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Concept to include cost-effectiveness and cost-benefit analysis approach into SAF

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CONTENTS

Abstract Current study gives a presentation on how cost effectiveness analysis (CEA) and cost benefit analysis (CBA) can be combined with the System Approach Framework (SAF). Both CEA and CBA are outcome oriented with the aims of reaching certain environmental targets and implementing project, respectively, at the best for society. SAF is a process oriented approach which suggests a systematic way of identifying environmental problems and finding solutions, which are close to the aims of both CEA and CBA. The difference is the stakeholder participations at different states of the SAF implementation, which is not necessary in CEA and CBA. It is therefore concluded that both CEA and CBA can provide useful inputs in the technical steps of SAF where solutions to problems are identified. The study shows how this can be made for decisions on opening beaches in Lithuania and for evaluating social net benefits of mussel farming in Germany.

Key words; cost-effectiveness analysis, cost-benefit analysis, system approach framework, bathing water quality, mussel farming

1.Introduction

Cost effectiveness and cost benefit analyses, CEA and CBA respectively, have a long tradition in economics and have been much used in practice as decision support for, e.g., international agreements on pollutant reduction and local implementation of water cleaning projects (Levin and McEwan, 2001, Bordman et al. 2014). In CEA, costs are minimized for reaching one or several environmental targets at minimum costs, such as the minimization of cost for reaching certain climate change targets (IPCC, 2014), water quality targets (e.g. Kneese ; Gren et al. 1997; Shortle and Horan 2008), air pollution reductions (e.g. Atkinson and Lewis, 1974), and biodiversity conservation (e.g. Gren et al. 2014).

CBA does not rest on predetermined targets but instead evaluates all costs and benefits associated with a particular project, such as construction of wetlands as nutrient sinks for down streams water recipient. CBA was used already in early 1900s to evaluate water cleaning and road safety projects (Boardmann et al., 2014), and has also been applied on a number of different topics including programs for improved air quality (e.g. Voorhees et al. 2001), climate change (e.g Tol 2003), and eutrophication management in the Baltic Sea (Gren et al., 1997).

Both CEA and CBA have developed over decades to manage problems associated with uncertainty, long term perspectives, and distributional effects on different stakeholder. However, neither CEA nor CBA approaches the entire negotiation and decision chain including the identification of the problems as such, and the final choice of solutions. This requires a more process oriented approach enabling interaction between stakeholders and decision makers. The System Approach Framework (SAF) is designed to facilitate solutions of environmental problems by providing a systematic approach to stakeholder engagement and interaction (e.g. Hopkins 2011). The purpose of this study is to investigate how CEA and CBA can be introduced into SAF.

The study is organized as follows. First we present the most simple theoretical framework of CEA and CBA. This is followed by a suggestion on introduction of CEA and CBA into SAF.

Section 4 gives examples of CEA or CBA applied to two case studies, and the study ends with a brief summary and conclusion.

2. Simple theoretical framework for CEA and CBA

The underlying basic theories of CEA and CBA are relatively simple. In principle, CEA is a part of CBA since the costs of a specific project should reflect the minimum cost for that project, such as the construction of a mussel farm. Similarly, CBA of improved water quality should contain a cost effectiveness analysis of the combination of measures that obtains different quality targets at minimum costs. In the following, we give a conceptual presentation of CEA and CBA.

2.1 Cost effectiveness analysis

CEA has been applied to numerous environmental problems (e.g. Baumol and Oates, 1988). In the most simple case this problem is formulated as the minimization of costs for reaching certain maximum pollution levels as:

$$\underset{M^i}{Min} \quad C = \sum_i C^i(M^i) \tag{1}$$

$$\text{s.t.} \quad P^{BAU} - \sum_i M^i \leq P^{TARG}$$

where C is total cost, M^i is abatement measure i, $C^i(M^i)$ is cost function for abatement measure i where $i=1,..,n$ measures, which is increasing and convex in M^i, P^{BAU} is the business as usual (BAU) pollution, and P^{TARG} is the maximum acceptable level of pollution.

Solving for the optimal combination of M^i in (1) give the first-order condition for a cost-effective solution as:

$$\frac{\partial C}{\partial M^i} = \frac{\partial C^i}{\partial M^i} + \lambda = 0 \qquad (2)$$

where $\lambda \leq 0$ is the Lagrange multiplier on the restriction in eq. (1). It shows the impact on total cost from a marginal change in the constraint in eq. (1), which is known as the marginal cost of reaching the target. In a cost effective solution, the marginal cost is thus equal to λ for all measures.

The necessity of the condition of equal marginal costs for all measures is illustrated in a simple numerical example where we have two alternative measures for, e.g. phosphorus reduction. One is reduction in agriculture with the marginal cost MC^A=Euro 2, and the other measure is increased cleaning at a sewage treatment plant with MC^S=Euro1.5. Obviously, the condition of cost effectiveness is not fulfilled since $MC^A > MC^S$. By reducing cleaning by 1 unit at the agricultural sector gains are made from cost savings corresponding to Euro2. In order to obtain an unchanged level of cleaning we increase it by 1 unit at the sewage treatment plant at the cost of 1.5 Euro. Thus, this switch in cleaning creates a gain of Euro 0.5, which implies that deviations from the condition of equal marginal costs for all measures never can imply a cost effective solution.

By a successive change in P^{TARG} we obtain a cost function for reductions in phosphorus loads which shows the minimum cost for reaching different targets where the condition for cost effectiveness is fulfilled at each point, which is illustrated in Figure 1

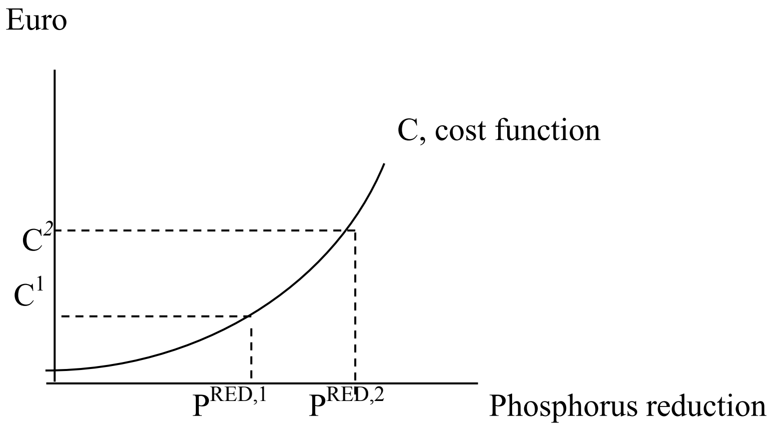

Figure 1: Illustration of a cost function for phosphorus reductions, P^{RED}

The function C shows the minimum cost for reaching different levels of phosphorus reductions. The condition for cost minimization is fulfilled at each point at the curve. For example at the reduction target $P^{RED,1}$ the minimum cost is C^1 and at $P^{RED,2}$ it is C^2. Note that the increase in cost is relatively higher than the increase in phosphorus reduction. This is a common shape of a cost function where it becomes successively more expensive to reduce pollutions.

2.2 Cost benefit analysis

In CBA, not only least costs of water quality targets are calculated, but also the associated values. In order to do this we need to construct a benefit function of pollution reduction, which we simply denote $B(M^i)$, which is assumed to be increasing and concave in M^i. This means that the benefit of improved water quality from, e.g., phosphorus reductions becomes successively less effective. Instead of formulating a problem as in eq.(1) with a constraint on pollution load we maximize net benefits, NB, of measures reducing phosphorus loads as:

$$\underset{M^i}{Max} \qquad NB = \sum_i B(M^i) - C^i(M^i) \qquad (3)$$

The associated first-order conditions for net benefit maximization are:

$$\frac{\partial NB}{\partial M^i} = \frac{\partial B}{\partial M^i} - \frac{\partial C^i}{\partial M^i} = 0 \qquad (4)$$

Since $\frac{\partial B}{\partial M^i}$ is the same for all abatement measures the condition of cost effectiveness is fulfilled, i.e. $\frac{\partial B}{\partial M^i}$ in eq. (4) replaces λ in eq. (2). The condition in eq. (4) shows that the optimal use of M^i occurs where its marginal cost equals the marginal benefit. As long as the marginal benefit exceeds the marginal cost, the use of the measure should increase, and vice versa. This is illustrated in Figure 2.

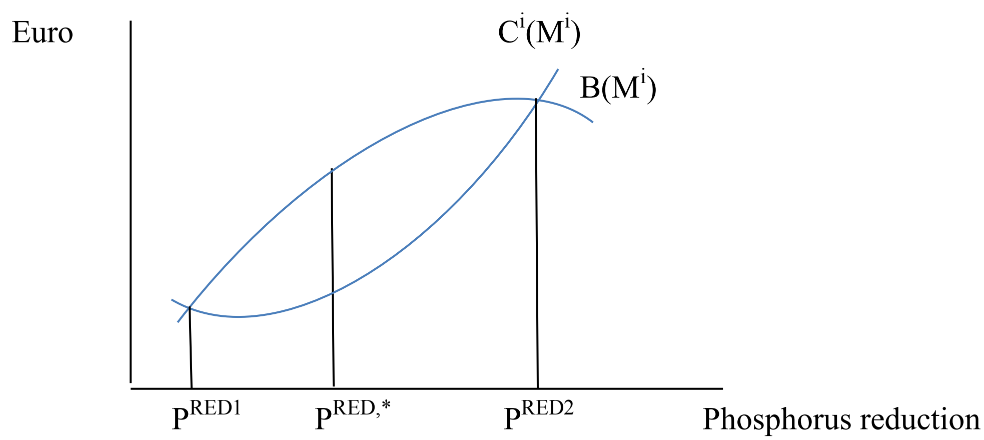

Figure 2: Illustration of optimality condition when maximizing net benefits of phosphorus reduction

Maximum net benefits are obtained where the difference between $B(M^i)$ and $C^i(M^i)$ is maximized which occurs at $P^{RED,*}$. At the left of $P^{RED,*}$ $\frac{\partial B}{\partial M^i} > \frac{\partial C^i}{\partial M^i}$ which means that an increase in costs of a marginal increase in the measure is lower than the decrease in damage from pollution, and the use of the measure should thus increase. The opposite is the case at the right side of $P^{RED,*}$. Only at $P^{RED,*}$ no changes can be made which imply increases in net benefits.

In general, it is not possible to the find functions for benefits, $B(M^i)$, and a common approach is then instead to take a specific measure, such as mussel farming, which gives a specific pollutant reduction and assess all associate benefits and costs. If the decision rule is to implement a project where benefits exceed costs, all projects generating reductions between P^{RED1} and P^{RED2} in Figure 2 would be accepted.

3. CEA and CBA in SAF

As shown in Section 2, CEA and CBA are outcome oriented approaches with specifications of decision makers' objective function, available technologies to achieve desired states, and the costs and effects of all technologies. It is a concrete tool for identification and calculations of the 'best' solutions, which depend on the specification of the objective function, benefits, costs, and technologies. In contrast, SAF is process oriented which includes, among others, identification of stakeholders' preferences with respect to what to be achieved, their analysis of different ways of achievements, and their tolerance and acceptance of different solutions. Therefore, SAF encompasses CEA and CBA at some, but not all, steps. In order to see this, we present the steps in CEA and CBA before making a comparison with SAF.

3.1 Steps in CEA and CBA

The main steps in CEA are:

CEA1. Determination of target(s) to be achieved, where and when. This can be enviromental targets such as a certain reduction in nutrient loads to a specific water recipient to be achieved at the latest within ten years. Another example is EU agreement on 80% reduction in GHG emissions at the latest in 2050. The targets can also include employment requirements or ensurance of health safety. In principle, there are no limits to the number and types of targets at this stage.

CEA2. Identification of all possible measures to obtain the target(s). There can be several ways of reaching a target. For example, nutrient loads can be reduced by land use changes and reductions in fertilizers in agriculture, improved cleaning at sewage treatement plant, and in situ cleaning by mussel farming.

CEA3. Calculation of effects on the targets of all possible measures. This implies that the impact of, e.g., reduced nutrient loads by land use change on the targeted water recipient and time period needs to be calculated. This may require quite advanced modelling to quantify links in time and space between measure(s) and target(s). For example, the impact of land use change on a water recipient necessitates bio-geo chemical and hydrological modelling of the catchment.

CEA4. Calculation of costs of different measures. As shown in section 2, most measures exhibit increasing and convex shape in the amount of, e.g., cleaning. The costs consist of outlays for labour, capital, equipment, and eventual opportunity cost of land. Cost functions for existing measures can be calculated by use of econometric methods applied to data on quantity and cost of the measure. For new technologies where such data are insufficient engineering methods are applied. When future targets are determined, there is also a need for quantifying eventual technological development of the measure, which can be of specific relevans for new technologies. Further, discount rate is needed which reflect decision makers' time preferences.

CEA5. Calculation of cost effective solutions. Given quantified targets, relations between measures and effects on targets, and estimated cost functions the cost effective solution can be calculated. These calculations can be quite involved and requires software such as GAMS to be be solved which is quite powerful and can manage a large number of variables, i.e. cost effective choices in time and space of a large number of measures (Rosenthal, 2016). Sensitivity analysis is carried out where parameters are changed and robustness of the results are investigated. In addition, scenario analysis of different states of the world, such as different climate change outcomes, are carried out.

In general, steps 3 and 4 provide the main impediments to a full-fledged CEA, where step 3 usually requires thorough modelling of within and between linkages of different ecosystems. For example, when targets are determined in terms of certain quality in a water recipient, such as water transparency, there is need of modelling impacts of pollutant on this quality indicator. Further, the transports of the pollutants in soil, water, air to the recipient need modelling since measures can be implemented at a variety of different places in the catchment. This integrated modelling is then linked to chosen measures, and associated estimates of costs.

Since these relations are likely to be determined only under conditions of uncertainty, the modeling approach presented in Section needs to be extended to account for this uncertainty. This can be made in several ways, where a common approach is to specify probabilistic targets instead of the deterministic formulation in the simple case illustrated in Section 2 (e.g. Gren et al., 2014). If this is chosen, both mean and variability in effects of measures have to be quantified in step 3.

Several, but not all, steps of a CBA are similar to those of CEA:

CBA1. Identification and definition of the project(s) included and choice of counter factual. For example, location and timing of a mussel farm and choice of alternatives to the mussel farm for improving water quality. A common counter factual is ‘do nothing’ or business as usual (BAU).

CBA2. Identify all effects of the project, who are affected where and when. For example, stakeholders of a mussel farm can be local enterprises who might gain profits from farming over of future period of time, and local labor and capital market from need of resources for building the farm.

CBA3. Quantification of the impacts of the project, when and where they occur. Similar to CEA3 this may require advanced integrated modelling, such as impact of mussel farming on nutrient loads, associated effects on fish populations and coastal communities. It also includes estimation of resources needed for building the mussel farms, such as labor hours and raw material. Both timing and location of these effects need to be quantified.

CBA4. Measurement of the quantified effects under CBA3 in monetary terms. For example, what is the monetary value of reduced nutrient loads from mussel farming? This may be determined by recreational values of eventual improved water sight depth and increases in fish populations.

CBA5. Comparison and assessment of current and future streams of costs and benefits under CBA4. This usually requires a choice of discount rate, i.e. conversion of future streams of cost and benefits into a present value. Similar to CEA5, sensitivity and scenario analyses are carried out in this step in order to identify robustness and sensitivity of results.

The main challenges in a CBA are steps 3 and 4. The difficulty in step 3 is similar to that in CEA3 where effects that are transmitted through different environmental and economic media need to be quantified in space and time. Common to both approaches in step 4 is the calculations of costs of, e.g. a mussel farm, but CBA4 contains an additional challenge by assessing the environmental effects in monetary terms. It is then not enough with e.g. a water quality target as in CEA, but also the valuation of this in monetary terms. The valuation of environmental changes in monetary has been highly debated, but the valuation methods have shown a rapid development since mid 2000s (e.g. Turner et al. 2003).

Another highly debated issue is the choice of discount rate, which is needed when effects occur over a period of time. This is needed in both CEA and CBA, and there is no consensus on which level of the discount rate is most appropriate. Another common difficulty is how to treat and account for different types of uncertainty, and distributional effects on different stakeholders.

3.2 Placing CEA and CBA in SAF

Both CEA and CBA are relatively pragmatic and output oriented approaches to solve problems in an economically efficient way. They provide tools for a systematic evaluation of costs (for CEA) and benefit (for CBA) once decision are made on environmental targets to be achieved or projects to be implemented. Unlike CEA and CBA, SAF is mainly process oriented. It presents a systematic way of identifying and solving different types of human created environmental problem. Due to its focus on stakeholder participations, it is oriented towards relatively local environmental problem. This is not to say that CEA and CBA are not process oriented. On the contrary, they are both quite concrete and provide a systematic discussion, data collection, and result evaluation of involved stakeholders but to different degrees. SAF on the other hand does not provide any concrete methods but instead point out how the need of these methods can be identified. In general, the SAF includes five main steps, and the similarities with the five steps in CEA and CBA are presented in the following.

SAF1. Issue identification, which aims at prioritizing of problems. The first step of both CEA and CBA is similar to this by the choice of targets in CEA1 and the identification of projects in CBA1

SAF2. System design defines the virtual system and describes the conceptual model. Neither CEA nor CBA contains the construction of a virtual system but starts up with concrete modelling and numerical representation of the systems relevant for the targets or projects chosen.

SAF3. System formulation. involves the mathematical formulation of quantitative sub-models for each system component. This step is the most important in both CEA and CBA which covers CEA2-4 and CBA2-4.

SAF4. System appraisal. Here, sub-models are appraised together with specialist before being linked to a complete system model for running scenario simulations. This phase is most similar to the final steps in both CEA and CBA where evaluations are made of cost effective paths, or whether a project generates net benefits under different scenarios and robustness tests.

SAF5. System output. Results of scenario simulations are discussed and evaluated together by stakeholders and managers. This is not a part of the CEA or CBA as such, rather they can provide input into this phase of the SAF.

Table 1: Comparison of action steps in SAF, CEA, and CBA

SAF	CEA	CBA
SAF1. Issue identification	CEA1. Definitions of environmental target(s) to be achieved	CBA1. Identification and definition of the project(s)
SAF2. System design	----------	------------
SAF3. System formulation	CEA2-CEA4 calculate costs and impacts on the targets of all the measures	CBA2-CBA4 identification, quantification, and valuation of all effects of a project
SAF4.	CEA5 based on steps 1-3 calculate cost effective solutions to different targets. Sensitivity and scenario analysis	CBA5. Compilations and assessment of all costs and benefits. Sensitivity and scenario analysis
SAF5	----	---

There is one noteworthy difference between CEA on one hand and CBA and SAF on the other. In general, CEA are applied to relatively large national and international scales. An early application is the minimization of costs for reaching different SO_2 targets in Europe (e.g Klassen, 1995), which was used as decision support for the successful international agreements on reductions in SO_2. Other examples are regional and international CEA for reaching climate change targets (IPCC, 2014), and nutrient load reduction targets to the Baltic Sea (Gren et al. 1997). Clearly defined reduction targets, which have often been defined in international agreements, provide input into CEA. On the other hand, CBA is most often defined for relatively local and well defined projects. The need to identify and quantify both costs and benefits of all effects makes it difficult to implement at a large scale. Similarly, the process and participatory approaches applied in SAF necessitate relatively few stakeholders, which are found mainly for local projects.

4. Applications to case studies

In the following we provide examples of how the CBA or CEA can be applied to some case studies in BaltCoast. This is ongoing work in the BaltCoast project and the applications presented here should thus mainly be regarded as examples.

4.1 Lithuania; bathing water quality and possible beach places on the Curonian Lagoon site

Several beaches in the Curonian Lagoon are closed because of unsatisfactory water quality according to the EU Bathing Water Directive. However, a change has been made with respect to the measurement of water quality which now focus only on E.coli and enterococci. This makes it possible to re-open closed beaches. The specific question for this study is if this should be made for the Nida beach located closely at the Neringe municipality in Lithuania. A specific problem is then the uncertainty in future bathing water quality because of stochastic weather and pollution loads, which may necessitate closing of the beach.

This is a typical project for a CBA, which will give answers of net benefits and their allocation among stakeholders and over time.

CBA1, SAF1. Definition of project

This first step requires the determination of the project, counterfactual, location and time period, which could look like as in Table 2

Table 2: CBA1 for reopening of a beach in Curonian Lagoon

Project	Counterfactual	Location	Time period
Creation (or reopening) of a bathing site in the Curonian Lagoon site under risk of water quality failure	BAU, i.e. no opening	Nida	2017-2037

In this case, it is assumed that the beach can be opened in 2017, and that the time period of 20 years is relevant for all benefit and cost items to occur.

CBA2, SAF3: Identification of effects

The second step, i.e. CBA2, implies the identification of all positive and negative effects of the project. Let us simplify and distinguish between two possible water quality outcomes: sufficient water quality with probability p^S and water quality failure where the beach must be closed with a probability $1\text{-}p^S$. Examples of benefit and cost items in these two cases are provided in Table 3

Table 3: Positive and negative effects of opening the Nida beach conditions of future sufficient and insufficient water quality.

Sufficient water quality with probability p^S (the beach remains open)		Water quality failure with probability $1\text{-}p^S$ (the beach closes)	
Positive	Negative	Positive	Negative
Increased number of visitors at the site	Investment and operational costs of the beach	Savings of operational costs for the remaining period	Lost investment capital
Source of income for the tourist sector in Neringa municipality	Less visitors to other areas	More visitors to other beaches	Loss of incomes for the tourist sector
Net employment opportunity	Eventual effects on a neighboring protected Natura 2000 area	Eventual positive effects on Natura2000 area	Lost employment opportunity

CBA3, SAF3: Quantification of all effects.

This step includes the quantification of the probability for sufficient water quality, p^S, which can be made by combining traditional monitoring methods, with 3D hydrodynamic transport models and strain-specific genetic fingerprint methods.

In addition to p^S, there is a need for listing all quantified effects at the time of their occurrence. For example, investment cost is likely to be born year 1, and operational costs for all years 1-20. Visitors may start to come already in the first year, and then at specific number in subsequent years. Similarly, employment and regional economic effects may act from the second year, see Table 4 for an example.

Table 4: Example of a CBA table with effects in different time periods with sufficient water quality.

Year	Positive	Negative
1	Visitors	Investment cost, decreased visitors to other beaches
2-10	Visitors, income, employment	Operational cost, decreased visitors to other beaches
10-20	Visitors, income, employment	Operational cost, decreased visitors to other beaches, impacts on Natura2000

In a similar vein, a table needs to be constructed in case of water quality failure, the positive and negative effects will then be affected by the timing of the failure. If the failure occurs already in the beginning there are no losses of investment capital.

Although the example presented in Table 4 seems relatively simple, the construction of such a table, or several tables, in practices can require much effort in terms of modelling and data collection.

CBA4, SAF3: Measurement of effects in monetary terms

If quantification of effects can be difficult, their valuation in monetary terms can pose more of a problem. In general, the monetary value assigned to an effect is measured by means of market prices. For example, the costs of capital for investments consist of the opportunity cost of other investment options, which is expressed in the market interest rate. Similarly, cost of labor is measured in terms of market wages.

When market prices are not available, such as for visitors' recreational value of the Nida beach, other approaches are needed. The basic principle for deriving visitors' recreational values and their spending on expenses is illustrated in Figure 3.

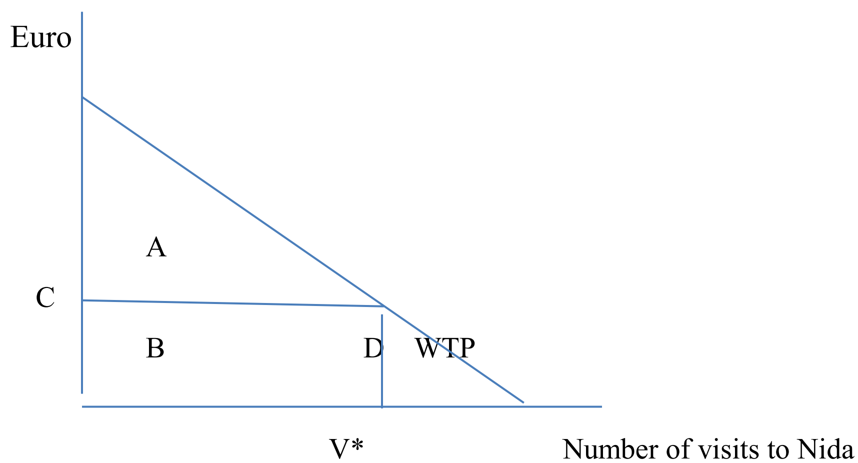

Figure 3: Illustration of visitors' willingness to pay (WTP) for a visit to Nida, incomes for the tourist sector at the hypothetical unit access cost C, and number of visitors V.*

The willingness to pay (WTP) curve shows the amount a visitor is prepared to pay a certain amount to visit the Nida beach. If we make the simplifying assumption that the cost of a visit is the same for all visitors, and amounts to C, the number of visits corresponds to V*. All WTP above this level create consumer surplus, which correspond to the area A and is thus the welfare impacts on visitors.

The total payments for visits amount to CxV*, or the area D in figure 1. These payments can be made to hotels, transport systems, and/or restaurants in the city Neringa, and thus provide associated incomes in the regions.

Although a relatively simple principle, the WTP for all visitors can be difficult to measure in practice. There are a number of methods for measuring values of non-market services which all have their advantages and disadvantages (see Turner et al. 2003 for a review). It is probably more easy to measure the visitors' payments for, e.g. recreational equipment, in Neringa which provide a source of income for the municipality.

CBA5, SAF4: Assessment of all cost and benefit items and final recommendation

Assume now that we have calculated all costs and benefit items in case of success and failure of bathing water quality as illustrated in Table 4. The most simple decision rule is then to accept the project if the expected net benefits in present terms are positive. This can be written as

$$NB = \sum_t \frac{1}{1+r}\left[p^S\left(\sum_i (B^{it,S} - C^{it,S})\right) + (1-p^S)\left(\sum_j (B^{jt,F} - C^{jt,F})\right)\right] \qquad (5)$$

Where $B^{it,S}$ and $C^{it,S}$ are benefit and costs in different time periods, t, of a success, and $B^{it,F}$ and $C^{it,F}$ are those of a failure when the beach must be closed. Since all items occur in different time periods we need to express them in present terms which is made by the discount factor $\frac{1}{1+r}$, where r is the discount rate. The higher the discount rate, the lower are future benefits and costs. In general, sensitivity analysis is carried out where, for example, r and/or p^S is changed, or one or several of the cost and benefit items. This gives a range of parameter values where NB is positive and, hence, the implementation of the project is recommended.

4.2 Germany, value of mussel farming as an option to combat eutrophication

The main question raised in this project is whether benefits of mussel farming exceed costs. Cultivation of mussel can contribute to improved quality of eutrophied waters. In addition, the harvested mussels can be used for feed or as an energy source. However, the performance of the mussels depends on weather conditions, which are stochastic. All outcomes are therefore associated with uncertainty. The CBA steps for this project can then be described as follows.

CBA1, SAF1: Definition of project

In this example, we consider a mussel farm in the Oder catchment, and a time period of 10 years.

Table 5: CBA1 for mussel farming in the Oder catchment

Project	Counterfactual	Location	Time period
Cultivation of Zebra mussels for reducing damages of eutrophication	BAU, i.e. no mussel farm	Szczecin Lagoon	2017-2027

CB2, SAF3 Identification and quantification of effects

Different positive and negative effects are associated with mussel farming, where we perceive the uncertainty in nutrient cleaning as a negative aspect.

Table 6: Identification of effects of a mussel farm in Szczecin Lagoon

Positive	Negative
Mussel as feed and/or food	Investment and operational costs
Employment opportunities	Eventual negative effects on the food web, fish
Water cleaning	Uncertainty in harvest and water cleaning

CBA3, SAF3: Quantification of effect

Table 7: Quantification of effects of mussel farming

Year	Positive	Negative
1	Employment opportunities in number of full time worker per year Water cleaning in ton N and P per year	Investment and operational costs in Euro Uncertainty in N and P cleaning as standard deviation
2-10	Employment opportunities in number of full time worker per year Water cleaning in ton N and P per year Mussel as feed and/or food in ton biomass	Operational cost Eventual negative effects on the food web, fish, reduction or increase in populations of other species Uncertainty in harvest and water cleaning in standard deviation of the calculated mean harvest in biomass and ton N and P uptake

CBA4, SAF3: Measurement of effects in monetary terms

Mussel as feed can be measured by associated market prices. The value of water cleaning depends on the access to alternative options and their expenses, which is illustrated in Figure 4.

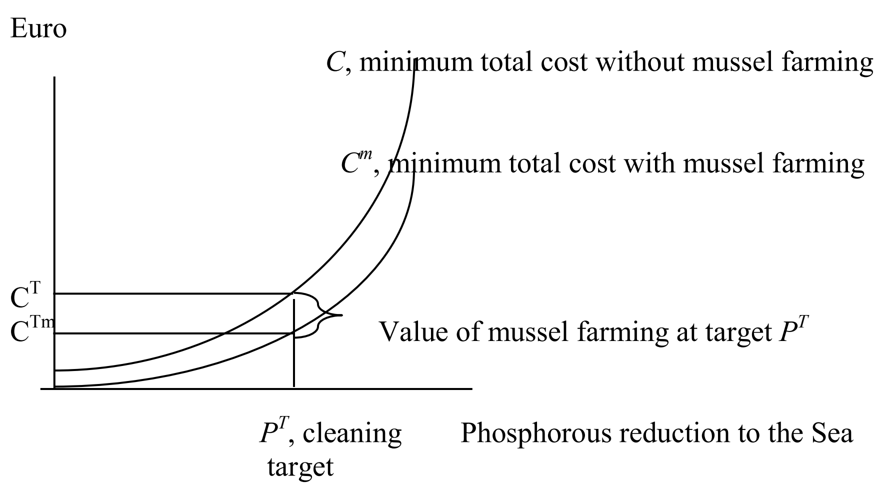

Figure 4: Illustration of calculation of the value of mussel farming as an abatement measure in a cost effectiveness framework

The value of mussel cultivation is calculated as the cost savings of including this measure in a nutrient cleaning program. Costs for achieving a certain cleaning target, P^T, is then calculated with and without mussel farming as an option. A value of mussel farming then emerges only when total minimum costs without mussel farming, C^T, exceeds the total minimum cost with mussel farming, C^{Tm}. Then, mussel farming replaces more expensive abatement measures.

A challenge in this project is how to measure uncertainty in harvest and nutrient cleaning of mussels. In general, society and private persons are risk averse, which means that they prefer a certain outcome compared with an uncertain which gives the same expected value (e.g. Boardman 2012). An example of measurement of the cost of risk is the WTP for a lottery. For example, consider a lottery that gives Euro 10000 with a probability of 0.5 and 0 with a probability of 0.5. The expected income of the lottery is Euro 5000, but the WTP of most people is less than 5000 because of the risk to obtain Euro 0. The different between 5000 and WTP is then the cost of risk, which, in turn, depends on the risk aversion. The larger risk aversion, the higher is the cost of risk.

CBA5, SAF4 Assessment and recommendation

Similar to the case study of opening a beach in Lithuania, costs and benefits of mussel farming occur under different time benefits, which mean that we need to use a discount rate. In addition, there is a need for considering the risk in benefits and costs. A common approach is the use a so-called mean-variance approach which considers both mean and variance in net benefits:

$$NBR = \sum_t \frac{1}{1+r}\left[E[\sum_i (B^{it} - C^{it})] - \theta Var(\sum_i (B^{it} - C^{it})\right] \qquad (6)$$

where E is the expectation operator, θ is a measurement of risk aversion, and *Var(.)* is the variance in annual net benefits. Thus, the higher θ and/or variance in net benefits the lower is the discounted total net benefits NBR.

5.Conclusions

The main purpose of this study was to analyse how CEA and CBA can be included into SAF. It was then found that both CEA and CBA are part of SAF, but not vice versa. This can be explained by the methods' different approaches to solve environmental problems. CEA and CBA are outcome oriented with clear definitions and formulations of objectives and means to reach them. Outputs provide information on least costs to achieve certain environmental target (CEA) or net benefits from specific environmental projects (CBA). SAF is a process oriented approach where environmental problems to be solved are identified by stakeholders, different solutions, are obtained, and choices are made by agreements.

However, once objectives and projects are identified CEA and CBA can be quite useful tools for assessment of all potential options and effects, and provide a basis for choices. Neither CEA nor CBA investigates the acceptance of outcomes but only a range of outcomes under different conditions. SAF, on the other hand, includes this acceptance step where the results from CEA or CBA can provide useful inputs.

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