Cost-minimization analysis

(model example)

Municipality has decided to build a civic amenity site. Two projects applied. Costs (investment and running) and revenues (for selling collected separated waste) throughout the predicted lifetime are in the following table. Which project would you choose according to the CMA if r = 0,05?

	Period	0	1	2	3	4	5	6
Variant A	Costs	1 500	100	100	100	100	100	100
	Revenues		300	300	300	300	300	300
Variant B	Costs	1 100	250	250	250	250	250	250
	Revenues		500	500	500	500	500	500

CMA is a basic cost-output method, in which the primary goal is to minimize the costs. It is an appropriate method if there is possible to sufficiently define the desired output, resp. the minimal desired parameters. In practical application of the CMA you then choose (from the available options) firstly those that meet the minimal desired requirements and from this subgroup choose the one with the lowest costs.

$$\sum_{t=0}^{T} \frac{Cost_t}{(1+r)^t} = min$$

CMA method is relatively popular due to its simplicity, but the appropriate usage requires sufficient preparation and appropriately exact specification of minimal desired requirements.

On the other hand, CMA cannot guarantee that the most efficient option will be chosen – in such cases a different method should be used that compares costs with the provided level of outputs, and do not consider outputs from the yes/no perspective. CMA does take into account only the fulfillment of the minimal required parameters, anything beyond that is irrelevant.

What can happen is that the most efficient variant would contain a significantly higher that required level of output. With CMA it, however, does not matter, how much the minimal requirements have been exceeded – if they have been met, all such variants are seen as equal in terms of outputs. In such cases, on the other hand, variants with less output are in advantage, as they did not have to spend extra sources for producing exceeding parameters.

Solution steps: For both variants we sum up discounted values of costs for the whole lifetime.

	0	1	2	3	4	5	6	Σ costs
A	1 500	95.238	90.703	86.384	82.270	78.353	74.622	**2 007.569**
B	1 100	238.095	226.757	215.959	205.676	195.882	186.554	2 368.923

Solution: From given projects we choose, according to the CMA, project A with costs **2 007.569** over the project B with costs 2 368.923.

Cost-effectiveness analysis

(model example)

Let us use the previous example. For both variants of CA site we would consider expected amounts of collected separated waste. Which project would you choose according to the criterion costs per collected ton of recyclable waste?

	Period	0	1	2	3	4	5	6
Variant A	Costs	1 500	100	100	100	100	100	100
	Recyclables		240	240	240	240	240	240
Variant B	Costs	1 100	250	250	250	250	250	250
	Recyclables		280	280	280	280	280	280

CEA je cost-output method that is used in cases when it is possible to measure outputs in relatively homogenous units (whether tangible or not), and the appraisal of such units in the monetary terms is (from whatever reasons) problematic. Typical situation is when there is no sufficient market for given type of output and the price is not available, the estimation of price is highly inaccurate and uncertain, or the appraisal in terms of money is unethical/politically inappropriate (e.g. healthcare).

$$\sum_{t=0}^{T} \frac{Cost_t}{(1+r)^t} \Big/ \sum_{t=0}^{T} Output_t = min$$

We can report the results of in form of costs per unit out output (lower value is better) – see the formulae above, or alternatively in the inverted form of output per unit of costs (higher value is better). The choice depends on the situation, resp. which option is more clear and easier to interpret.

CEA method is popular in the area of environment or healthcare, where using units of output instead of their transformation into the monetary form reduces the problems related to the defense of whether they economically pay off.

With CEA we generally expect that it pays off to spend resources in order to acquire certain output, and we are concerned with the choice of variant with the best input to output ratio (in other terms the efficiency). The question whether it makes sense to spend resource in order to get such output is in with CEA not considered.

Solutions steps: We sum up discounted costs for the whole lifetime as in CMA, divide it with the sum of collected recyclables (outputs), and choose variant with the lowest costs per unit of output.

Solution: From given projects we choose, according to the CEA with output of ton of collected recyclables, project A with costs **1 394.15** per ton of waste (resp. 0.717 ton per 1 000 units of costs) over the project B with costs of **1 410.07** per ton of waste (resp. 0.709 ton per 1 000 units of costs).

Cost–utility analysis

(model example)

Let us use the previous example with the addition of the CA site opening hours – variant A is open 2x per week, variant B 3x per week, CA site operates 50 weeks/year. We presume that correct sorting of 2 tons of collected recyclables takes 1 full working day. Whatever beyond this the worker will not manage to sort and will be considered as mixed waste, that the collection company will take away with the rest of the regular mixed waste. Which project would you choose according to the criterion od costs per ton of collected and sorted recyclables?

CUA is almost identical with the CEA, however, the output is in case of CUA usually more complex – typically it is some kind of utility that is represented by some combination of outputs. Typical example from healthcare is conversion of cost to the (output) unit QALY – Quality adjusted life-year. The unit of QALY represents the combination of expected additional life year gained by undergoing certain type of treatment and estimated level of life quality after this treatment. In case of QALY less additional years with higher life quality can be considered as more valuable than more years with lower life quality.

$$\sum_{t=0}^{T}\frac{Cost_t}{(1+r)^t}\Big/\sum_{t=0}^{T}Utility_t = min$$

The use of this method is then practically identical with the CEA. After calculating the total amount of utility for each considered variants we calculate costs per unit of utility and choose variant with costs per utility ratio – the goal is again the efficiency. The question whether it makes sense to spend resource in order to get such utility is again irrelevant.

Solution steps: We sum up the costs for the whole lifetime as in case of CMA, divide them with the sum collected and also sorted recyclables (utility), and choose variant with lower costs per unit of utility. When determining the total level of utility we need to find out how many tons of waste will get both collected and sorted. With sufficient amount of working days is the utility limited by the amount of collected waste, on contrary with large amount of collected waste is the utility limited by the amount of working days.

Solution: From given projects we prefer, according to the CUA method with unit of utility collected and sorted ton of recyclables, project B with costs **1 410.07** per ton of sorted recyclables (resp. 0.709 ton of sorted recyclables per 1 000 units of costs) over the project A with costs **1 672.97** per ton of sorted recyclables (resp. 0.598 ton of sorted recyclables per 1 000 units of costs).

Cost–benefit analysis

(model example)

Municipality is deciding between 2 projects of CA site. Variant A is a larger CA site (10x20m, more containers, expected 240 ton of incoming recyclables per year), variant B is a smaller CA site (10x16m, expected 170 ton of incoming recyclables per year). Property will be donated by the municipality. Paved surface costs 1700 CZK/m^2, gate 10 thousand CZK, 1 m fence 150 CZK, lights 30k CZK (smaller CA site 1x, larger 2x), containers for plastics 30k CZK and paper 25k CZK (larger CA site 3x, smaller 2x), WEEE box 9k CZK (1x both), shelter for employer 80k CZK, and mobile WC 25k CZK. City will provide subvention for the construction of 250k CZK during investment period. Running costs consists of energies (fix) 5k CZK/year + 3k CZK/year for each light, maintenance costs 180 CZK/m^2 of area per year, and personal costs of 20k CZK/month for full-time employee (+34% social security contributions). In larger CA site the employee will be available 3x per week, smaller 2x week, usual working hours. As social benefits consider tax corrections from wage (difference between total personal costs and net income – the difference that is paid to the state), another social benefit is 200 CZK for each collected ton of recyclables (expert estimation), and on contrary social cost for local people is the visual side of CA site and related noise estimated as 10k CZK/year for each single day of operation per week. Recyclables consists of 40% paper (selling price 1 200 CZK/ton), 50% plastics (1 900 CZK/ton) and 10% WEEE (700 CZK/ton). Which project would you prefer based on CBA (financial and economic analysis) according to R_i if project lifetime is 4 years, $r = 4\%$ and $r_e = 5\%$?

We use CBA in cases where we can estimate monetary values of all costs and benefits, whether directly from their market price or indirectly based on alternative appraisal methods. The steps of CBA consist of 2 main parts, the financial analysis, where we use direct costs and revenues related to the project (investor's perspective), followed by economic analysis, that takes the result of financial analysis and adds social costs and benefits expressed in monetary forms. The result of economic analysis can, depending on the situation and scope of impact, significantly affect the final results of CBA, both positively and negatively. Moreover, in CBA the key role is the initial part of complex identification of costs and revenues/benefits of the project. The more important is the item that is not included in the CBA, the more biased results we will get.

To put it simple, the financial analysis consists of summing up investments costs together with the cashflow of the project during its lifetime, and the economic analysis further adds to that, for instance, the impacts on the environment, employment, life quality, etc.

The procedure of financial analysis is basically the NPV calculation, or the identification of costs and revenues of the project in individual periods of its lifetime and their cumulative discounted sum, eventually with the calculation of R_i. In economic analysis we take non-discounted cashflow from individual periods (because in economic analysis we usually discount with different rate) and add social costs and benefits, and calculate NPV (or R_i) of these "economic" cashflows. Financial and economic analyses are usually calculated separately due to the different discount rate used. In financial analysis of the projects co-financed by EU we use 5% discount rate, in economic analysis we use 5.5%. Considering the result, acceptable project is again the one with non-negative values of NPV, at least in economic analysis.

Solution steps: For both projects we determine investment and running costs.

Type of cots	A investment	B investment	A running	B running
Paved surface	340 000	272 000		
Gate	10 000	10 000		
Fence	9 000	7 800		
Light	60 000	30 000		
Container (plastics)	90 000	60 000		
Container (paper)	75 000	50 000		
Container (WEEE)	9 000	9 000		
Shelter	80 000	80 000		
Mobile WC	25 000	25 000		
Subvention from city	-250 000	-250 000		
Energies (fix costs)			5 000	5 000
Energies (lights			6 000	3 000
Maintenance			36 000	28 800
Personal costs			192 960	128 640
Sum	**448 000**	**293 800**	**239 960**	**165 440**

personal costs (in CZ) are (gross wage)(work range)*(12 moths)*(1.34 social security contributions)

**!!<u>we do not consider decision analysis costs when calculating CBA, if there are some – sunk costs</u>!!

Then we determine running revenues of the projects (per year)

	Buyout price/ton	Revenues A (240 ton/year)	Revenues B (170 ton/year)
Plastics	1 900	228 000	161 500
Paper	1 200	115 200	81 600
WEEE	700	16 800	11 900
Sum		**360 000**	**255 000**

We calculate financial analysis (*r = 5%*), according to which we accept project B

	0	1	2	3	4	NPV (FA)
A cashflow (FA)	-448 000	120 040	120 040	120 040	120 040	
A discounted CF	-448 000	115 423	110 984	106 715	102 611	**-12 267**
B cashflow (FA)	-293 800	89 560	89 560	89 560	89 560	
B discounted CF	-293 800	86 115	82 803	79 619	76 556	**31 293**

According to the financial analysis (FA) we accept only project B with NPV <u>**31 293**</u> CZK, project A is not acceptable with NPV <u>**-12 267**</u> CZK. According to the R_i we automatically choose project B.

Then follows economic analysis, which continues on the result of financial analysis and includes

	Social impacts A	Social impacts B
Tax corrections	68 940	48 060
Benefits from waste	48 000	34 000
CA site negatives	-30 000	-20 000
Sum	**86 940**	**62 060**

Tax corrections from wages were calculated as the total personal (employment) costs – gross wage*1.34 minus net wage which is in this case 16 080 per month. Do not forget that we consider part-time jobs and 12 months per year.

Finally we calculate economic analysis (EA). We take non-discounted cashflow from FA, add social costs and benefits and then calculate NPV again ($r_e = 5\%$).

	0	1	2	3	4	NPV (EA)
A cashflow (EA)	-448 000	206 980	206 980	206 980	206 980	
A discounted CF	-448 000	197 124	187 737	178 797	170 283	**285 941**
B cashflow (EA)	-293 800	151 620	151 620	151 620	151 620	
B discounted CF	-293 800	144 400	137 524	130 975	124 738	**243 837**

According to the economic analysis both project are now acceptable, finally we calculate R_i.

Solution: From available projects we prefer, according to the CBA, project B with R_i **0.83** over project A with R_i **0.64**. Both projects are acceptable.