WaterStrategyMan
EVK1-CT-2001-00098

MANUAL OF THE INTEGRATED DECISION SUPPORT SYSTEM

Chapter Seven

Economic Analysis

.

Chapter 7: Economic Analysis

The economic analysis in the WSM DSS consists of a tentative implementation of the principles associated to the estimation of the *Full Water Cost* and its components. The articles of the Water Framework Directive 2000/60 pertaining economic issues build on the perception of water as a social common good, as it came out from important international conferences: *"water has an economic value in all its competing uses and should be recognized as an economic good"* (Water and Environment, Dublin 1992) and *"integrated water resources management is based on the perception of water as an integral part of the ecosystem, a natural resource, and a social and economic good"* (Environment and Growth, Rio 1992).
Article 9.1 of the Directive refers to the recovery of the full cost of water services and clarifies the cost components that should be included in the full costs. The include:

- The supply cost that represents the costs of investments, operation and maintenance, labour, administrative costs and other direct economic costs.

- The resource cost that represents the loss of profit because of the restriction of available water resources.

- The environmental cost that represents the cost from the damage on the environment and aquatic ecosystems caused by the water uses and services.

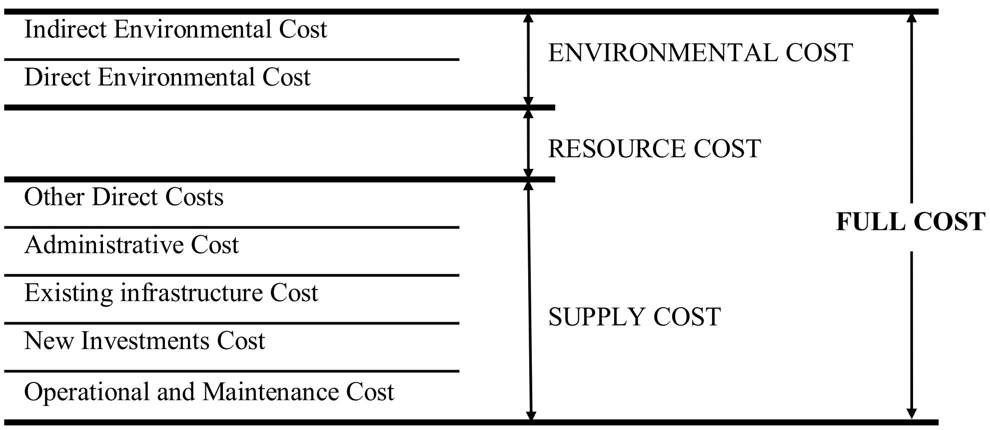

Fig. 1 Components of the full cost of water services

The formulation defining the Resource Water Cost that has been implemented within the WSM DSS is presented in the following section. For the purpose, a simple network of water sources and users is supposed to exist, the one supplying water to the others. The notation and the approximations used are:

- i - generic water source;
- j - generic water user;
- $C_{i,j}$ – average cost of allocating water from source i to user j;
- $Q_{i,j}$ – amount of water from source i allocated to user j;
- The marginal value of water for each user V_j is assumed to be identical to the average value and it is defined by the DSS user according to the specific water user: for instance, it can be approximated by the marginal cost of the most

expensive source under use, in the case of urban use, or it can depend on crops market price, average annual yield, annual water supplied and the alternative value of land;

The following equations express the economic parameters involved in the calculation of the cost recovery for water, which is defined as the percentage ratio of the total income to water suppliers over the total cost of water production. As far as the latter, the cost of water supply for each water source is computed first and then that is summated over the sources to get the total cost.
The Cost of water supply from source i to all the users j derives from the unit cost for allocating the resource multiplied by the amount of it that is actually allocated:

$$TC_i = \sum_j C_{i,j} \cdot Q_{i,j}$$

The Total Cost of water production and supply is the summation on sources of the Cost of water supply:

$$TC = \sum_i TC_i$$

The total income (*TI*) to water suppliers is computed with an analogous formulation, where the prices $P_{i,j}$ is the price of water from source i allocated to used j:

$$TI = \sum_i \sum_j P_{i,j} \cdot Q_{i,j}$$

Note that, in case the price of water from source i allocated to user j is assumed to equal the average costs of allocating water from source i to user j, the total income of water suppliers is equal to the total cost of water production and supply. As a consequence, all the water costs are recovered (rate of recovery is 1).

Other economic parameters are implemented in the WSM DSS in order to analyse the rate of cost recovery and how it changes when water prices are subsidized. They are the Total Water Value, the Private Water Surplus and the Social Water Surplus.
The Water Value *TV* associated with water consumption accrue to the j^{th} user is given by marginal value of water for each user multiplied by the amount of water allocated:

$$TV_j = \sum_i V_i \cdot Q_{i,j}$$

Based on the Water value, the Private Water Surplus, which signifies the Net Benefit from Water Use, accrue to each water user is:

$$PWS = \sum_j PWS_j = \sum_j \left(TV_j - \sum_i P_{i,j} \cdot Q_{i,j} \right)$$

On the other side, the total social water surplus (SWS) in the hypothetic network considered can be approximated by the difference between the total value and the total cost:

$$SWS = TV - TC = \sum_j TV_j - \sum_i TC_i$$

Going back to the assumptions on prices, if prices coincide with the average costs for allocating water from resources to users, the rate of cost recovery is 1 and the private water surplus equals the social water surplus. If prices are subsidized, prices are lower than costs and the total income to water suppliers is less than the total cost for water supply. In this case the rate of cost recovery is less than 1 and the private surplus exceeds the social surplus by the level of subsidy.

What follows now in this chapter about the economic analysis in the WaterStrategyMan Decision Support System is a presentation of the approach to environmental costs (EC) that is currently under practice by the French Agencies de l'Eau. This approach includes three issues: environmental costs for pollution charges, environmental benefits produced by wastewater treatment plants and cost by abstractions and consumptions.
An *Environmental Cost* can be defined as the cost that a "society" will have to pay in the future (soon or later) because of the impacts on environment caused by economic activities, products or services. Most of time this type of cost is *external*; this means that the cost is equal to the monetary value attributed to the reduction of an advantage or to a damage undergone by society because of a deterioration of the environmental quality which was not taken into account in a market operation.
According to the neo-classical theory, it is essential to reintegrate (internalise) this monetary value in market operations. There are different justifications for this assumption in the case of the water resources degradation:

a) if this cost is underestimated or disregarded, then the future users of the resource will have to pay for the measures needed for the restoration of the resource degraded by currents users;

b) the polluter doesn't pay for the damage he caused;

c) if this cost is underestimated or disregarded, the current users are not encouraged in taking care of the water resource.

For these reasons, the European Water Framework Directive underlines the following principle: *"The use of economic instruments by Member States may be appropriate as part of a programme of measures. The principle of recovery of the costs of water services, including environmental and resource costs associated with damage or negative impact on the aquatic environment should be taken into account in accordance with, in particular, the polluter-pays principle."*
Different methods are developed and applied to place monetary values on environmental services. They are outlined in the next table.

Name	Definition
Market methods	These methods use values from prevailing prices for goods and services traded in markets. Values of goods in direct markets are revealed by actual market transactions and reflect changes in environmental quality: for example, lower water quality affects the quality of shellfish negatively and hence its price in the market.
Cost-based valuation methods	This method is based on the assumption that the cost of maintaining an environmental benefit is a reasonable estimation of preventive and / or mitigation measures. This assumption is not necessarily correct. Mitigation may not be possible in all cases, for example, in cases where actual mitigation cost could be an underestimation of true environmental cost. On the opposite, a mitigation measure might not be cost-effective and these costs might lead to an over-estimation of environmental costs. A distinction needs to be made between: The costs of measures already adopted, which are theoretically already included in financial cost category. These costs should be reported as a distinct financial cost category. Counting them as environmental costs would be double counting. The costs of measures that need to be taken to prevent environmental damages up to a certain point, such as the Directives' Objectives. These costs can be a good estimate of what society is willing to forego.
Revealed preference methods	The underlying assumption is that the value of goods in a market reflects a set of environmental costs and benefits and that it is possible to isolate the value of the relevant environmental values. These methods include recreational demand methods, hedonic pricing models and averting behaviour models (see below)
Hedonic Pricing	This method explains variation in price (in the price of goods) using information on "qualitative and quantitative" attributes. They are used in the context of water to value how environmental attributes and changes affect property prices. In addition to structural features of the property, determinant of property prices may include proximity to, for example, a river or lake. The change in property price corresponding to an environmental degradation, for example the pollution of a river or lake is the cost of this degradation.
Averting Behavior	This method derives from observations of how people change defensive behavior – adapt coping mechanisms – in response to changes in environmental quality. Defensive behavior can be defined as measures taken to reduce the risk of suffering environmental damages and actions taken to mitigate the impact of environmental damages. The costs for mitigating the impact may entail expenditure on medical care needed as a consequence of drinking poor quality water. The expenditure produces a value of the risk associated with the environmental damage.
Recreation Demand Models (RDM)	Improvements or deterioration in the water quality may enhance or reduce recreation opportunities (e.g. swimming) in one or more sites in a region. However, markets rarely measure the value of these changes. RDM can be used on the choices of trips or visits to sites for recreational purposes and the level of satisfaction, time and money spent in relation to the activity. By assuming that the consumer spends time and money as if he was purchasing access to the goods, for example a river stretch, patterns of travel to particular sites can be used to analyse how an individual values the

	site and, for example, the water quality of the river stretch. Reductions in trips to a river due to deterioration of water quality and associated changes in expenditures reveal the cost of this deterioration.
Stated preference methods	These methods are based on measures of willingness to pay through directly eliciting consumer preference on either hypothetical or experimental market. For hypothetical market, data are drawn from surveys presenting a hypothetical scenario to the respondents. The respondents make a hypothetical choice, which is used to derive consumer preferences and value. Methods include contingent valuation and contingent ranking. It is also possible to build experimental market where money changes hand, e. g. using simulated market models. In the questionnaire, it is possible to ask respondents how much they would pay for avoiding an environmental cost or how much they value a given environmental benefit.
Contingent Valuation	Contingent Valuation is based on survey results. A scenario including the good that would be delivered and how it would be paid for (e.g. through an increase of the water bill) is presented to the respondent. Respondents are asked for their willingness to pay (WTP) for the specified good. The mean willingness to pay is calculated to give an estimated value of the good. One of the difficulties with this approach lies in ensuring that respondents adequately understand the environmental change that is being valued.
Use of Value Transfer	It is an alternative option to direct valuation of environmental costs or benefits - more commonly known as benefit transfer in the case of benefits): This method uses information on environmental costs or benefits from existing studies and uses this information for the analysis in the river basin under consideration. As a result, a data set that has been developed for a unique purpose is being used in an application for a different purpose, i.e. it transfers values from a study site to a policy site, i.e. from the site where the study has been conducted to the site where the results are used. Above all, benefit transfer is suitable when technical, financial or time resources are scarce. However, among other problems, it is important to note that since benefits have been estimated in a different context they are unlikely to be as accurate as a primary research. A step-wise approach should be developed in order to ensure that the transfer of values derived in other contexts could minimise the potential for estimation errors.

Table 1 Available methods to place monetary values on environmental services

The environmental cost for pollution is a quantity associated to quality parameters, and depends on the their quantities *A* rejected by the different users during a normal day of the month when the maximal discharge occurs (*charge base*). Charge bases can be given either by monitoring measurements or estimated. Other variables defined for each quality parameter are involved in the environmental cost estimation: the charge rates *R* in euros per unit concentration, and a coefficient *Coef*, that take into account the sensibility of the aquatic ecosystem,. The equation used for each quality variable *QW* is:

$$EnvCostPollution_{QW} = A_{QW} \cdot Coef_{QW} \cdot R_{QW}$$

And the Total Environmental Cost for pollution is given by the summation over all the present quality variables.

The environmental cost for a quality variable represents an estimate of the costs of measures that need to be taken to prevent environmental damages up to a certain point, such as the Directives' Objectives (*Cost-based* valuation approach), that is should equal the total of investment, maintenance and operation costs of treatment for each quality parameter, both waste water and water production.

The general methodology applied by the French Agences de l'Eau, and implemented in the WSM DSS, for estimating the environmental benefit produced from a wastewater treatment plant starts from the same equation as for pollution charges, and applies a new term, namely the Bonus Annual coefficient. This value is defined for each quality variable as its pollution abatement coefficient, estimated according to an overall appreciation of the wastewater process operation effectiveness. The equation expressing the environmental benefit (EB) by waste water treatment for all the QW quality variables is:

$$EB = \sum_{QW} \left(A_{QW} \cdot Coef_{QW} \cdot R_{QW} \cdot BonusAnnualCoef_{QW} \right)$$

Where A_{QW} and $Coef_{QW}$ are charge base and the sensibility coefficient respectively for the quality parameter QW.

The environmental cost for water abstraction and consumption applied in the WSM System is estimated through the following equation:

$$EnvCost_{Abs,Cons} = \left[Abs \cdot AbsCB \cdot (AreaCoef + ImpactCoef) \right] + \left[Cons \cdot ConsCB \cdot (AreaCoef + ImpactCoef) \right]$$

The involved terms are: *Abs* and *Cons*, as the abstraction and consumption during the reference period, *AbsCB* and *ConsCB* as the corresponding charge base, and a set of coefficients. The Area coefficients vary according to type of the water resource, either surface or groundwater, and to the intake localisation, that is if the abstraction affects a resource that is overexploited or not in that area.
An impact coefficient may be applied when the two following conditions occur at the same time:

1) *Abstraction* > *Y* m^3 during the reference period in no over exploited area

2) The ratio between the average monthly flow at the abstraction point and the natural flow in the driest month within a five-years frequency at the abstraction point is greater than *X* m^3, where Y and X must be chosen according to local conditions.

The reference periods are user-defined and depend on the type of the resource; normally for surface water it runs from 1st of May to the 30th of November and for groundwater from the 1st of April to the 31st of October. In principle, they should be chosen according to the local meteorological and hydrological conditions.

The supply cost, or Direct cost is another component of the full cost of water. It comprises of:

a) Operating cost: all costs needed to maintain the operation of an environmental facility (e. g. material and staff cost).

b) Maintenance cost: cost for maintaining existing (or new) assets in good functioning order until the end of their useful life.

c) Capital cost:
   - New investments: costs for new investment expenditures and associated costs (e.g. site preparation costs, start-up cost, legal fees)
   - Depreciation: the depreciation allowance represents an annualized cost of replacing existing assets in future. The estimation of depreciation requires the definition of the value of existing assets and a depreciation methodology.
   - Cost of capital: It is the opportunity cost of capital, i.e. an estimation of return that can be earned by alternative investments. The cost of capital applied to the asset base (new and existing, give the profits that investors are expecting to gain from their investments).

d) Administrative cost: administrative cost related to water resource management.

e) Other direct cost: this mainly consists of the costs of productivity losses due to restrictive measures.

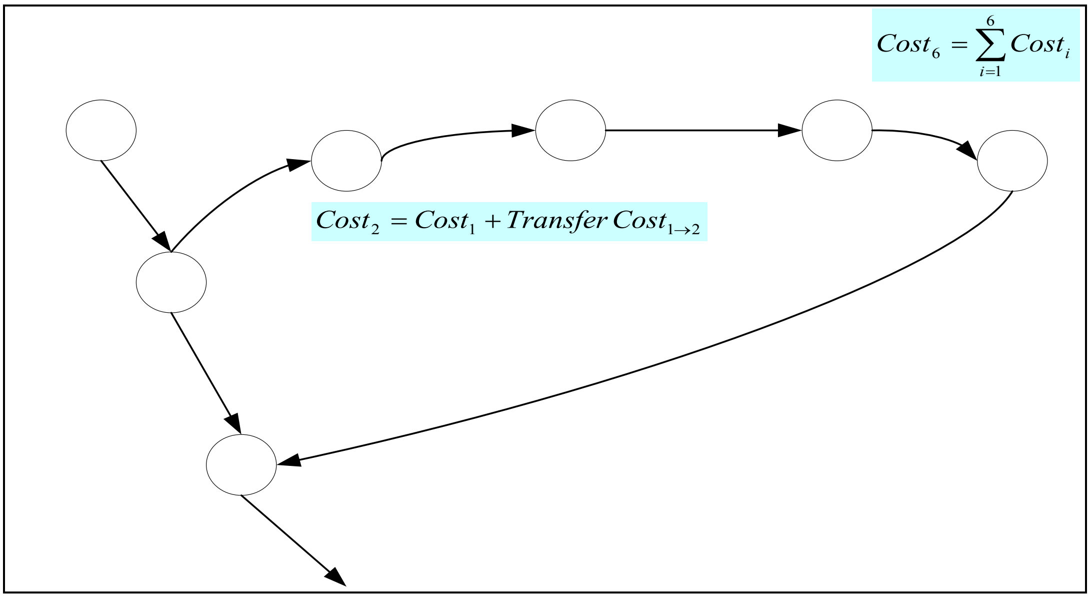

Fig. 2 Example of direct cost estimation for a settlement (node 6 - city)

In the WSM DSS the direct cost of whatever node A, taking water from the water source B, both belonging to the regional water resource network, is computed by summating the direct costs and the transfer costs of all the nodes along the water path connecting them. For example, if a city receives water from a water treatment plant, which is fed by a

storage reservoir, which is in turn supplied by a river reach node, then the direct cost of water to the city derives from the direct costs of the four nodes plus the three direct cost of the link carrying water from one another.
The direct cost of each node is based on the present value of the different parts of the infrastructure. Present values can be estimated by using one of the following methods:

a) Historical value (used as methods of valuation of capital asset): It is the value of assets at the price they were originally purchased. Because of inflation, this value bears nor relation with what it would actually cost today to replace those assets – therefore, it is not the best measure for estimating economic costs.

b) Current value (used as methods of valuation of capital asset): It is the historical value multiplied by an inflation index. Calculating this value raises a number of issues:
   - Estimating the inflation index may be open to interpretation [should the general inflation or the construction (or consumer) price index be used];
   - This method does not take into account technical progress: a water treatment plant that costs a given amount 10 years ago might cost half today thank to technical progress.

   However, this method is relatively easy to apply and is more appropriate than the historical value method.

c) Replacement value method (used as method of valuation of capital asset). This method estimates the present value of an asset from the current cost of replacing it for an identical service level. The advantage of this method is that it allows taking into account technical progress. However, it might be difficult, costly and time-consuming to apply to all the capital stock.

For the evaluation of the Direct Cost (DC) per m^3 for the entire time horizon, all fixed and variable costs should be estimated in present value (PV) terms:

$$DC = \frac{PV_{Fixed\ cost} + PV_{Variable\ cost}}{PV_q}$$

Where *Fixed cost* refers to capital-investment costs while *variable costs* are the Operation, Maintenance and Energy Costs, Running Costs in the DSS, which depend on the monthly flows in network links computed by the allocation module of the DSS. For the estimation of energy cost, a tariff system for energy prices has been introduced in the structure of the regional WSM Geodatabase in order for the DSS to be able to estimate the marginal cost of water production. The present value of quantities allocated to demand nodes, for the entire simulation time horizon *T*, is computed through the annual real interest rate *r* relevant for the investor, the price *P* per unit of supplied water charged by the water company, and the annual quantity of supplied water *Q* :

$$PV = \sum_{t=0}^{T} \frac{P.Q_t}{(1+r)^t}$$