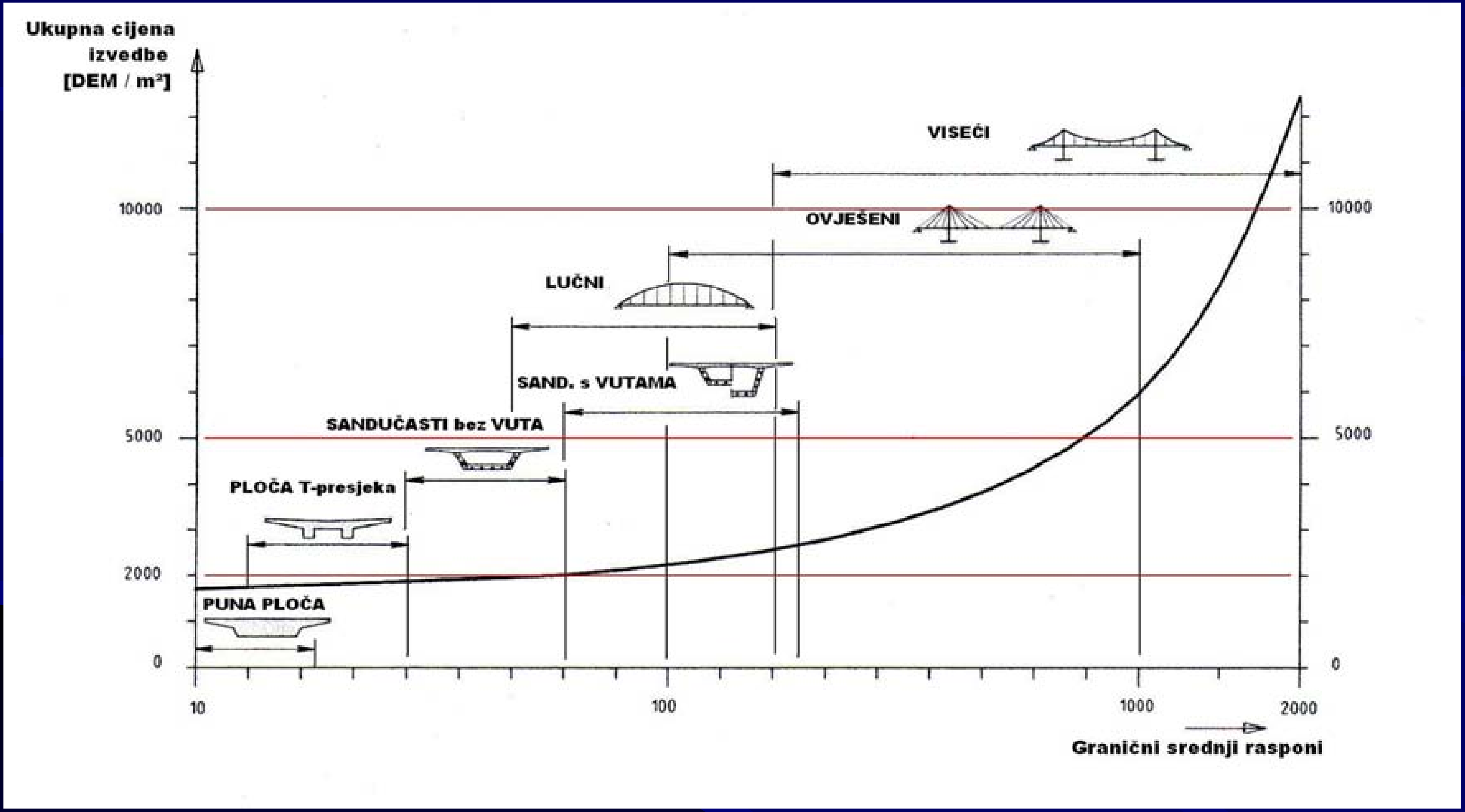
Criterium for the most feasible solution :

* economical feasibility (lowest price)

At the end of construction => required budget size is known (planned budget + unexpected costs)

2. Limits of „feasible span lenghts“

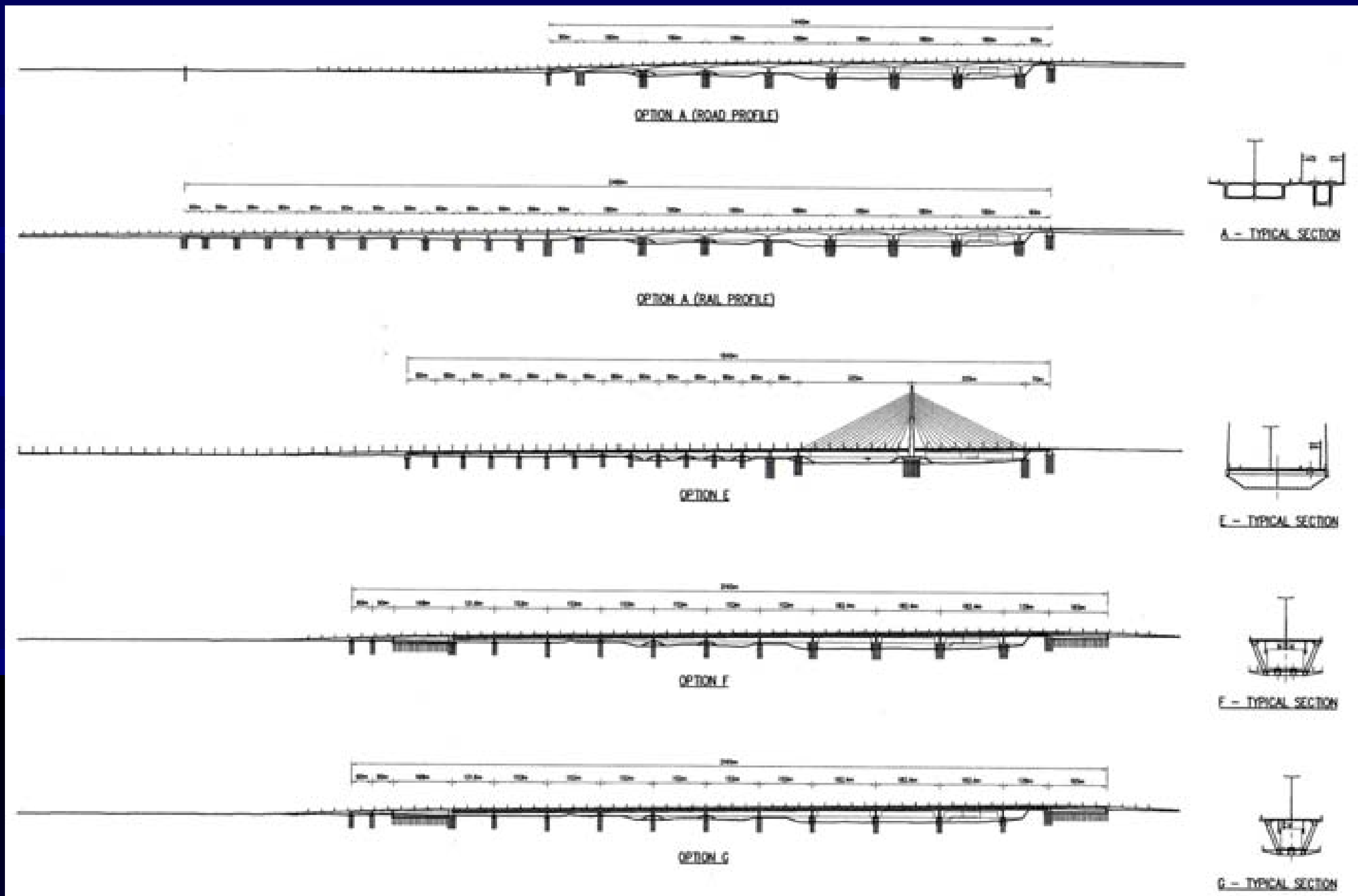
Saul R. (2003) : “Aesthetics vs. Economics...”, Barcelona



Distribution of limits of feasible span lenghts for different bridge types according to construction price on traffic surface unit.

2. Limits of „feasible span lenghts“

big crossings less than 2000 m



2. Bridge over Danube Vidin (Bg) – Calafat (Ro)

L = rail 2480 m / road bridge 1440 m, Dunube width 1300m, 2 rail and 4 road lanes, in construction

Lenghts L < 2000 m :

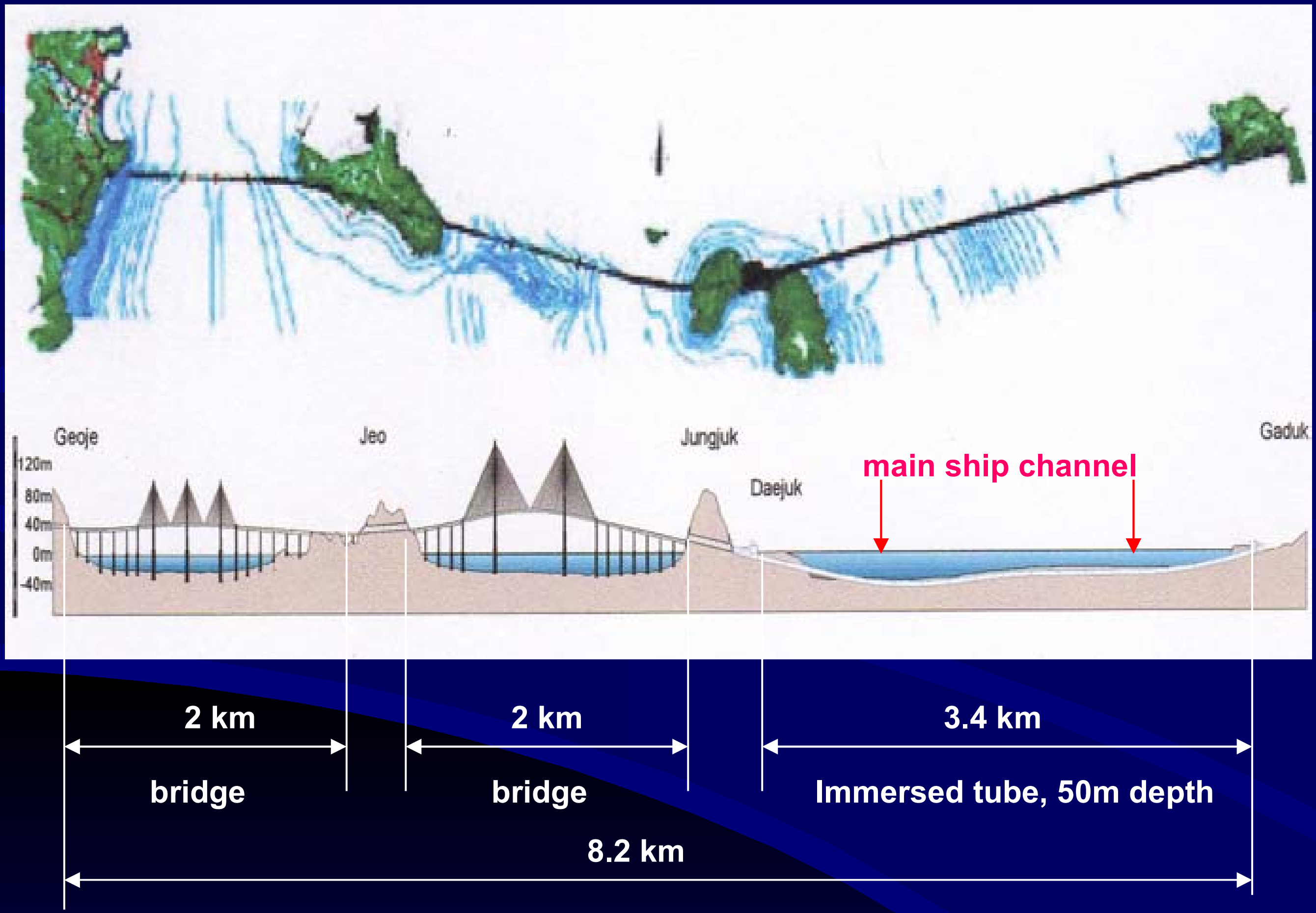
- bridges
- Immersed tubes

Decision on structure type:

* Ship channel
* Geological conditions
* Weather condition
* Vicinty of towns

2. Limits of „feasible span lenghts“

big crossings from 2000 – 10 000 m



Bridge Pusan – island Geoje (S.Korea)

L = 8.2 km, 4 road lanes

Wind up to 288km/h, earthquake, sea depth 50 m

Lenghts L = 2–10 000 m :

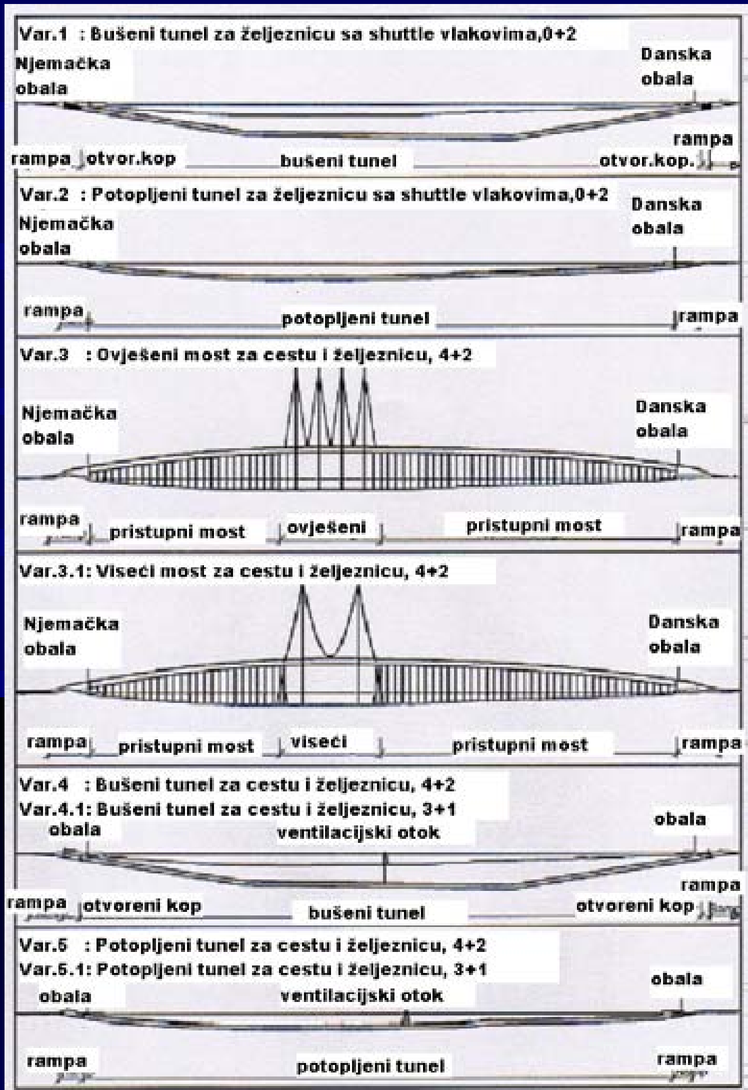
- bridges
- Immersed tubes
- Bored tunnels
- Kombinations

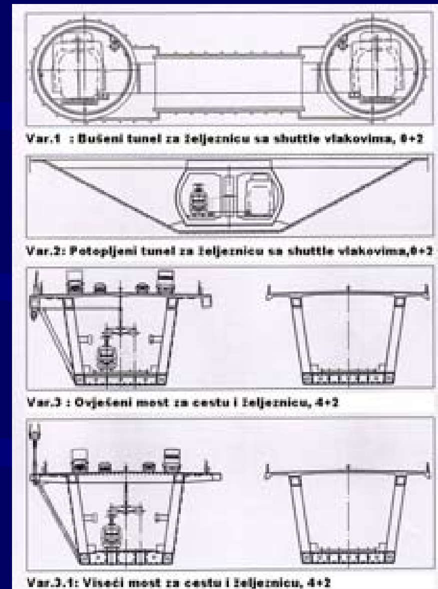
Decision on structure type:

* Ship channel
* Traffic requirements
* Geologic conditions
* Weather conditions
* Location specialities

2. Limits of „feasible span lenghts“

big crossings longer than 10 000 m





Fehmarnbelt

(Danska–Njemačka)

L = 19 km

4 road lanes

2 rail lanes,

wind, sea depth 30 m, to be constructed

Lenghts L > 10 000 m :

- bridges
- Immersed tubes
- combinations

(No immersed tubes €!)

Decision on structure type: :

* Ship channel
* Traffic requirements
* Geologic conditions
* Weather conditions
* Location specialities

* Addit. structures (€!)

3. Bridge systems for big crossings

Freasible bridge types for optimal big crossing :

- Arch wit hbox section in steel and concrete
- Continuous box girders in steel and presstressed concrete
- Suspension bridges in steel (composite)
- Cable stayed bridges
  (steel, concrete, composite, combinations)

Su Tong (Kina), over river Yangtze

L = 8.15 km, L_{cbs}.= 2088 m, L_{mid}= 1088 m

6 road lines, piles 120 m deep

Most often bridge combination for big crossing : CBS + continuous girder.

3. Bridge systems for big crossings

Comparison :

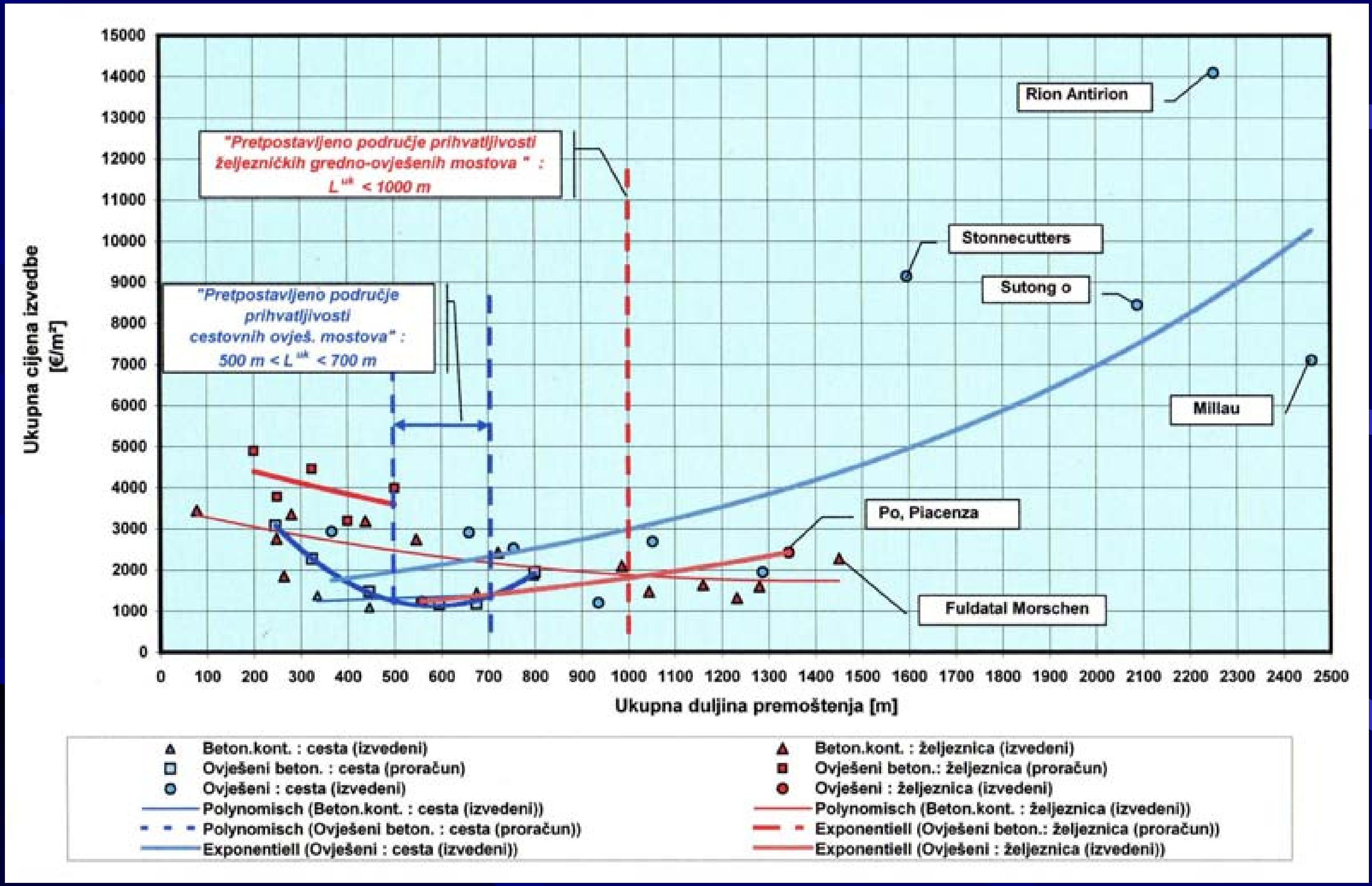
Cont.girder and

cable stayed
bridge up
to 2500 m

For loading :

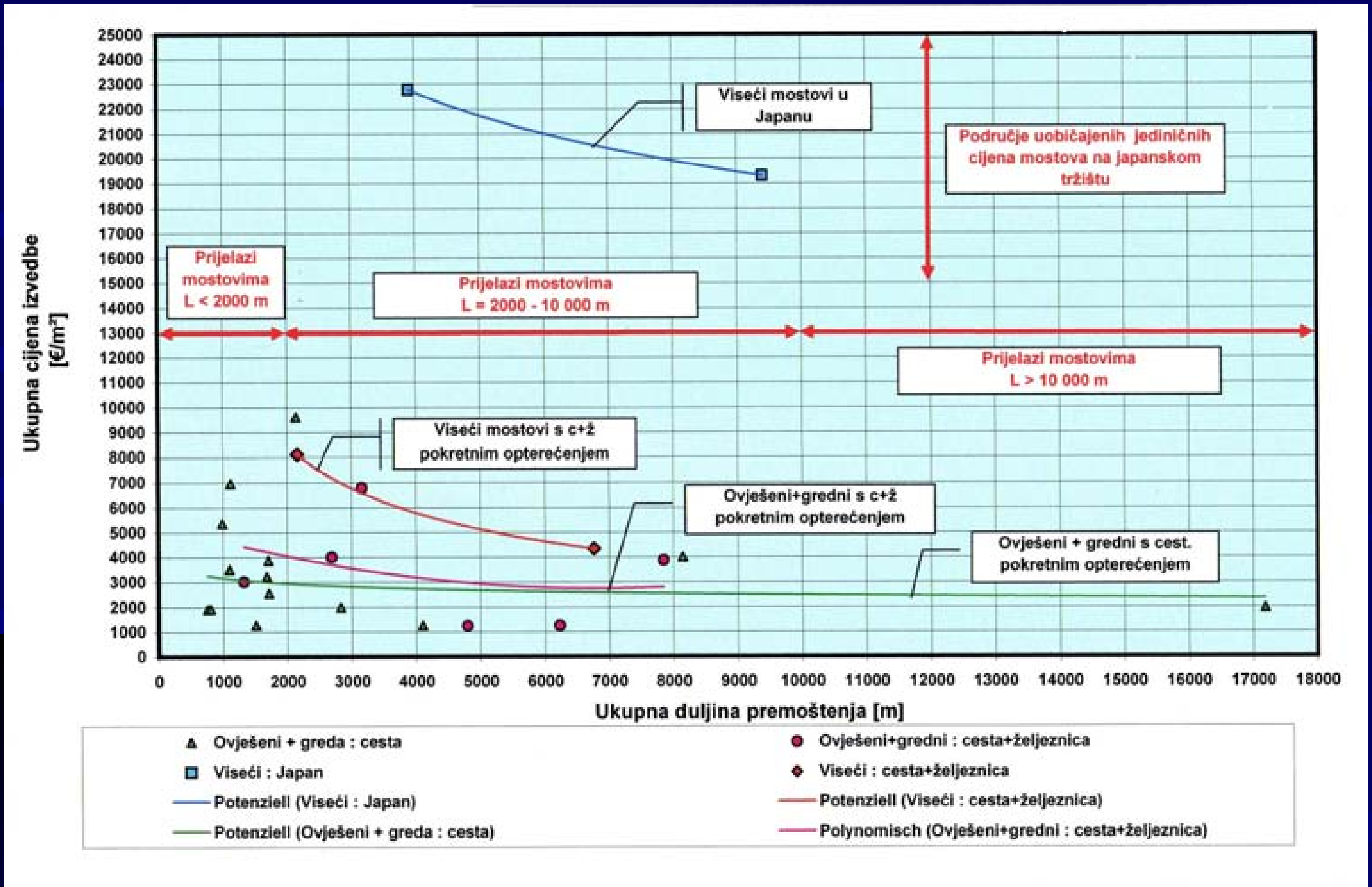
* road

* rail



Relation : overall crossing length vs. unit construction price.

3. Bridge systems for big crossings



Relation of overall crossing lengths and unit construction price.

Comparison :

Suspension bridges

and

CBS + cont.girders

up to 18 000 m

For loading :

* road

* road + rail

3. Bridge systems for big crossings

Unsure feasible studies :

- problem of „unhonest numbers“
- rough analyses
- possibility to manipulate

Intentions :

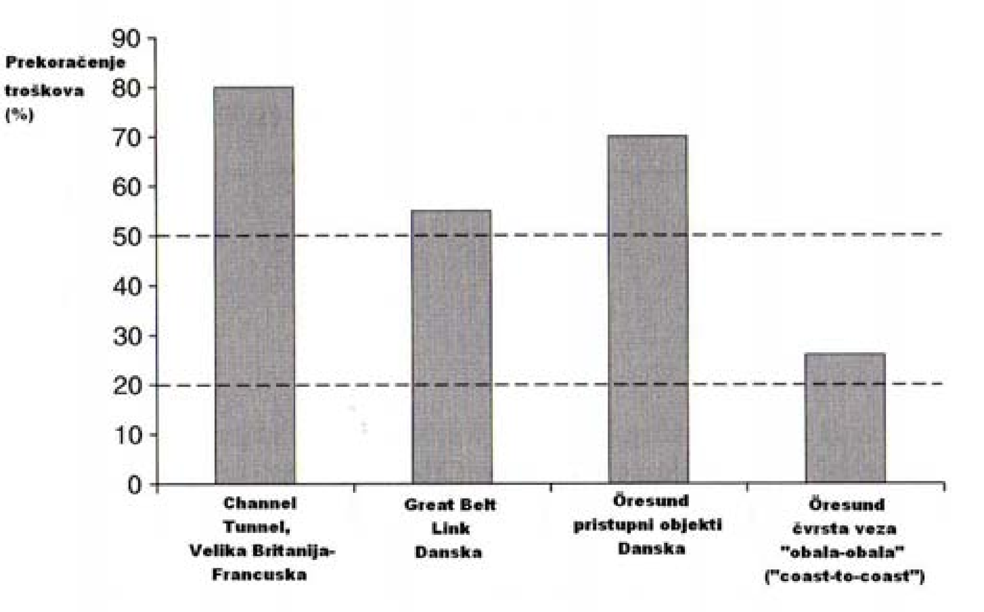
- make project more attractive
- animate investors
- start with construction asap

Results :

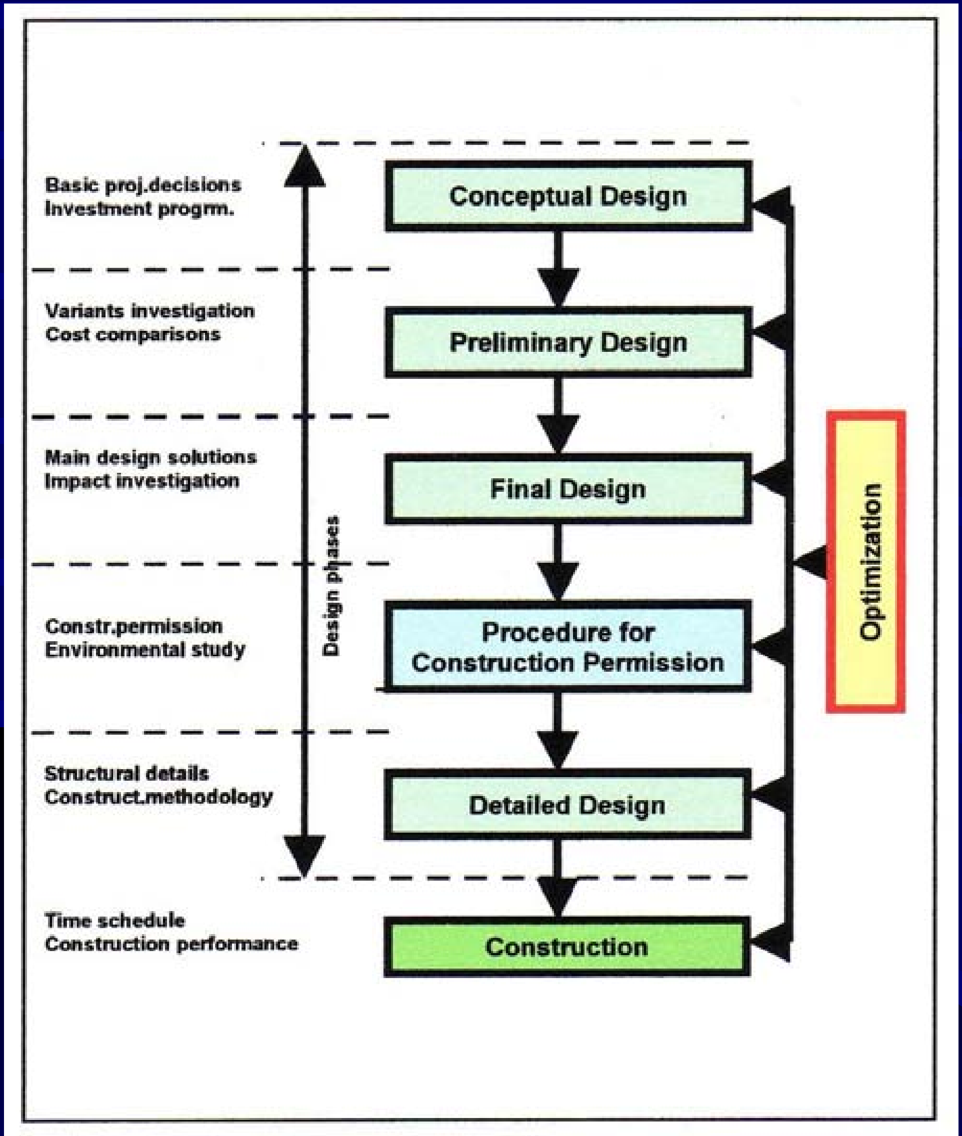
- phenomena of massive budget cost - overruns

Project budget overruns during construction in traffic infrastructure :

- steady phenomena in last 100 years
- overruns up to 250 %



4. Optimization method



Method development :

- Considering project development phases
- Optimization during all phases

Optimization method following :

Design phase :
Empirical knowledge + numerical analysis

Cost calcualtion :
Empirical knowledge + costs, numerical

Construction :
Empirical knowledge + cost control, numerical evaluation

4. Optimization method

Modul F A U S T

Optimization module :

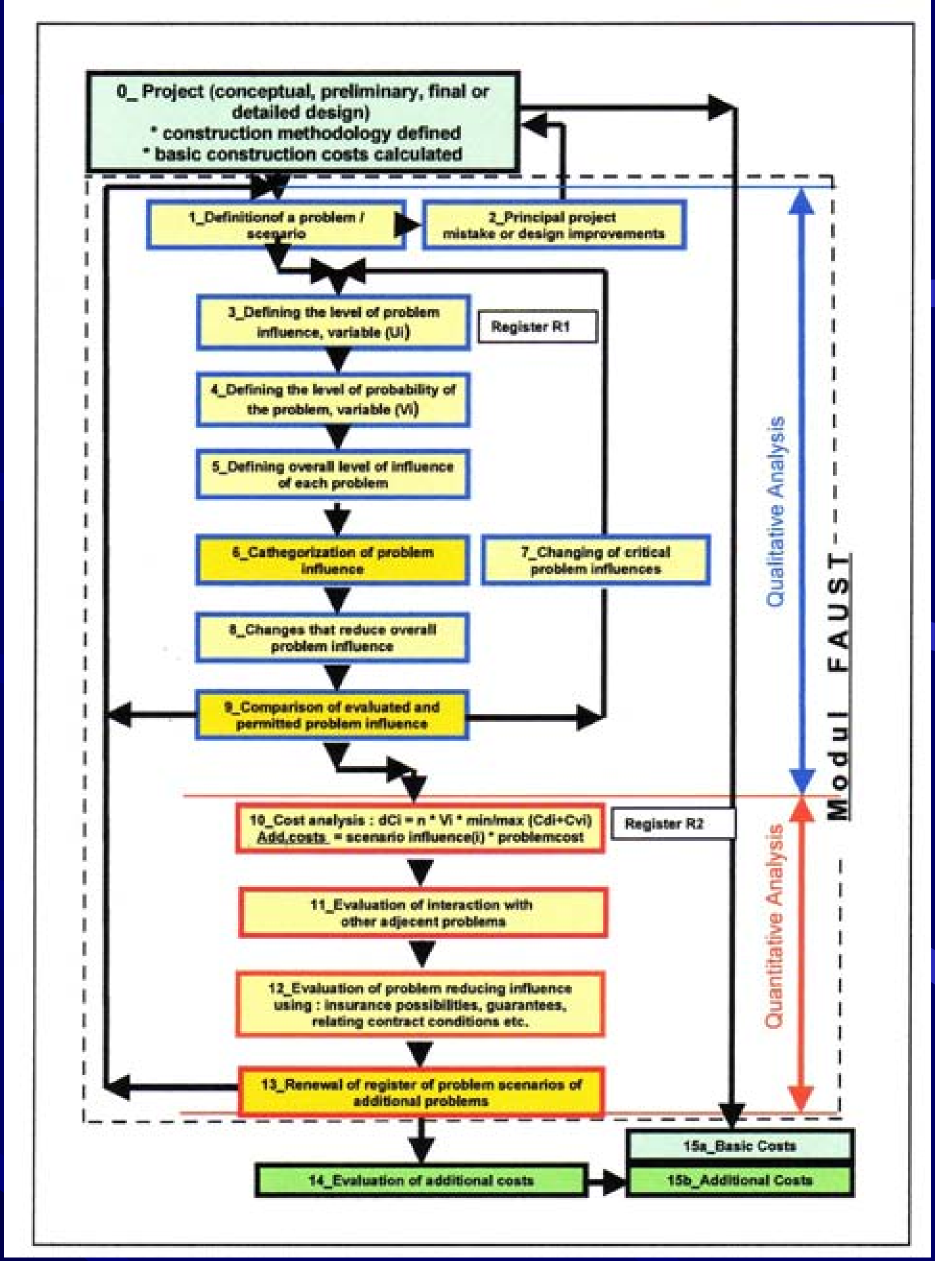
Multicriterial analysis wit hqualitative and quantitative part

Qualitative analysis :

Method PPA („Potential-Problem-Analysis“) ebvaluation of negative scenarios of unexpected happenings

Quantitative analysis :

Numerical cost analysis of values of negative scenarios of unexpected happenings



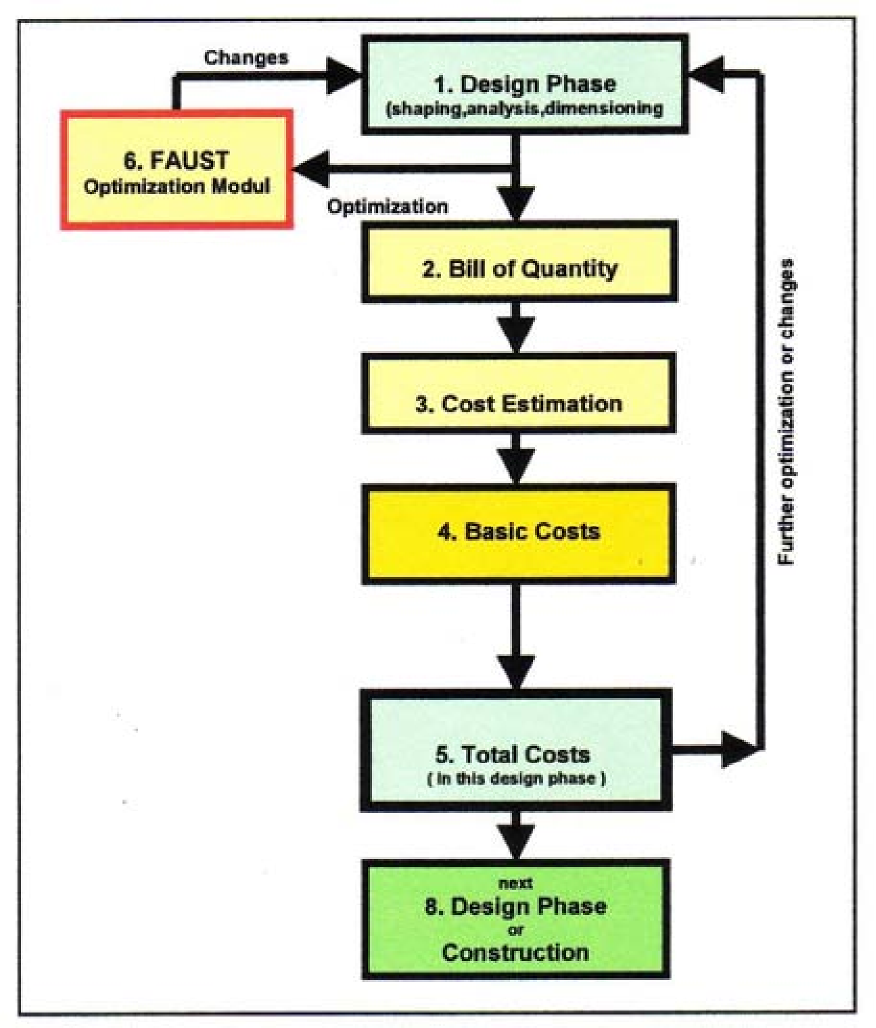
4. Optimization method

Qualitative Analysis

1. Design phase :
- Basic solution
- Overview of dimensions and structural solutions
- Comparison with results of NA and other similar projects
- Changes, improvements

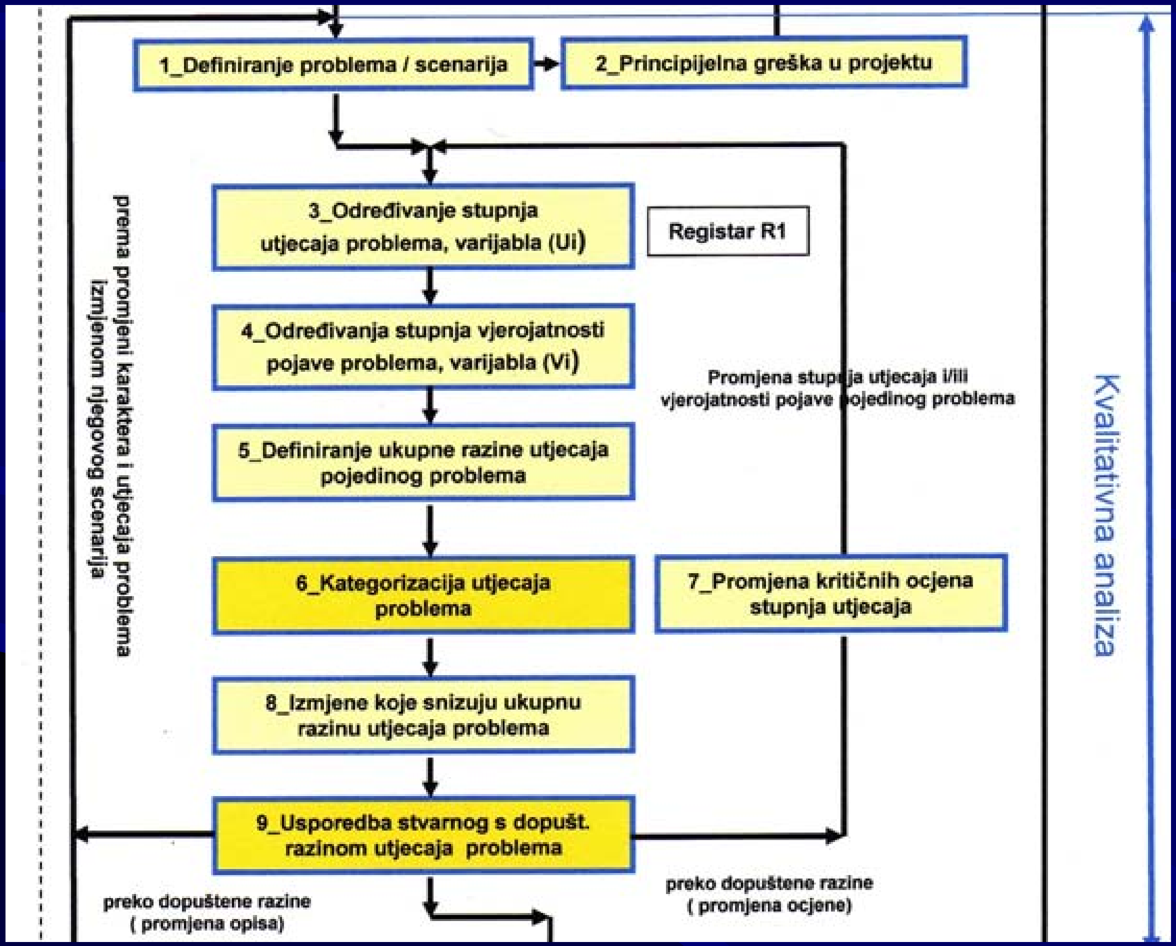
6. Optimization
- What is missing ?
- Negative scenarios of unexpected items
- Evaluation of negative scenario
- Decision on change

1. Design phase :
- change of structural detail
- improvements and additions



4. Optimization method

Qualitative Analysis – Register R1



4. Optimization method

Qualitative Analysis – Register R1

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 zaštitinih 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.

4. Optimization method

Qualitative Analysis

Cathegorization matrix

Ui	Vi = 1	Vi = 2	Vi = 3	Vi = 4	Vi = 5
0 – 2.5	zanemarivo	zanemarivo	zanemarivo	zanemarivo	prihvatljivo
2.5 – 5.0	zanemarivo	zanemarivo	zanemarivo	prihvatljivo	prihvatljivo
5.0 – 7.5	zanemarivo	zanemarivo	prihvatljivo	prihvatljivo	ozbiljno
7.5 – 10.0	zanemarivo	prihvatljivo	prihvatljivo	ozbiljno	ozbiljno
10.0 – 12.5	zanemarivo	prihvatljivo	prihvatljivo	ozbiljno	kritično
12.5 – 15.0	prihvatljivo	prihvatljivo	ozbiljno	ozbiljno	kritično
15.0 – 17.5	prihvatljivo	prihvatljivo	ozbiljno	kritično	kritično
17.5 – 20.0	prihvatljivo	ozbiljno	ozbiljno	kritično	kritično
20.0 – 22.5	prihvatljivo	ozbiljno	kritično	kritično	kritično
22.5 – 25.0	ozbiljno	ozbiljno	kritično	kritično	kritično

Levels of influence and required action

Rang	Opis	Opis potrebne aktivnosti na rješavanju problema
I	zanemprivo	bez dodatnih aktivnosti , nastaviti s procjenom i izvedbom
II	prihvatljivo	provjeriti da li su moguće promjene u projeku i izvedbi, nastaviti s procjenom i izvedbom
III	ozbiljno	potreba za varijantnim projektnim i izvedbenim rješenjima, poduzeti mjere za smanjenjem utjecaja u projektiranju i izvedbi
IV	kritično	potreba za varijantnim projektnim i izvedbenim rješenjima, obustavljanje aktivnosti u projektu i izvedbi do primjene novog rješenja

4. Optimization method

Quantitative Analysis

Numerical evaluation of negative scenarios in economical way :

Evaluation of still-stands and costs that are caused

(based on the still–stand duration) :

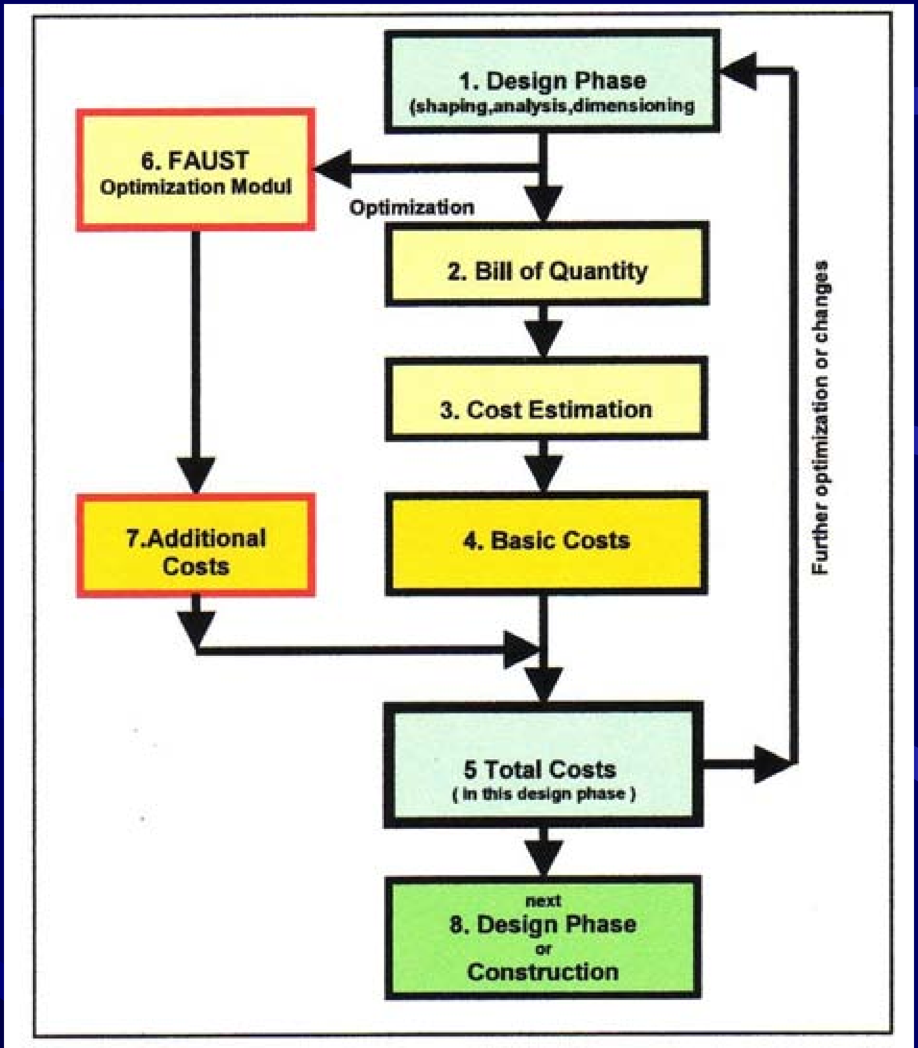
$$U_i = V_i * P_i * C_i$$

"U_i" – overall cost

"V_i" - possibility

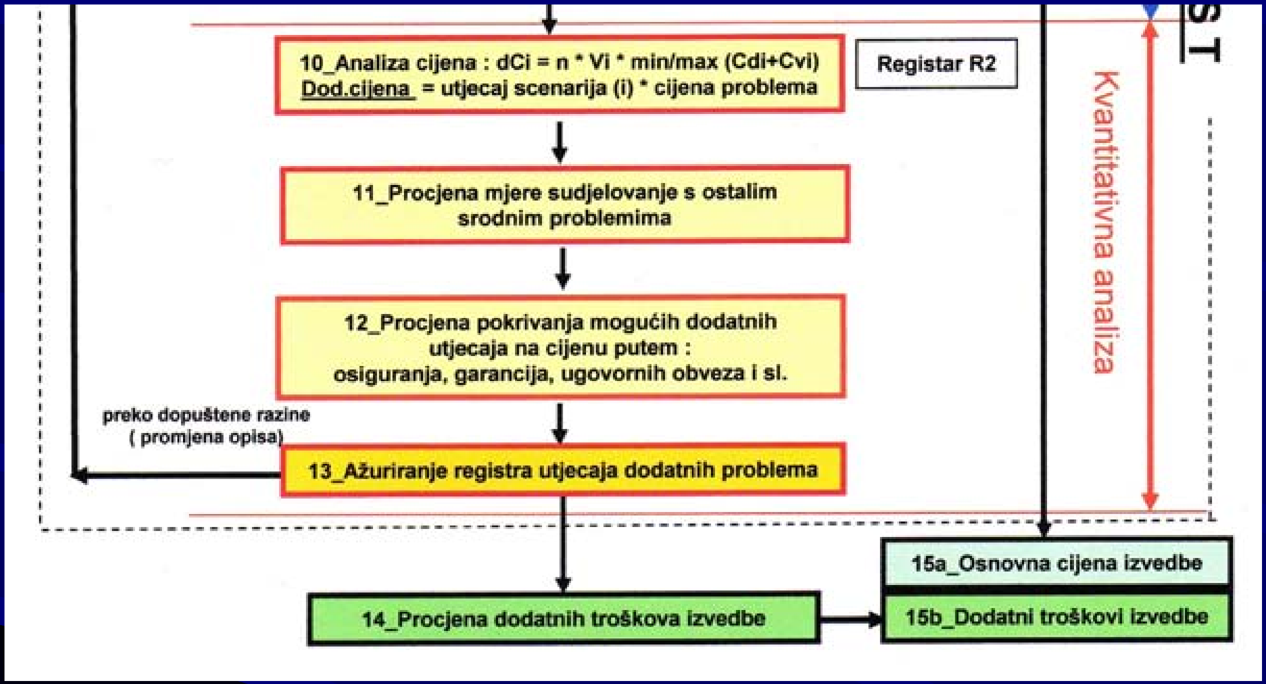
"P_i" - influence

"C_i" – cost of a scenario



4. Optimization method

Quantitative Analysis



$$dC_i = n * V_i * \min/\max (Cd_i + Cv_i)$$

4. Optimization method

Quantitative Analysis

Registar scenarija _2

Kvantitativna analiza

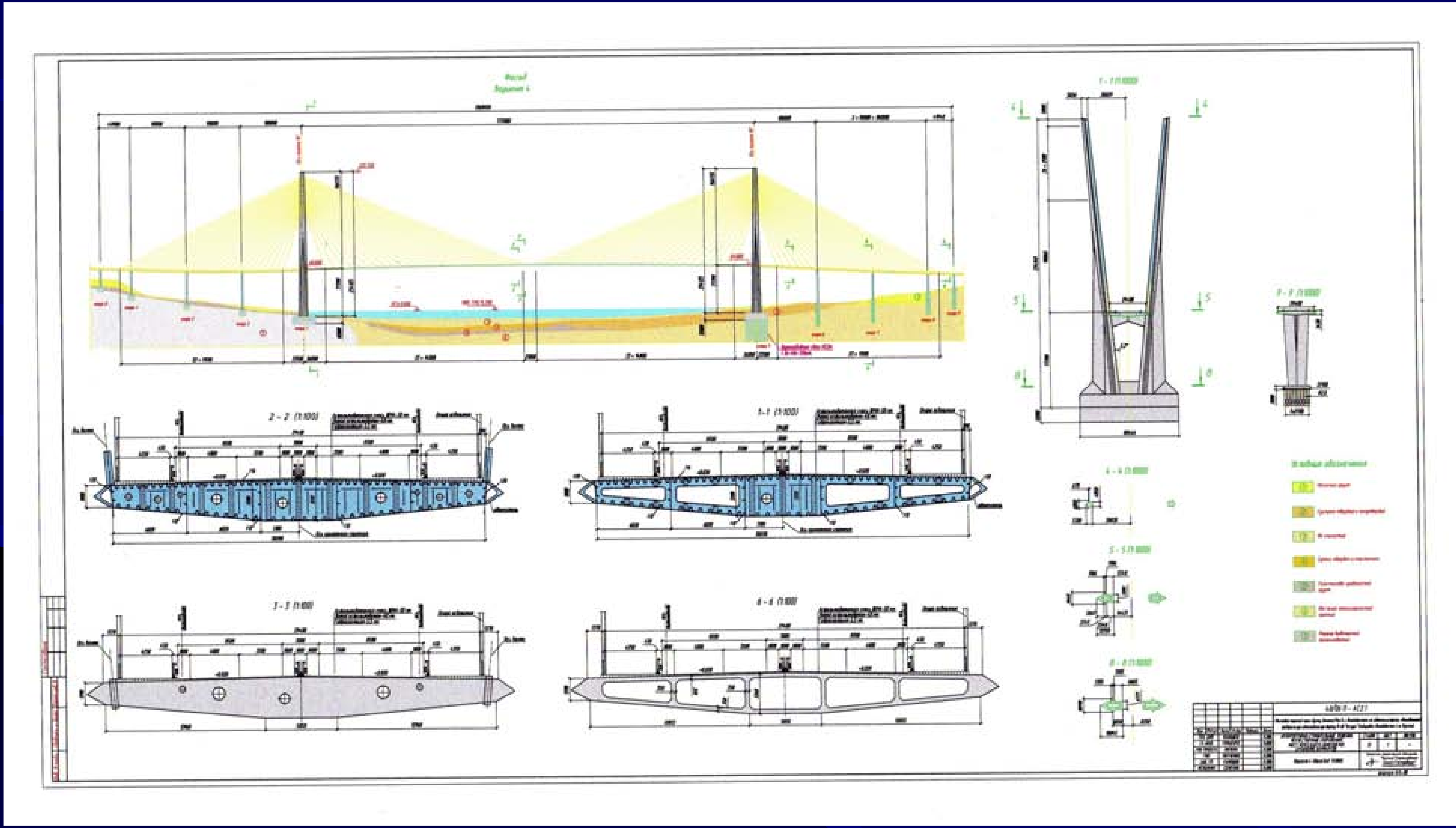
br.	PODRUČJA		Potpodručja	Br.poj. na L mosta (-)	Direktni troškovi min (-) / max (+) €	Vremenski zastoj od-(dne).	-do (dne)	Zastoj od 1 rd (€ / rd)	Vremenski ovisni troškovi od-(€)	-do(€)	Vjerojatnost pojave	Ukupno troškovi od-(€)	-do(€)
1	2	3	4	5	6	7	8	9	10=9*7	11=9*8	12	13=5*12*(6+10)	14=5*12*(6+11)
1	Uvjeti lokaliteta	1.1	priključak na post. prometnice	1	35.000,00	1,00	14,00	3.500,00	3.500	49.000	0,01	385,00	840,00
		1.2	dubina na plov. puta ispod mosta	1	150.000,00	7,00	30,00	15.000,00	105.000	450.000	0,01	2.550,00	6.000,00
		1.3	udar plovila u stup mosta	12	125.000,00	7,00	30,00	15.000,00	105.000	450.000	0,10	276.000,00	690.000,00
		1.4	vjetar	1	200.000,00	1,00	30,00	7.500,00	7.500	225.000	1,00	207.500,00	425.000,00
		1.5	potres	1	350.000,00	1,00	90,00	7.500,00	7.500	675.000	0,10	35.750,00	102.500,00
2	Geološki uvjeti	2.1	meki slojevi	2	25.000,00	1,00	90,00	12.500,00	12.500	1.125.000	0,010	750,00	23.000,00
		2.2	podzemne vode	0	25.000,00	1,00	90,00	12.500,00	12.500	1.125.000	0,001	0,00	0,00
		2.3	rasjedi temeljnog tla	0	35.000,00	1,00	90,00	10.000,00	10.000	900.000	0,001	0,00	0,00
3	Koncept konstrukcije mosta	3.1	podvodni i vanjski dio stupova	1	100.000,00	1,00	30,00	10.000,00	10.000	300.000	0,01	1.100,00	4.000,00
		3.2	oslonci	2	45.000,00	1,00	30,00	7.500,00	7.500	225.000	0,10	10.500,00	54.000,00
		3.3	poprečni presjek	1	34.000,00	1,00	45,00	7.500,00	7.500	337.500	0,01	415,00	3.715,00
4	Tehnologija izvedbe	4.1	klizna oplata stupova	2	26.000,00	1,00	30,00	7.500,00	7.500	225.000	0,10	6.700,00	50.200,00
		4.2	ovjesi kolničkog nosača	2	40.000,00	1,00	60,00	7.500,00	7.500	450.000	0,10	9.500,00	98.000,00
	Suma											551.150,00	1.457.255,00

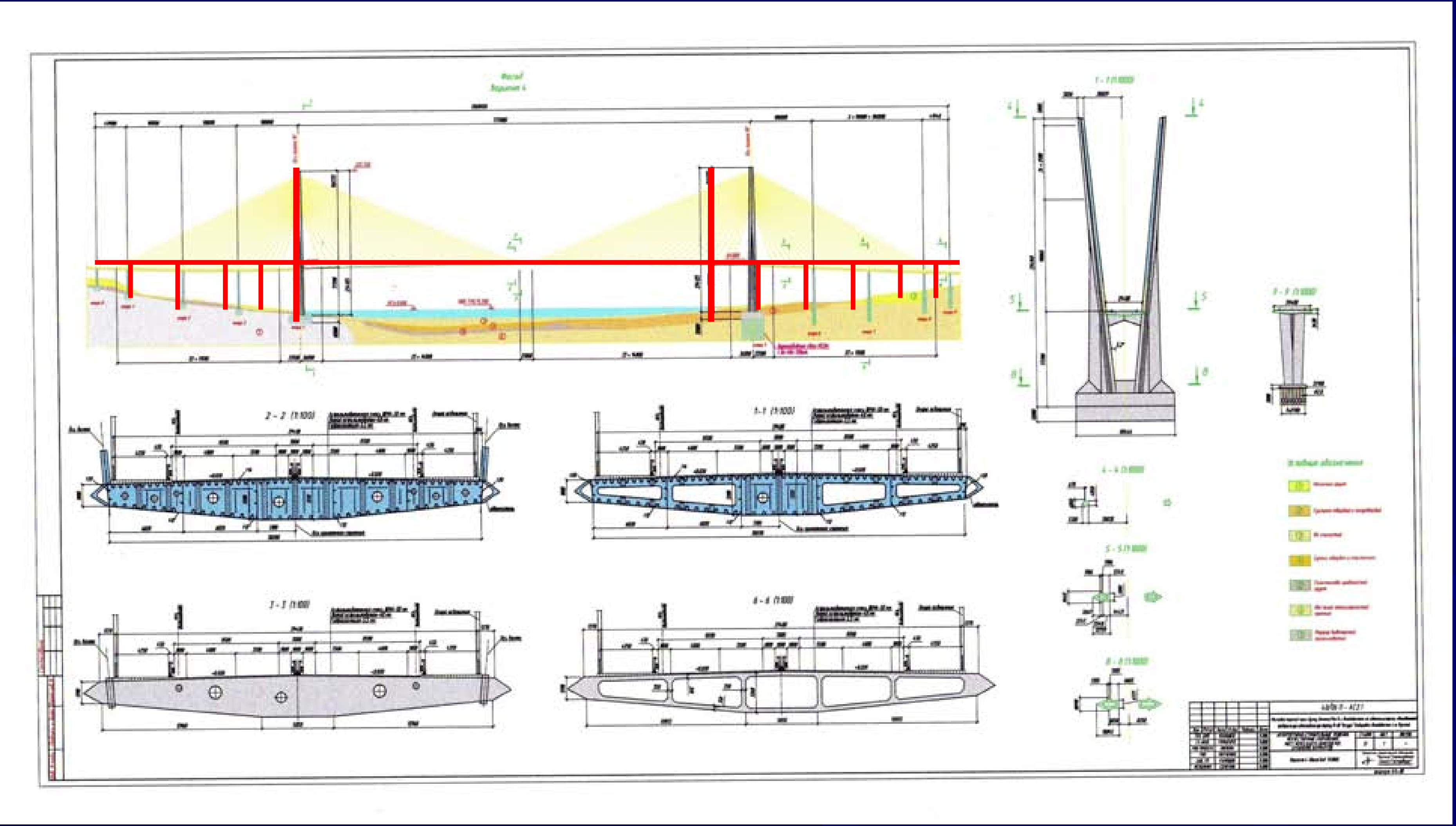
5. Example from practice

Bridge over Golden Horn in Vladivostok, L = 329,98 +737+ 321.94 = 1388.92m

5. Example from practice

Bridge over Golden Horn in Vladivostok, L = 329,98 +737+ 321.94 = 1388.92m





6. Conclusion

Cost calculation during different project development phases:

- analyses based on structural project capacity

Optimization :

- structural and economical feasibility to be evaluted
- Optimization method to minimize and cotrol the project budget

Financing types :

- Private financiog or hybrid financing models

Project development :

- Concessions :
- BOT – build-operate-transfer, etc.
- DBOT, DBOT, DBOM, or other PPP types