Cost–benefit analysis

(model example)

Municipality is deciding between 2 projects of a 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 (for the gate as well), 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 the employer 80k CZK, and mobile WC 25k CZK. Ministry will provide subvention for the construction of 250k CZK during the investment period. Running costs consist 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 gross for a full-time employee (+34% social security payments). In a larger CA site the employee will be available 3x per week, in smaller 2x week (usual working hours). As social benefits consider tax corrections from the wage (difference between total personal costs and a net income – the difference that is paid to the state), another social benefit is 200 CZK for each collected ton of recyclables (an expert estimation of the value), and on contrary social cost for local people is the visual aspect of the 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 the CBA (financial and economic analysis) according to R_i if project lifetime is 4 years, $r_{fa} = 4\ \%$ a $r_{ea} = 5\ \%$?

We use CBA in cases where we can estimate monetary values of all considered costs and benefits, whether directly from their market price or indirectly based on some 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 the economic analysis, that takes the result of the 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 the CBA the key role is the initial part of the 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 society in general).

The procedure of financial analysis is basically an 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 the subsequent economic analysis we take the non-discounted cashflow from individual periods (because in economic analysis we usually discount with a different discount 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 the financial analysis of the projects co-financed by the EU we use 4% discount rate, in the economic analysis we use 5%. Considering the result, an acceptable project is again the one with non-negative values of NPV, at least in the 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 ministry	-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) = (gross wage)(work range)*(12 months)*(1.34 social security contributions)

**!!<u>we do not consider decision analysis costs when calculating CBA, if there are some</u>!!
<u>These are in fact sunk costs that occur independently from whether we realize the project or not.</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 ($r_{fa} = 4\%$), 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 the economic analysis, which continues on the result of financial analysis and includes

	Social impacts A	Social impacts B
Tax corrections	71 124	51 864
Benefits from waste	48 000	34 000
CA site negatives	-30 000	-20 000
Sum	**89 124**	**65 864**

Tax corrections from wages were calculated as the total personal (employment) costs – gross wage*1.34 minus net wage. Do not forget that we consider part-time jobs and 12 months per year (net wage is 10 153 for the larger CA site and 6 398 for the smaller CA site).

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

	0	1	2	3	4	NPV (EA)
A cashflow (EA)	-448 000	209 164	209 164	209 164	209 164	
A discounted CF	-448 000	199 204	189 718	180 684	172 080	**293 685**
B cashflow (EA)	-293 800	155 424	155 424	155 424	155 424	
B discounted CF	-293 800	148 023	140 974	134 261	127 868	**257 326**

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

Solution: From the available projects we prefer, according to the CBA, project B with R_i **0.88** over project A with R_i **0.66**. Both projects are acceptable.

Shadow pricing – deriving prices from the demand curves

(model example)

Region plans to build a new bridge that would lower the travelling costs between two cities by 100 CZK/trip. This costs reduction includes shorter travelling time, lower vehicle depreciation and lower fuel consumption of 120 CZK/trip in total minus 20 CZK toll per bridge crossing – a Region's income. Before the bridge there were total of 1 million trips per year, an estimate after the bridge is built is 1.5 million trips per year. Calculate annual benefits of the new bridge for drivers and for the Region.

Shadow pricing represents a way how to estimate the value of goods and services using a ***market-based approach***. In an optimal situation it is possible to find an alternative to the evaluated goods/service and use this price. If not, we can try to use shadow prices.

We use *shadow pricing* in situations where the actual price of goods/services does not exist or does not reflect the true value (often due to the regulations, temporary fluctuations, or some other market failures). A shadow price then can be perceived as a price that would be achieved in a perfect competition market. Shadow price represents a *proxy* value, usually considered as a value of what one has to sacrifice in order to get an additional unit. An estimation of a shadow price is usually done by observing subjects' behavior. The two main approaches to estimated shadow prices are based on benefits or on costs.

Benefits approach includes estimation methods like *change in productivity*, or *forgone earnings*. We can calculate these prices using a CBA for the specific goods/service. Costs approach includes methods like *replacements/restoration costs*, *preventive expenditure*, *damage avoidance costs*, etc.

In praxis these methods can be used in a form of a natural experiment or pilot projects (small scale experiments). Impacts of such projects are classified, quantified and monetized. Using an extrapolation, shadow prices can be estimated for the whole project.

Alternative way of estimating shadow prices is by using pseudo- or quasi-demand curves. We use the initial state and the expected state after the project's realization and based on that estimate the demand curve. We then calculate consumer's benefit resulting from the change of the state.

Solution steps: In our case we have data about demand before and after the project realization, thus we derive shadow prices from the relevant demand curve. We can start with benefits to the Region, which are basically number of trips multiplied by the bridge crossing toll (*de facto* revenues).

In case of drivers we need to separate the group that would travel regardless of the new bridge – they would enjoy benefits of the full cost saving, and the remaining group with decreasing benefits due to the slope of the demand curve. In other words, benefit for the driver no. 1,000,001 is almost the full costs savings, while the benefit for the driver no. 1,500,000 is basically zero – this is the very last driver that decided to do the trip, as it was practically on par with the alternative of, for instance, staying at home or taking an alternative route.

Solution: Benefit for the drivers is **125 mil. CZK/year**, benefit for the Region is **30 mil. CZK/year**.

WTP – Willingness to Pay

(model example)

Municipality is considering introducing a new waste collection system – instead of central container (fully paid by the municipality) use bins for the individual households. Estimate the social benefits of such new system using WTP. This could tell the municipality at what level should it set the fee for the new system in order to cover the additional expenditures.

Population (200 total) has been sorted based on their willingness to pay for the new system from the lowest fee to the highest and divided into the quartiles. Assume that the willingness to pay grows linearly within each quartile. First person is not willing to pay anything, person at the first quartile can pay 300 CZK, at the second quartile 380 CZK, at the third quartile 440 CZK, and last one 560 CZK.

WTP method represents the second approach how to estimate shadow prices and is based on ***stated*** (declared) ***preferences*****.** It is a kind of a ***Contingent Valuation Method (CVM)*** that uses questionnaires/surveys. In contrast with the market-approach based on observation of the subjects, this approach estimates the values based on subjective opinions (theoretical preference), not from actual behavior, that has been confirmed at the market.

The method itself consists of collecting data from a survey, in which a relevant sample of subjects state the maximum price they are willing to pay for some goods or service. Survey can start with lower amounts and continue higher until maximum price is stated. An alternatively is a directly question about the highest price. Based on collected data we derive a pseudo-demand curve.

The benefits estimated by WTP method is, as with other methods based on preferences, calculated as the consumer surplus – the area under the derived pseudo-demand curve.

Analogical method is ***WTA – Willingness to Accept***, where you estimate the price, resp. equivalent that would make subject accept the presence of some negative factor.

Main problem of WTP and WTA methods is in often observed difference between stated and revealed (real, market) preferences, and the correct use of this method requires taking this into the consideration. Respondents in case of WTP and WTA often overstate their willingness to pay, resp. their minimal accepted equivalent for sustaining some negative effect. Another problem of these methods is acquiring the data from a representative sample during the survey.

Solution steps: Based on the collected data we derive a pseudo-demand curve of the willingness to pay and calculate the area under it. Total willingness to pay in 4^{th} quartile is (50*440+(560-440)*50/2) = 25 000 CZK, in 3^{rd} quartile is (380*50+(440-380)*50/2) = 20 500 CZK, in 2^{nd} quartile is (50*300+(380-300)*50/2) = 17 000 CZK, and in the first quartile is (300*50/2) = 7 500 CZK.

Solution: Social benefit from new waste collection system using bins would be **70 000 CZK**.

Hedonic pricing method

(model example)

You are asked to evaluate benefits of an anti-flood dam that would reduce the probability of a flood in a residential area of 80 houses. Use hedonic method for the evaluation if you know that the price of houses in given area can be estimated using linear regression model:

$$p_i = \alpha + \beta(prob) + \gamma(x_i) + \varepsilon_i$$

where p_i means estimated price of the house, $prob$ probability of a flood occurrence in some time horizon, and x_i some other parameters of house that we do not need to consider in this case.

Based on the survey of house prices the coefficients have values $\alpha = 75$, $\beta = -200$ and $\gamma = 1$. Dam construction is estimated to reduce the risk of flood in some time horizon from 0.4 to 0.05.

Hedonic method represents an approach used for estimating the values of certain measures, good or services that directly affect the market prices of some other goods. Usual application area is the realities market, which reflects the impacts of changes of local environmental attributes.

Hedonic method assumes that the price of a certain market good is directly influenced by its characteristics and our considered measure (resp. good, service). Steps of this method consist of collecting sufficient data regarding prices and characteristics of considered market goods and their subsequent statistical analysis. The result is then a price function of a market good consisting of effects of individual characteristics. Based on the impact of changing individual parameters we estimate the social benefits of introducing evaluated measure (good, service). In contrast with the stated preferences, here we use the real data, ***revealed preferences***.

When applying this method in a project evaluation we examine the impact on the welfare (e.g. change in the prices of realities) when changing selected variables that we can influence (deciding whether to undergo the project). Final monetized value of the project realization (resp. measure introduction) is then calculated as a difference between the original state and the new state after the project realization.

Solution steps: In our case we calculate the difference the value of houses before and after the construction of the anti-flood dam. Specifically we compare the total value of houses using regression model using the original and new parameters. Numerically this is a difference between $p_i = 75 - 200 * (0.4) = -5$, and $p_i = 75 - 200 * (0.05) = 65$, resp. simplified into $\Delta p_i = -200 * (0.05 - 0.4) = 70$ for a single house. Other parameters than flood occurrence probability in this case do not change, therefore we do not need to consider them in the calculation.

Change in the value of a single house in this case is a value increase by 70.

Solution: Total benefit of building an anti-flood dam for the residential area has a value of **5600**.

TCM – Travel Cost Method

(model example)

A municipality owns a lookout tower. Annual maintenance costs including personnel are 300,000 CZK (material, repairs, etc.). Municipality wants to know the value of the social benefits of the tower. Calculate them using TCM. Consider travel costs of 2 CZK/km, travel pace of 30 km/hour, average hourly wage 120 CZK, and an entrance fee of 10 CZK/person. Further parameters are in the table. Assume discontinuous changes in demand for visits (each zone has same demand level), and irrelevant visits from additional zones. Also consider that visits are not cumulative (only the tower).

Zone	Distance	Population	Probability of visit per year
0	1	200	50%
1	10	10,000	5%
2	30	100,000	2%

TCM represents a method of evaluating nonmarket goods based on observing the market behavior of subject (***revealed preferences***). It is used mostly when appraising attractive locations (points of interest, POI) or ecosystems, where it is naturally difficult to set a direct market monetary value.

This method assumes that the value of evaluated goods is equal to the loss (costs), that subjects are willing to accept by travelling to the destination with the POI, specifically the costs for travelling (fuel, public transportation), value of the lost time due to the travelling, and the entrance fees, if there are any. These costs are different for each of the considered zones based on the distance.

Initially we identify the demand zones in the form of amounts of visits and related total costs per visit for each considered zone. From these zones we derive a pseudo-demand curve for visiting considered POIs. The value of POI is then represented by the area under the pseudo-demand curve.

Disadvantage of this method is, for instance, the necessity of sufficient data, as well as inaccuracies due to the combined visits to the multiple POIs (costs are then shared between the visits), or the perceived benefits from the travelling itself.

Solution steps: We have data about three zones, we do not consider more. We also do not consider standard demand curve shape, but only three homogenous groups of visitors based on the zones. We calculate costs per visit for each zone: 0) 100*(2CZK*2*1km+120CZK*2*1km/30+10CZK); 1) 500*(2CZK*2*10km+120CZK*2*10km/30+10CZK); 2) 2000*(2CZK*2*30km+120CZK*2*30km/30 +10CZK).

Solution: Benefits of the lookout tower are 2200 CZK + 65000 CZK + 740000 CZK = **807 200 CZK/year**.