EVALUATION OF VARIANTS

Multi-criteria assessment compares variants by a larger number of incommensurable (hard to be compared) criteria.

For transport structures frequently use:

a) The ecological point of view:

- *noise*
- *emission*
- *vibration*
- *confiscation of land resources*
- *load the landscape ecosystem*
- *impact on fauna and flora (intervention to the national parks and other environmental protection areas)*
- *impact on European important locality (NATURA 2000)*

b) from the point of view of the founder

- investment costs *(exercises)*
- *induced investments and* the costs of land *(exercises)*
- costs of project preparation *(exercises)*
- costs of maintenance and repairs *(exercises)*
- *time options of implementation*
- *option of stage construction*

c) from the point of view of users

- *consumption of fuel and time*
- *traffic safety*
- flow of traffic – the capacity and quality of traffic *(exercises)*

d) society-wide viewpoints

- *relation to residential and recreational function of territories*
- *aesthetic effect of route*
- *relation to the occupation of land*
- *demolition of existing buildings*

Simplified economic comparison of variants

The decisive criterion – minimization of the total financial cost of the construction (CN)

$$\boxed{CN = IN + PN}$$

- IN........... investment costs
- PN .... operation costs (rising gradually over the life the building)

As more efficient variant is considered the one with lower total costs in the end of the design period.

INVESTMENT COSTS (IN)

(calculate for both variants)

$$\boxed{IN = SN + P + PD}$$

- SN .... construction costs
- P............ costs of land acquisition
- PD .... cost of project preparation

1. Construction costs – SN:

$$\boxed{SN = VS + SS + O}$$

- VS .... costs of superstructure
- SS .... costs of substructure
- O .... costs of objects not included to substructure

a) costs of superstructure – VS:

- include price:
  - *pavement*
  - *shoulders*
  - *road equipment (crash barriers, delineator posts, traffic signs, road marking)*

$$\boxed{VS = |X;Y| \bullet MVS}$$

  - [VS] = CZK
  - [|X;Y|] = km
  - [MVS] = 10^6 CZK/km
- Determination of TDZ (class of traffic load):
  - *peak hour – take place during each day due to traffic variations*
    - the most frequent occurrence of peak hour on Friday afternoon (see *fig. 0230*) in the spring and summer months (see *fig. 0240*)

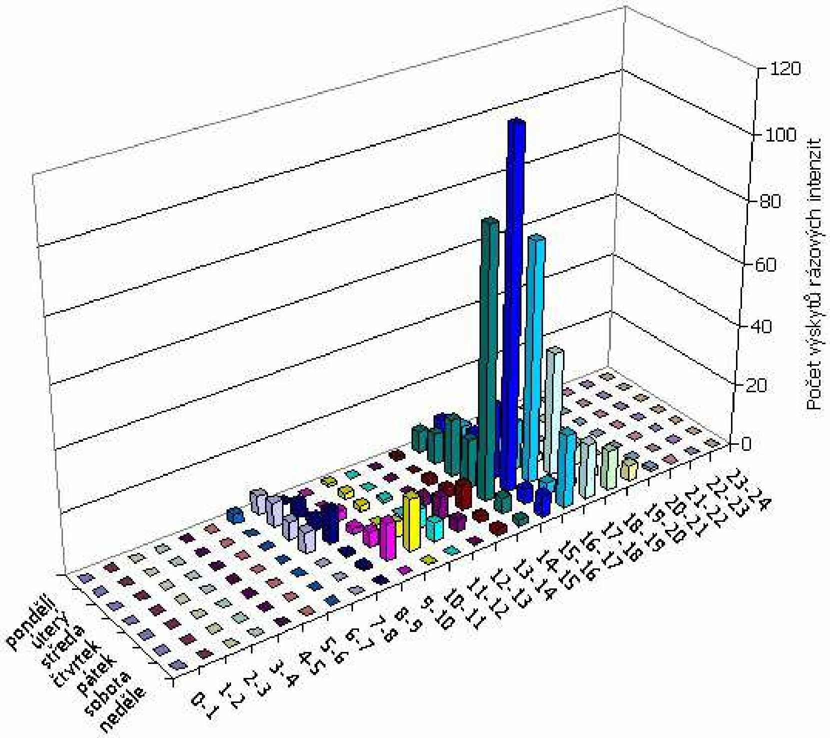

fig. 0230 (occurrence of peak hour in different days)

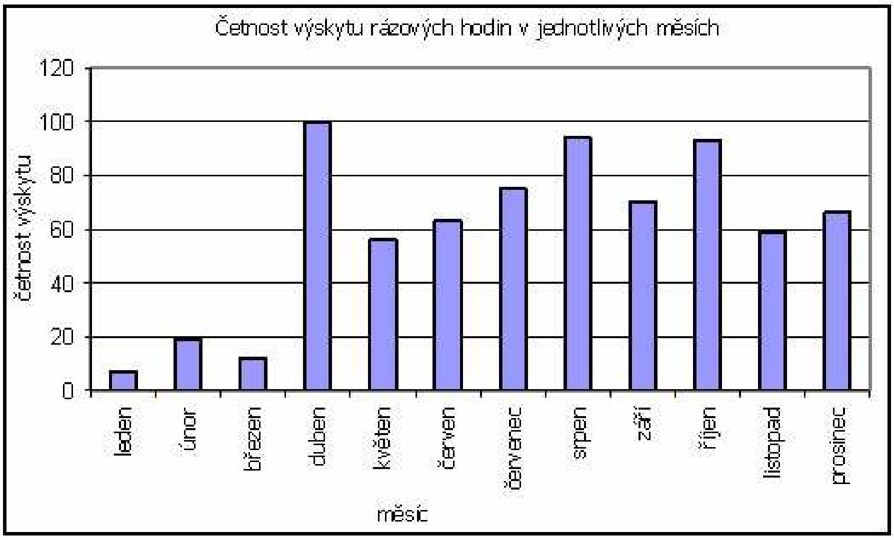

fig. 0240 (occurrence of peak hour in different months)

- *50 times a year occurring hourly traffic volume (exceeded 50-times a year) ⇒ the 50th largest peak hour throughout the year ⇒ approximately 0.09 of AADT (Annual Average Daily Traffic) (see fig. 0250)*

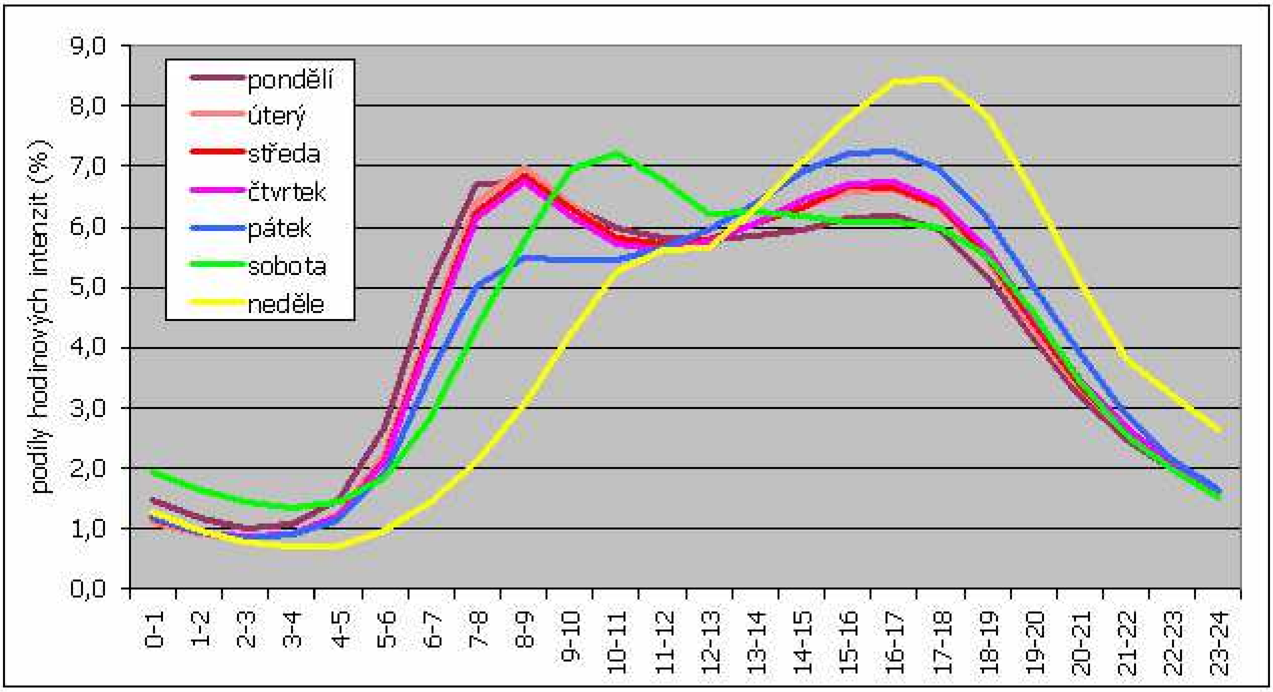

fig. 0250 (daily traffic variation in different week days)

- recreational traffic ⇒ 0,15~0,18
- Pilsen ⇒ 0,076
- Praha ⇒ 0,070 (see *fig. 0260*)

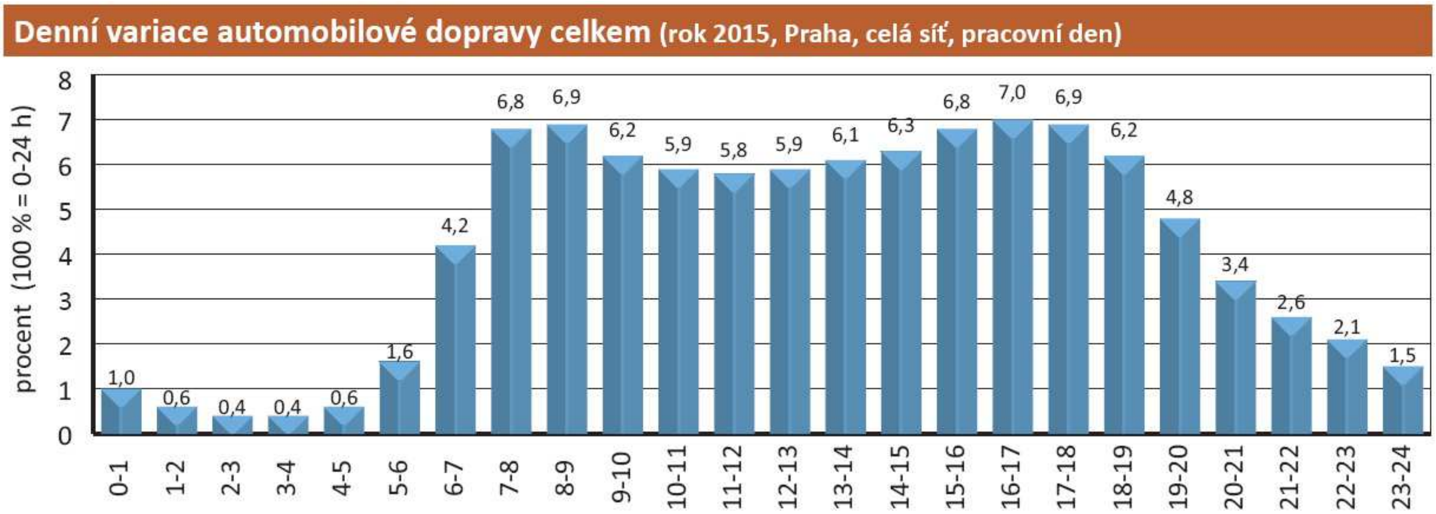

fig. 0260 (daily traffic variation in Prague)

$$T_{50} = I_N^{X \to Y} + I_N^{Y \to X}$$

$$T = \frac{T_{50}}{k_{50}}$$

- *k_{50}........coefficient of conversion from 50 times a year occurring hourly traffic volume to annual average daily traffic volume $\Rightarrow$ various according to the type of communication, value and occurrence of peak hour*
  - road I. class.. k_{50} = 0,101
  - road II. and III. class................................ k_{50} = 0,122
- *T..........annual average daily traffic volume of lorries (including trailers) in both directions*

$$\boxed{TNV = 0{,}7 \bullet C_1 \bullet T}$$

- *C_1 ....coefficient of allocation of traffic*
  - 2-lane road $\Rightarrow$ C_1 = 0.5 (exercise)
  - 4-lane road $\Rightarrow$ C_1 = 0.35

- *TNV.....annual average daily traffic volume of lorries in 1 direction (at some point) of the road in the year of traffic survey*

$$\boxed{TNV_p = \frac{TNV \bullet \left(k_{2020,n} + k_{2040,n}\right)}{2}}$$

- *TNV_p....annual average daily traffic volume of lorries in 1 direction (at some point) of the road in the end of the design period*

TNV_p	TDZ
101 – 500	IV
501 – 1500	III

- Specific construction costs of superstructure (MVS) in million CZK per 1 kilometre of road:

Category of road	Class of traffic load	
	III	IV
S 6,5	19,3	17,6
S 7,5	22,6	21,0
S 9,5	24,1	22,6
S 11,5	27,6	27,6

b) costs of the substructure – SS:

- evaluate from the volume of earthworks
- from value Δh (from longitudinal profile) in the nomogram (see *fig. 0270*) determines the area of each cross-section ($F_{N(i)}$ oder $F_{V(i)}$)
  - $\Delta h \geq$ *circa* $0{,}75\ m \Rightarrow \Delta h = h_N \Rightarrow F_{N(i)}$
  - $\Delta h \leq$ *circa* $0{,}75\ m \Rightarrow \Delta h = h_V \Rightarrow F_{V(i)}$

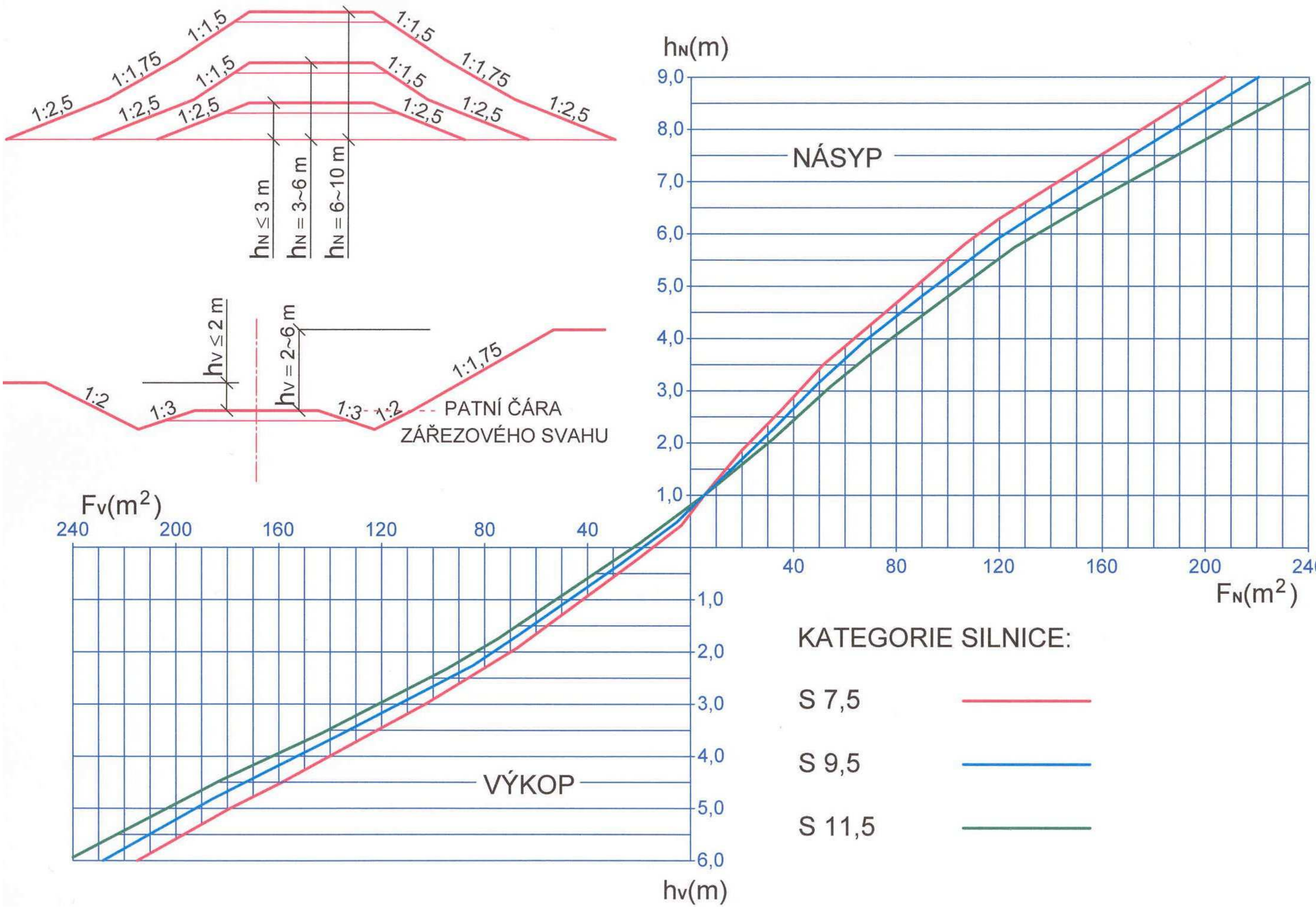

fig. 0270 (nomogram to estimate earthworks)

draft the earthworks volumes calculation table (see *fig. 0280*):

- i ..... serial number of the cross-section
- n .... total number of cross-sections
- values $S_{N(i)}$, $S_{V(i)}$, $I_{p(i)}$, $K_{N(i)}$, $K_{V(i)}$ are in the earthworks volumes calculation table calculated from $i = 2, \ldots, n$

ORIENTAČNÍ VÝPOČET KUBATUR - *VELKORYSÁ VARIANTA*										
i	Staničení	Δh		Plocha příčných řezů		Součet ploch		1/2 vzdál. příč. řezů	Kubatury	
		násyp	výkop	násyp	výkop	$S_{N(i)}$	$S_{V(i)}$	$O,5{*}l_{p(i)}$	násyp	výkop
				$F_{N(i)}$	$F_{V(i)}$				$K_{N(i)}$	$K_{V(i)}$
	km	m	m	m^2	m^2	m^2	m^2	m	m^3	m^3
1	0,00000		0,00		20					
2	0,05000		-1,63		75	0	95	25,00	0,00	2375,00
3	0,20346		0,00		20	0	95	76,73	0,00	7289,35
4	0,37838	2,23		35		35	20	87,46	3061,10	1749,20
5	0,45000	1,23		10		45	0	35,81	1611,45	0,00
6	0,47838		0,55		10	10	10	14,19	141,90	141,90
7	0,51055		0,00		20	0	30	16,09	0,00	482,55
8	0,57838		-0,46		40	0	60	33,92	0,00	2034,90
9	0,65000		-0,96		55	0	95	35,81	0,00	3401,95
10	0,73864		0,00		20	0	75	44,32	0,00	3324,00
11	0,80000		0,50		10	0	30	30,68	0,00	920,40
12	0,88653		0,00		20	0	30	43,27	0,00	1297,95
13	0,90000		-0,12		25	0	45	6,73	0,00	303,08
14	0,97742		-0,80		50	0	75	38,71	0,00	2903,25
15	1,07742		-1,36		65	0	115	50,00	0,00	5750,00
16	1,15000		-1,82		80	0	145	36,29	0,00	5262,05
17	1,17742		-1,54		70	0	150	13,71	0,00	2056,50
18	1,24184		0,00		20	0	90	32,21	0,00	2898,90
19	1,40000	3,23		55		55	20	79,08	4349,40	1581,60
20	1,44484	3,12		50		105	0	22,42	2354,10	0,00
21	1,52352		0,00		20	50	20	39,34	1967,00	786,80
22	1,60000		-2,92		120	0	140	38,24	0,00	5353,60
23	1,64484		-2,54		105	0	225	22,42	0,00	5044,50
24	1,74302		0,00		20	0	125	49,09	0,00	6136,25
25	1,84484	2,12		30		30	20	50,91	1527,30	1018,20
26	1,97990		0,00		20	30	20	67,53	2025,90	1350,60
27	2,00000		-0,59		40	0	60	10,05	0,00	603,00
28	2,10000		-1,34		65	0	105	50,00	0,00	5250,00
29	2,13726		0,00		20	0	85	18,63	0,00	1583,55
30	2,25000	2,44		35		35	20	56,37	1972,95	1127,40
31	2,39037	2,47		40		75	0	70,18	5263,88	0,00
32	2,40000	2,43		35		75	0	4,82	361,13	0,00
33	2,51083		0,14		20	35	20	55,42	1939,53	1108,30
34	2,51903		0,00		20	0	40	4,10	0,00	164,04
35	2,55000		-0,44		35	0	55	15,48	0,00	851,62
36	2,63129		-0,17		25	0	60	40,65	0,00	2438,70
37	2,65000		0,00		20	0	45	9,36	0,00	420,98
38	2,75165	1,29		10		10	20	50,83	508,25	1016,50
39	2,80000	1,18		10		20	0	24,17	483,50	0,00
40	2,83344		0,00		20	10	20	16,72	167,20	334,40
41	2,91218		-1,98		85	0	105	39,37	0,00	4133,85
42	3,00000		-3,56		145	0	230	43,91	0,00	10099,30
43	3,07271		-1,25		60	0	205	36,35	0,00	7452,77
44	3,10184		0,00		20	0	80	14,57	0,00	1165,20
45	3,23669	5,07		105		105	20	67,42	7079,62	1348,50
46	3,35000	6,33		145		250	0	56,66	14163,75	0,00
47	3,40512	5,78		125		270	0	27,56	7441,20	0,00
48	3,52252		0,00		20	125	20	58,70	7337,50	1174,00
49	3,57355		-4,14		170	0	190	25,52	0,00	4847,85
50	3,60000		-6,00		245	0	415	13,23	0,00	5488,38
51	3,65000		-4,95		200	0	445	25,00	0,00	11125,00
52	3,70796		0,00		20	0	220	28,98	0,00	6375,60
53	3,80000	7,86		200		200	20	46,02	9204,00	920,40
54	3,85000	9,93		280		480	0	25,00	12000,00	0,00
55	3,95000	9,67		270		550	0	50,00	27500,00	0,00
56	4,05000	7,21		175		445	0	50,00	22250,00	0,00
57	4,19921		0,00		20	175	20	74,61	13055,88	1492,10
	Σ								147766,53	133983,96

fig. 0280 (earthworks volumes calculation table)

$$S_{N(i)} = F_{N(i-1)} + F_{N(i)} \qquad K_{N(i)} = S_{N(i)} \bullet 0{,}5 \bullet l_{p(i)}$$
$$S_{V(i)} = F_{V(i-1)} + F_{V(i)} \qquad K_{V(i)} = S_{V(i)} \bullet 0{,}5 \bullet l_{p(i)}$$

- calculation costs of the substructure (SS):
  - include any *mass haulage*, construction of *road bed* and costs of *culverts* and other *smaller objects:*
    - retaining and base walls (up to a height of 2 m above modified terrain)
    - surface water drainage
  - if $\boxed{\sum K_{V(i)} > \sum K_{N(i)}}$

    $$\boxed{SS = 630 \bullet \sum K_{N(i)} + 955 \bullet \left(\sum K_{V(i)} - \sum K_{N(i)}\right)}$$

    - [SS] = CZK
    - total excavated mass will be moved to fills (perhaps technologically adapt) at the price of 630 CZK/m^3:
      - *loading + transport + unloading........ 150 CZK/m^3*
      - *technological improvement .... 365 CZK/m^3*
      - *loading + return transport + unloading + adjustment .... 115 CZK/m^3*
    - residual surplus excavated mass will be taken to the mound (dump) at the price of 885 CZK/m^3:
      - *loading + transport + unloading........ 405 CZK/m^3*
      - *storage area fee (depending on local conditions) 550 Kč/m^3*
  - if $\boxed{\sum K_{N(i)} > \sum K_{V(i)}}$

    $$\boxed{SS = 630 \bullet \sum K_{V(i)} + 640 \bullet \left(\sum K_{N(i)} - \sum K_{V(i)}\right)}$$

    - [SS] = CZK

- total excavated mass will be moved to fills (perhaps technologically adapt) at the price of 630 CZK/m^3 (loading + transport + unloading + technological improvement + loading + return transport + unloading + modification)
- lack of fill mass will be bought at the price of 640 CZK/m^3 (transport, storage to embankments)

c) costs of objects (bridges and tunnels) – O:

$$\boxed{O = M + T}$$

- M .... costs of bridges
- P .... costs of tunnels

bridges:

- considering reinforced concrete bridges
- price is calculated according to methodology "pricing norms"

$$\boxed{M = \sum_{i=1}^{n} \left(\frac{l_{Mi}}{1000} \bullet m_i \right)}$$

$$[M] = CZK$$

- n .... number of bridges in particular variant
- l_{Mi}...... bridge length in meters (from longitudinal profile)
- m_i ..... base price of 1 kilometre long bridge according to the price normative RSD (Road and Motorway Directorate of the Czech Republic) from year 2010 and effects of inflation

Year	Category of road	Price per 1 kilometre of bridge „m_i“ [CZK / km]
2017	S 6,5	370 300 000
	S 7,5	431 000 000
	S 9,5	531 200 000
	S 11,5	631 500 000

tunnels:

- considering 2-line short tunnels up to 500 m in rural area with full safety equipment
- price calculate according to methodology ”pricing norms“ (Price normative RSD from year 2010 and effects of inflation)

$$\boxed{T = \sum_{i=1}^{n}\left(\frac{l_{Ti}}{1000} \bullet t_i\right)}$$

[T] = CZK

t_i = 1 006 800 000 CZK

- t_i .... base price 1 kilometre of tunnel
- n .... number of tunnels in particular variant
- l_{Ti} ...... tunnel length in meters (from longitudinal profile)