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CHAPTER 12
ECONOMIC AND FINANCIAL ASPECTS OF DRINKING WATER AND WATER TREATMENT PLANTS

Abstract

The chapter starts by looking at the evolution of economic and financial aspects of drinking water and water treatment plants. Then examines the economic and financial procedures of drinking water. Accordingly, this chapter defining includes strategic content and assessment of environmental impacts for the water treatment plants. The demand analysis of the drinking water treatment plants discussed in detail under the economic and financial procedures. Includes, main parameters of demand projections and how to asses and different approaches to the evaluation of the demand. Then addressed estimation cost of water for drinking water treatment plant provides a selection of the various classification systems. Finally, the chapter presents an overview of treatment and sanitation costs for the infrastructure services.

12.1. Introduction

As mentioned Chapter 11, achieve to drinking water has been on the global agenda for decades and water authorities are trying to satisfy the growing urban water and sanitation demands. However, urban water management for providing essential services are costly. Because in many places it is impossible to obtain the desired quantity and quality of safe drinking water supplies using the proprietary technology, in accordance with the water supply and pollution levels. The development of treatment project is a complex and resource-intensive process. Therefore, careful planning and analyzing have an important role to play in treatment and sanitation process. In addition, reliable cost calculations and estimation, which based on financial and economic analysis, are essential in the water sector.

12.2. Basics of Economic and Financial Analysis

Economic and financial analysis can inform decisions at the project identification and preparation stages by contributing to strategic choices for offering specific levels of service. These analyses are essential for designing appropriately scaled, cost-effective projects as well as avoiding unnecessary costs of delay and unwise investment. Key areas for analysis are the demand for different levels of service, the use and targeting of public subsidies, and how to reform tariffs and improve utility finances Both economic and financial appraisal are vital parts of project monitoring and evaluation (URL 1). At the same time, economic and financial analyses are clearly distinguished with respect to analytical perspective. Economic analysis considers benefits and costs of a project for the society as a whole and compares alternatives that address an identified problem and objective. Each alternative is analyzed using the same period of analysis and baseline conditions. Financial analysis should be completed if the economic analysis demonstrates that the project is justified. A financial analysis is concerned mostly with a project's ability to generate enough revenues to pay back financial costs incurred in facility construction and operation (Souza et al. 2011). Therefore, distinction between financial and economic analysis is an important for the project. For example, if the financial and economic boundaries of a project are the same, as in public utility projects differences between financial and economic returns come down to differences between financial and economic prices. The main differences between the economic and financial values of project costs and benefits (Nielsen, 2005). Because, for instance, when calculating the discount rate, inflation is included in financial analysis, which uses nominal prices. Discount rates are used in economic analysis to convert benefit and revenue streams to monetary units of a year of reference thus real prices in economic analysis excludes inflationary effects, but accounts for individual price changes. Similarly, the marginal cost of raw water comprises not only the investment and operation and maintance costs calculated as average incremental cost, but also the opportunity cost of water. The opportunity cost of water is the benefit forgone in the next best alternatives of water. On the benefit side, financial benefits may include both quantifiable and nonquantifiable benefits associated with water from alternative sources being displaced by the project, and new and additional sources of supply becoming available (ADB, 1998). But both approaches include an evaluating process for each alternative then compared to the "without project" scenario, the alternatives are ranked, and the best alternative is selected (Souza et al. 2011).

Table 12.1 Key Aspects of Economic and Financial Analyses

Aspect	Economic Analysis	Financial Analysis
Analysis perspective	Accounts for all benefits and costs "to whomsoever they shall accrue	Accounts only for benefits and costs realized by a project proponent
Inflation adjustment	Uses real prices, which exclude general inflationary effects but accounts for individual resource price changes different from the general inflation rate (labor, energy).	Uses nominal prices and revenues which include inflationary effects
Discount rate	Calculates net present value using two real (no inflation) discount rates: 1) the consumption discount rate of and 2) return to private capital	Not Applicable
Interest Rate	Not Applicable	Nominal (includes inflation) cost of borrowing money

The basic framework of the financial and economic analysis is given below (Figure 12.1) in accordance with Table 12.1.

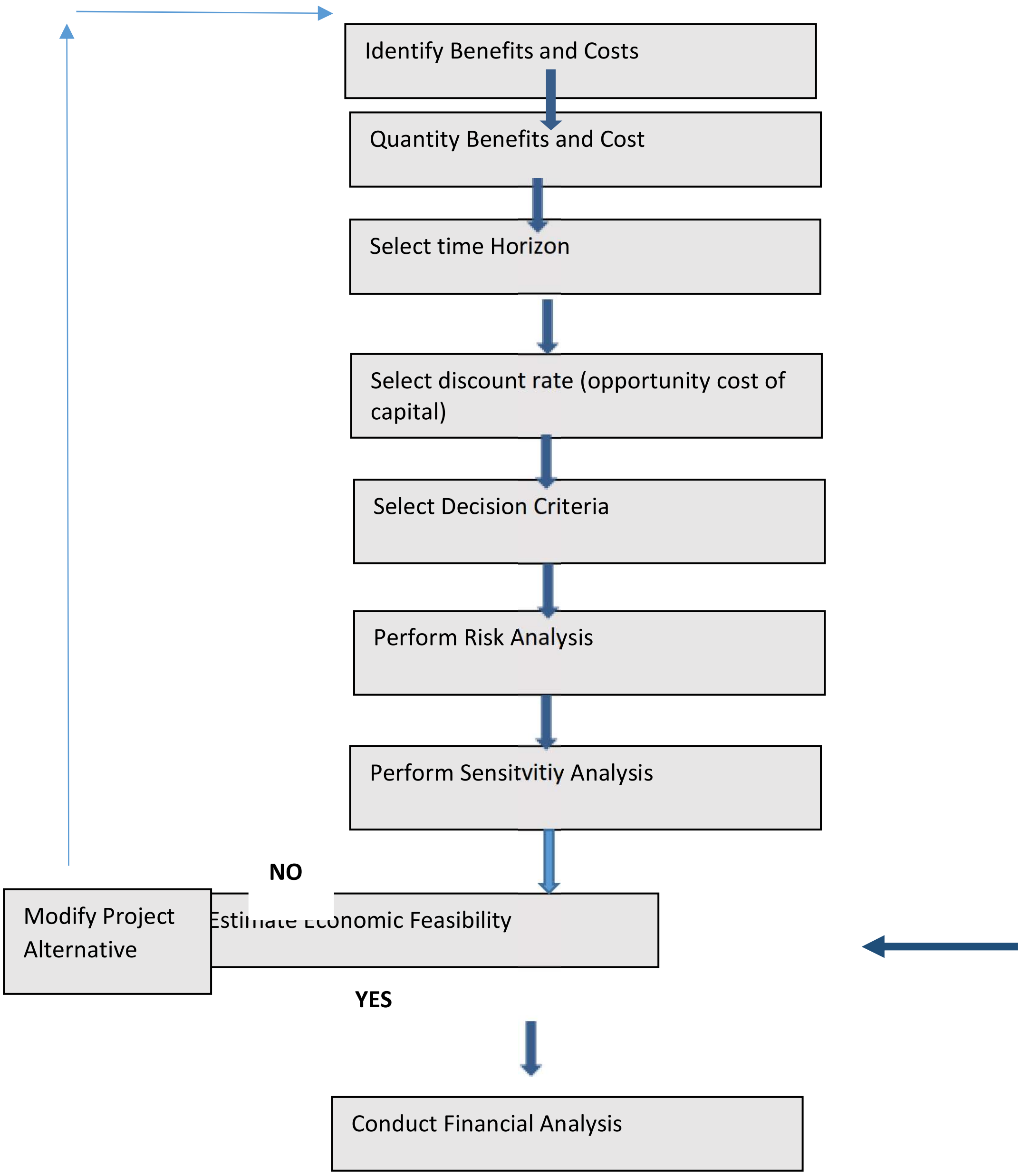

Figure 12.1 Economic and Financial Analysis of a Project Alternative (Souza *et al*. 2011)

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12.3. Economic and Financial Procedures of Drinking Water Treatment Plants

Many factors are involved in analysing the economic and financial aspects of drinking water treatment infrastructure. For example, the water that is used for drinking water treatment plants and for many industries is categorised, according to its source, as upland surface water, lowland surface water, groundwater, brackish well water and seawater. Also scale of plant, level of using technology it shows different features. These characteristics that determine the level of treatment required and thus costs. Nevertheless, basically, the strategies and principles are offered the same approach at the pre-treatment phase for drinking water treatment plants. This procedure is as follows, and then will be discussed in the following this sections.

- Priority Level: (in sector or regional level, economies, ecosystems, protection of human health)
- Assessment environmental impacts of the project (the following matters description that inspired the project factors into action, driving forces, the project's main goals and objectives, expected positive environmental effects, the project's effects on health, the size of the population benefiting from the project implementation)
- Demand analysis (estimated future population served by the project, the estimated drinking water)
- Cost estimates (pre-feasibility, feasibility, financing, procurement, construction, commissioning, personnel training, operation investment costs, material / feature list, exploration and operating costs)
- Estimated cash flow (preparation phase, construction, total)

12.3.1. Priority level for the drinking water treatment plant

In the pre-treatment phase for drinking water treatment plants should be planned in an integrated manner, taking into account long-term planning needs for the efficient and equitable infrastructure investment. On the other hand 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, whose quantity and quality determine the nature of its utilization. To this end, water resources have to be protected, taking into account the functioning of aquatic ecosystems and the perennially of the resource, in order to satisfy and reconcile needs for water in human activities. In developing and using water resources, priority has to be given to the satisfaction of basic needs and the safeguarding of ecosystems (URL 2). Therefore, priority level can be defined activities and processes applied to prevent or minimize hazards occurring. In line with mentioned above requirements, the general objective is to make certain that adequate supplies of water of good quality are maintained for the entire population, while preserving the hydrological, biological and chemical functions of ecosystems, adapting human activities within the capacity limits of nature and combating vectors of water-related diseases (URL 3). In accordance with this purpose, Priority Level for the Drinking Water Treatment Plant - strategic content- includes defining project rationale and objectives.

12.3.2. Assessment of environmental impacts

During construction and start up of the facilities to the Drinking Water Treatment Plants environmental impact assessment provides a systematic process for identifying, describing and evaluating natural and human resources in order to improve decisions about their management. Because apart from the quality and safety of the finished drinking water, numerous other health and environmental protection issues are also evident when considering the impacts of desalination processes. At this stage the qualitative and quantitative data should show that the overall environmental impacts. For example use of land, use of natural resources, use of chemicals, waste generation, emissions, noise, etc. as well as reduction of health risk for population; employment at the plants and poverty reduction impact of the project should be assessed.

12.3.3. Demand analysis for the drinking water treatment plant

The demand analysis is an integral component of the project development cycle. Municipal water demand projections are calculated using the projected populations. Changes in population, income and employment will influence water demands. As population, economic activity, and water use changes, water treatment needs will also change. The domestic water demand category covers number households, household size and its composition; present water use in both peak and nonpeak periods; household income; present prices paid or incurred by households; present quality of services and whether elements (ADB, 1998). The main parameters for demand projections are:

- Population level
- Average household size
- Number of households
- Connection rate
- Type of connection
- Metering rate
- Changes in household income levels
- Changes in cost of water

Factors affecting per capita demand

- Size of the city: Per capita demand for big cities is generally large as compared to that for smaller towns as big cities have sewered houses.
- Presence of industries.
- Habits of people and their economic status.
- Quality of water: If water is aesthetically medically safe, the consumption will increase, as people will not resort to private wells, etc.
- Pressure in the distribution system.
- Efficiency of water works administration: Leaks in water mains and services; and unauthorized use of water can be kept to a minimum by surveys.

- Policy of metering and charging method: Water tax is charged in two different ways: on the basis of meter reading and on the basis of certain fixed monthly rate (URL 4).

The influence of the various factors strongly varies from country to country and regions depending on the development level. The International Water Consumption Data (2008) show that this composition which differences between countries with regard to water consumption per person in liters The data are shown in Table 12.2 for a few selected countries and areas.

Table 12.2. Fresh water consumption per person in liters

Countries	Per person / Per day (Liters)
Average Low-income	123.4
Average Middle-Income	119.5
Average High-Income	403.1
Other Asia Pacific	168.1
Latin America and Caribbean	271.4
Africa	86.4
North America	614.8
Europe	239.8

The quantity of water account

The quantity of water required for municipal uses for which the water supply scheme has to be designed requires following data:

- Water consumption rate (Per Capita Demand in liters per day per head - per capita water use, is usually expressed as gallons of water used per person per day)
- Population to be served and;

Quantity= Per capita demand x Population

Water consumption rate

Because there are many factors that affect the demand for water, it is difficult a complete determination of the people's water needs. As a sample frame various types of water demand can be categorized as in the Table 12.3 below (URL 4):

Table 12.3. Water Consumption for Various Purposes

	Types of Consumption	Normal Range (lit/capita/day)	Average	%
1	Domestic Consumption	65-300	160	35
2	Industrial and Commercial Demand	45-450	135	30
3	Public Uses including Fire Demand	20-90	45	10
4	Losses and Waste	45-150	62	25

Total consumption is derived by applying the projected population in each consumer category against the projected average consumption level in that consumer category.
Average Daily per Capita Demand = Quantity Required in 12 Months / (365 x Population)

Fluctuations in Rate of Demand

If this average demand is supplied at all the times, it will not be sufficient to meet the fluctuations. These may also originate: Seasonal variation; Daily variation depends on the activity; Hourly variations are very important as they have a wide range. So, an adequate quantity of water must be available to meet the peak demand. To meet all the fluctuations, the supply pipes, service reservoirs and distribution pipes must be properly proportioned. The water is supplied by pumping directly and the pumps and distribution system must be designed to meet the peak demand. The effect of monthly variation influences the design of storage reservoirs and the hourly variations influences the design of pumps and service reservoirs. As the population decreases, the fluctuation rate increases (URL 4).
Maximum daily demand calculates with the following:
Maximum daily demand = 1.8 x average daily demand
Maximum hourly demand of maximum day i.e. peak demand can be calculated with the following equation:

= 1.5 x average hourly demand
= 1.5 x Maximum daily demand/24
= 1.5 x (1.8 x average daily demand)/24
= 2.7 x average daily demand/24
= 2.7 x annual average hourly demand

12.4. Different Approaches to the Evaluation of the Demand: Market-Nonmarket Valuation

Some distinctive economic features make the demand of water different and more complex than that of most other goods[3]. Water gives numerous intangible benefits due to features and difficult to measure unless understanding the reasons why individuals value water. Consumers have different consumption patterns determinated by different factors. They may be consumptive, such as use of water for irrigation or the harvesting of fish, or they may be non-consumptive such as recreational swimming, or the aesthetic value of enjoying a view. Also different sources may be selected for different domestic uses (e.g. drinking, cooking, bathing, and clothes washing),

[3] This is the case in many areas water related economic analysis. According to Young and Loomis (2014) water's unique characteristics are described under four headings: hydrological and physical attributes, water demand, social attitudes, and legal–political considerations.

and they may vary seasonally. Although the extent to which this is attributable to a specific site (Turner et al., 2004). The distinction is important for the way in which benefits are valued. Therefore understanding the true value of water is important aspect to the water treatment projects. In this respect, Total Economic Value (TEV) offers a good approach is described below.

12.4.1 Total economic value concept of water

The total economic value (TEV) uses to resource base in order to determine the value of the environment. Accordingly, identification and quantification of all types of values, called Total Economic Value (TEV). The quantification of the economic value of water resources and the identification of those instrumental values is important to the management of water resources. Comparison of water's value in various uses and locations assists public water agencies in making decisions about management and allocation of publicly supplied water, and can contribute to better evaluation of the benefits and costs of water related projects and policies (Colby, 1989). In addition, estimating value water attributed by individuals in different ways can help to identify the potential demand curve, which reflects perceived benefits.

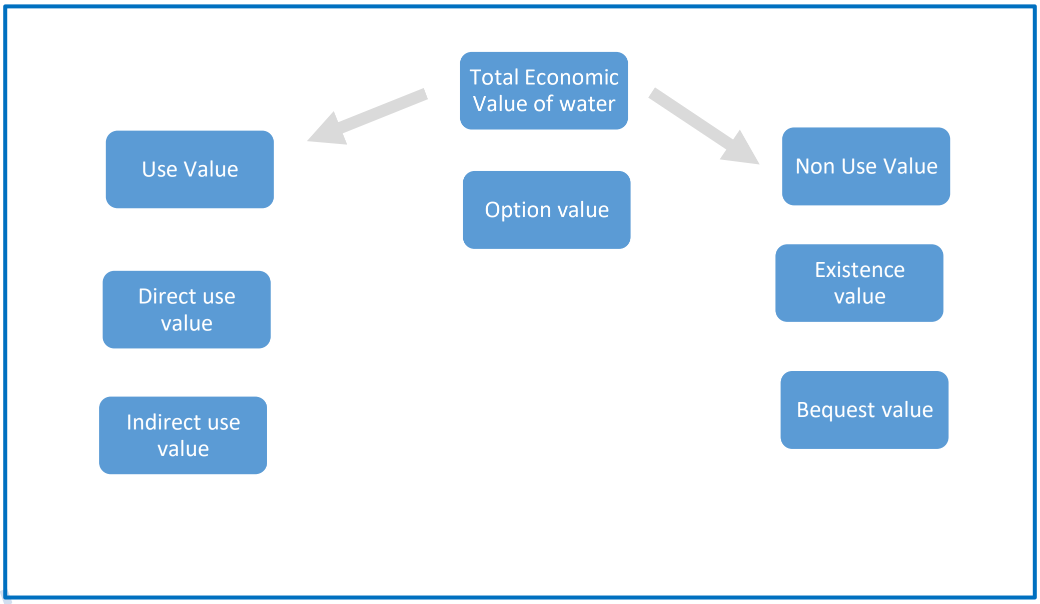

Figure 12.2. Components Total Economic Value of Water

As seen as Figure 12.2, Total Economic Value (TEV) of water is divided into two main values those are use and non-use values. Use values includes direct and indirect use. On the other hand, non-values splits into existence and bequest value. The calculation for total economic value can be expressed as follows:

Total Economic Value = Use Value + Option Value + Non-use Value

Use Value: Related to values derived from using water. Refers to the benefit an individual receiver from the direct or indirect use of water.

Direct use value: arise from direct interaction with water resources. For instance, drinking water, domestic and industrial water supply includes direct use values.

Indirect use value: is value of functions of the water. Indirect of water receives is characterized by its less tangible benefits thus rather difficult to quantify the value as nonmarketed services, such as waterfall's aesthetic values or enjoying such as sightseeing and boating, also water purification is taken into account indirect use value.

Non-use value: unrelated to the value of current or planned use of the water. It is not based on the actual use of water. Rather, it is predicated on the notion that people appreciate water even if they are not actually using it (Winsconsin 1999). Non-use water can have subdivided into Existence value and Bequest value

Existence value: of knowing that the environmental good exists even if no one in this generation or in the future generations will ever use it. Existence value can be reflected benefits from improvement of domestic water supply services that can play an important role to avoid health dangers and impacts. Also many households are willing to pay for protection from such health impacts of water services, even those located remove (Hejazi, 2014).

Bequest value: is value of knowing that future generation will benefit from the water. For example, a waterfall includes bequest value. Household might be willing to pay to restore water quality for the time being and in future. But from knowledge that their heirs and future generations will have good water quality (Hejazi, 2014).

Option Value: Values of conserving of option of making use of the water in the future even though no current use is made of it. The option value for water resources therefore represents their potential to provide economic benefits to human society in the future (Birol et al. 2006). Exemplified by a groundwater resource, a hydropower potential. The preservation of sensitive lakeshore provides other example of a situation in which future option value is taken into account. Total Economic Value (TEV) can be estimated using "environmental valuation methods". According to Lange (2004) water valuation methods provides critical information for decisions about;

- Efficient and equitable allocation of water among competing users, both within the present generation between present and future generation
- Efficient and equitable infrastructure investment in the water sector (how much, where, when)
- Efficient degree of treatment of water
- Design of economic instruments: water pricing, property rights, tradable water rights' markets, taxes on water depletion and pollution, etc.

12.4.2 Valuation methods the water sector

Generally, economic value is represented by the maximum amount a consumer is willing to pay for a commodity thus the worth of a good or service determined by people's preferences. In addition, the economic value of water is defined as the amount that a rational user of a publicly or privately supplied water resource is willing to pay for it (Ward and Michelsen, 2002). Willingness to pay (WTP) is a set of valuation methods (Table 12.4) that relate the value of a water or improved domestic water supply services to what people are willing to pay for it.

Table 12.4. WTP Based Valuation Methods

Revealed Preference Method	Stated Preference Mathod
Hedonic Pricing Method	Contingent Valuation Method
Travel Cost Method	Choice Experiment Method

Valuation methods uses two different ways. Firstly, observes people's actual behavior (or revealed preferences'). Secondly, asks people about what they are willing to pay for some resource (or their stated preferences*).* In this framework, valuation methods are broken down into two main methods those are: Revealed Preference Method and Stated Preference Method as shown Table 12.4.

Revealed Preference Method also known as *indirect valuation* methods look for related or surrogate markets in which the environmental good is implicitly traded. Information derived from observed behavior in the surrogate markets is used to estimate WTP, which represents individual's valuation of, or the benefits derived from, the environmental resource. Revealed Preference Method includes Hedonic Pricing Method and Travel Cost Method.

These methods are suitable for valuing those water resources that are marketed indirectly and are thus only able to estimate their use (direct and indirect) values (Birol et al. 2006). *Hedonic Pricing Method* (HPM) is used to estimate the economic values of an environmental good that directly affect prices of marketed goods. It is most commonly applied to variations in property prices to estimate the value of local environmental goods. It can be used to estimate economic benefits or costs associated with: environmental quality, including air pollution, water pollution, noise, soil quality, water quality, erosion, drainage, proximity to waste sites; environmental amenities, such as aesthetic views (sea, lake, forest) or proximity to recreational sites (e.g. coast, open space) (Birol *et al*, 2006). On the other hand, *Travel Cost Method* (TCM) is a technique is associated with estimating the value of the use of non-market goods for recreational purposes. The focus of this method is the number and frequency of recreational trips made by individuals to and from some natural area and the cost of realizing these trips (Koundori et al., 2016). The cost of performing a trip captures the cost of direct monetary cost of traveling, such as petrol expenses, depreciation of vehicle, fares and so on.

Stated Preference Method: Stated preference methods (SPM) is also called as *hypothetical method* or *direct valuation* methods, performed by asking people about what they are willing to pay for improved domestic supply services with their 'stated preferences'. Stated preference methods (SPM), have been developed to solve the problem of valuing those environmental resources that are not traded in any market, including surrogate ones. In addition to their ability to estimate use values of any environmental good, the most important feature of these survey-based methods is that they can estimate the nonuse values, enabling estimation of each component of TEV. Since many of the outputs, functions and services that water resources generate are not traded in the markets, SPM can be used to determine the value of their economic benefits (Birol et al. 2006).

Stated-Preference Method divided into two main areas as the *Contingent Valuation Method* (CVM) and *Choice Experiment Method (CEM)*. The most common form of questioning on hypothetical futures is the contingent valuation method involves directly asking people, in a survey, how much they would be willing to pay for specific environmental for example water treatment services. Water treatment and sanitation are often taken for granted as essential services, if wanted to be known about how much consumers are willing to pay for these service, the method will exhibit an appropriate approach. In some cases, people are asked for the amount of compensation they would be willing to accept to give up specific environmental services. It is called "contingent" valuation, because people are asked to state their willingness to pay, *contingent* on a specific hypothetical scenario and description of the environmental service (URL 5). The most WTP studies used CVM in order to identify to potential demand curve for improved water supply and quality (Awad & Holländer 2010*).* *Choice Experiment* (CE) as a willingness to pay (WTP) techniques can be used to show that cultural resources do generate significant positive externalities or non-market benefits.

12.5. Estimation Cost of Water for Drinking Water Treatment Plant

Agenda 21 is a non-binding, voluntarily implemented action plan of the United Nations with regard to sustainable development.[4] According to Agenda 21 of UNEP a prerequisite for the sustainable management of water as a scarce vulnerable resource is the obligation to acknowledge in all planning and development its full costs. Planning considerations should reflect benefits investment, environmental protection and operation costs, as well as the opportunity costs reflecting the most valuable alternative use of water. Actual charging need not necessarily burden all beneficiaries with the consequences of those considerations. Charging mechanisms should, however, reflect as far as possible both the true cost of water when used as an economic good and the ability of the communities to pay (UNEP, 1993).

Water treatment plants function largely to bring raw water quality to potable standards. In fulfilling this function, treatment process costs vary depending on the quality and source of the raw water and the availability of treatment resources. For example, RO treatment cost of brackish water depends on salinity, peak demand, and local energy costs (Glueckstern, 1991; Avlonitis, 2002). The economics of potable water treatment are also impacted by the distribution of demand types (Stevie and Clark, 1982). Small systems tend to serve almost exclusively residential demands while larger systems serve increasingly smaller fractions of residential demands. In addition, treatment costs are impacted by a variety of design variables including flow rate, site constraints, water quality objectives, manufacturer quotes, and other factors. Due to the large number of variables, the same treatment train may have significantly different costs from one site to another (Plumlee et al., 2014). At this process, economic cost includes opportunity costs of diverting raw water from alternative uses to the household; storage and transmission of untreated water to the urban area; treatment of raw water to drinking water standards; distribution of treated water within the urban area to the household and any remaining costs or damages imposed on others by the treated water (Radke, 2013). Therefore, it is useful to provide a brief overview of a few key issues involved, as a means of introducing the general topic to understanding of the costs involved with the provision of water, both direct and indirect.

Full Supply Costs

[4] The "21" in Agenda 21 refers to the 21st Century.

Full supply costs are composed of two separate items: Operation and Maintaince (O&M) Cost, and Capital charges, both of which should be evaluated at the full economic cost of inputs (Rogers at al 1988). Fully supply cost also can be classified as "financial costs", which is included capital cost, operation and maintenance cost, and administrative cost (Figure 12.3).

Treatment costs include operating and capital costs associated with the purification of source of water by the plant and distribution expenditures involve all costs incurred in delivery of the finished or treated drinking water to the consumer (Stevie & Clarck 1980).

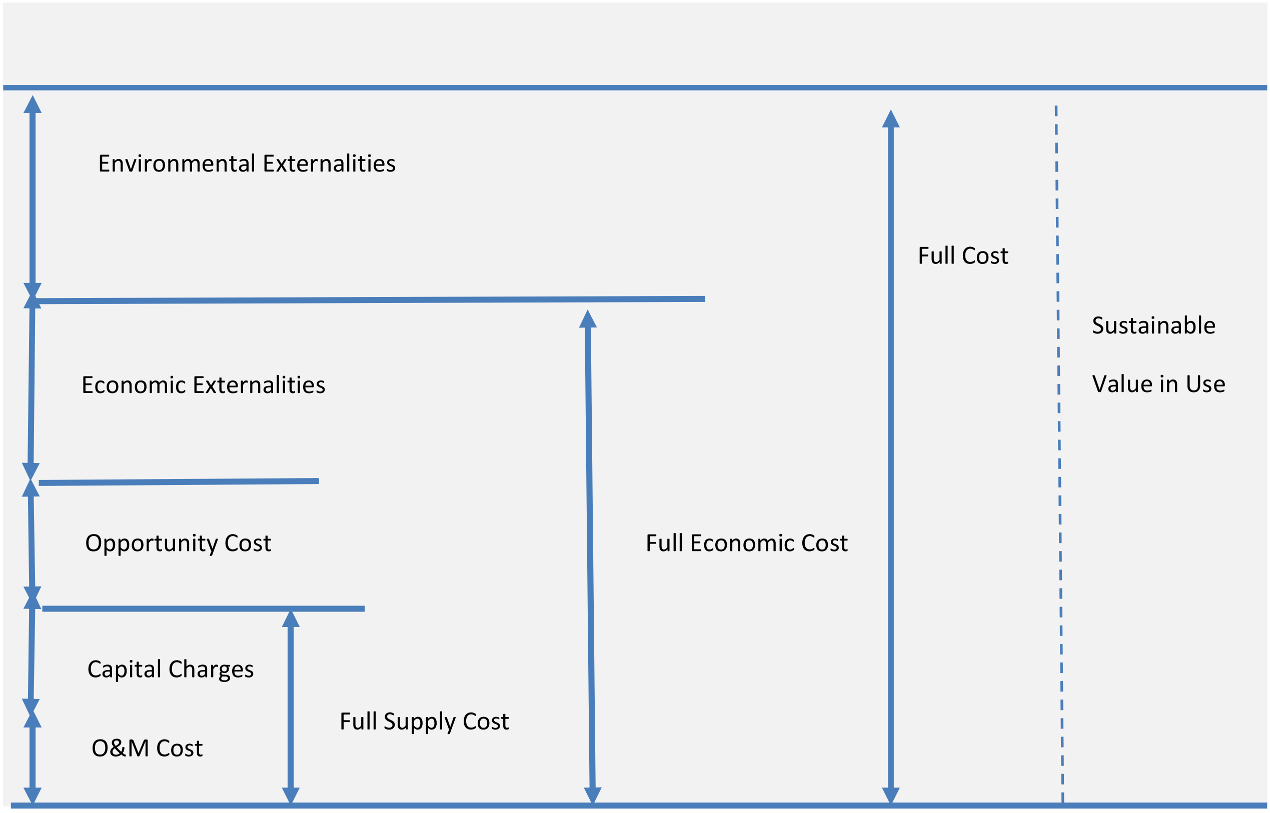

Figure 12.3. General Principles for Cost of Water (Rogers *et al*., 1998)

Capital Costs

Capital costs can occur during the operational lifetime of the system include installation, maintain building and the treatment plant itself and can be categorized as direct and indirect costs.

Direct costs included purchase of equipment, land, construction charges and pre-treatment of water. These costs for the preparation and construction of the system up to the moment that the system becomes operational. Thus, include the costs related to the construction and equipment of the new system during the pre-investment (planning) stage. Generally, for the water treatment facility Building& Construction have the largest share in the total cost of the treatment plant and new mains network. According to European Commission, (2005) is about 75-80% of the total costs of during the construction phase of the project. In addition, a drinking-water system consists of a variety of fixed (constructed) installations, such as filter units, clear water reservoirs, and pipes. Installation cost assumed to be 30% of equipment costs (Plumlee at al. 2014). The project requires equipment, which will be a capital cost, for example items such as pumps and power systems

Indirect capital costs are costs that are not directly related to the treatment technology used or the amount or quality of the treated water produced, but are associated with the construction and installation of a treatment process and appurtenant water intake structures. They can be considerable and must be added to cost estimates if they are not included as a line item component or a factor in the major (cost driver) elements of a technology. They include indirect material costs (such as yard piping and wiring), indirect labor costs (such as process engineering) and indirect burden expenses (such as administrative costs) (EPA 2014).

Capital charges include capital consumption (deprecation charges) and interest costs (Whittington & Hanemann 2006). Installition capital expense includes the deprecation and interest spent to make the plant operational. Depreciation is a particularly important aspect of fixed costs for this approach can allow for the build-up of funds to replace especially larger pieces of equipment and parts in the system i.e. pipes (Jagals, P. & Rietveld, 2011).

O&M Cost

O&M Cost means all actual cash operation, maintenance and administrative costs relating to the Projects. For example, labor, energy, chemicals, consumables spares etc. However, because of associated with the acquisition and treatment of water O&M cost will vary according to treatment technology, annual production volumes and the type of source water processed, raw water quality, local electricity costs etc.[5]. According to EPA (2014) O&M Cost, include annual expenses for water treatment plants are:

- Labor to operate and maintain the new treatment equipment and buildings
- Chemicals and other expendable items (e.g., replacement media) required by the treatment technology
- Materials needed to carry out maintenance on equipment and buildings
- Energy to operate all equipment and provide building heating, cooling, lighting and ventilation
- Residuals discharge fees

Opportunity Cost

Opportunity Cost is the alternate use of the same water resource. Ignoring the opportunity cost undervalues water leads to failures to invest, and causes serious miss- allocations of resource between users (Rogers et al., 1998). So that achieving efficient water use is fundamentally about recognizing water's opportunity costs. The opportunity cost of water is zero only when there is no alternative use; that is no shortage of water. Depending on the availability or scarcity, opportunity costs may vary widely in different conditions and locations. For example, in a location with abundant fresh water the opportunity cost of diverting water from existing or future users be very low or even zero. However, it is seen rarely today condition, in more and more places

[5] For example, Statictic Canada, examines the effect O&M costs for two drinking water treatment systems: conventional systems, which treated the most surface water and unfiltered systems, which treated the most groundwater. Their model suggest that O&M costs per ML for treating surface water are higher than those treating groundwater for annual production (URL 6).

these opportunity costs associated with water diversion and the externalities. In this perspective, the opportunity costs of water resource use and the economic value of the benefits can be compared in terms of whether the use is economically sustainable or socially optimal.

It is also important to analyse the infrastructure's opportunity costs of water project. Based on difference in costs of production, so it is a good technique to estimate value of water. In here opportunity cost of capital, reflects discounting rate. It is that rate of return, which can be earned from next best alternative investment opportunity with similar risk profile. The use of a single discount rate to account for both the social opportunity cost of capital and the social rate of time preference is appropriate for the water and sanitation infrastructure.

Economic Externalities

As indicated Chapter 11, externalities as an action that affects the welfare of people via a non-market process. Externalities may be positive or negative, and it is important to characterize the situation in a given context, estimate positive and negative externalities, and adjust full cost by the impacts (Rogers, et al). Existence of an environmental or social impact does not necessarily imply that an externality occurs. An externality only exists if there is also a cost or benefit associated with a particular impact where cost or benefit is not recognized in any markets (URL 7). Externalities affect of economic activity, because costs and values are not revealed and, hence, not taken fully into account in production process and in market-place transactions. Thus, externalities are "spillover" or "third-party" effects associated with economic activity. A failure to account correctly for externalities have very real and significant impacts of community well-being and hence efficiency, effectiveness and desirability of alternative options for resource use in society. For that reason, a large array of regulatory, community and political processes are used to reveal cost and value of externalities to water users.

Some externalities can be quantified directly from market prices. For example, a change in water quality of a river could affect the magnitude of fish catches; the decline in fish catches could be quantified economically by considering the loss of income from commercial fishing, or by estimating the cost of a food substitute. Similarly, if drinking water quality is affected, economic costs might be equated to increased health costs for treating water-related sicknesses, or also to the costs of improved water treatment (UNEP 2015). There are also externalities due to over extraction from on contamination of, common pool resources such us lake, groundwater aquifers. In general, many of the externalities associated with common-pool resources are negative. Examples of upstream or supply externalities include both direct impacts at the storage site and, also, effects that storage has on the performance of river and groundwater systems. These externalities are generated, in part, by competing demands for water. The more water diverted into the urban supply system, the less available to support agriculture and to maintain valuable environmental functions. All water has an opportunity cost and, in the absence of a competitive market for it, sometimes allocation to the urban sector may not be its highest and best use (CSIRO, 2000).

Environmental Costs

The Environmental externalities are those associated public health and ecosystem health. (Rogers at al. 1998). The environmental cost represents the costs of damage that water users impose on the environment and ecosystems and those who use the environment (e.g. a reduction in the ecological quality of aquatic ecosystems or the salinization and degradation of productive soils). Additionally, the environmental costs refer to those associated with the depletion of water ecosystem quality, which in turn leads to a decrease in the capacity of water-related resources to provide goods and services that are beneficial for human well-being (Koundouri at al. 2016.) On the other hand, water treatment industry can be responsible for global environmental impacts, the most common amongst which are the depletion of natural resources and indirect release of pollutants into the water, land and air through chemicals and energy consumption. From this point various environmental, impacts may arise from the various aspects of urban water service provision, including catchment management, the water supply system, water delivery, drinking water treatment, and wastewater treatment. These impacts can be either direct or indirect.

To estimate the environmental damage, it is necessary to apply appropriate valuation techniques that allow the estimation of the total economic value of water resources across the various economic sectors, and willingness to pay for the conservation of water resources of all affected individuals (Koundouri et al., 2016). The identification of the potential ways, Life Cycle Assessment (LCA) use in evaluating the systems in an environmental impacts – based an in a holistic way that enables the identification of critical processes and the potential improvements for existing structures. The LCA methodology helps to calculate of environmental impacts in a systematic and scientific way by regarding all the inputs and outputs of a system. Hence, it allows for comparison on environmental grounds. LCA has been used widely in the field of urban water management whether for a whole urban water system or for a part of the system

Full Economic Cost

The full economic cost of water is the sum of Full Supply Cost and also consisted of Opportunity Cost and Economic Externalities. For economic equilibrium the value of water the value of water, should just equal the full of cost water. At this point, the classical economic model indicates that social welfare is maximized. In practical case, however, the value on use is typically expected to be higher than the estimated full cost. This often because of difficulties in estimating the economic and environmental externalities (Rogers et al., 1998).

In this context, cost-benefit analysis **(**CBA) is a technique for assessing monetary social costs and benefits of a capital investment project along a given period. In these analyses, the external cost and benefits considered alongside the internal cost and benefits. Thus, the total social cost and are benefits are measured. CBA uses in the water sector to justify investment needs and improvements of water quality and other serviceability parameters. It provides a structured comparison of all the costs and benefits when deciding on the optimum level of water quality improvement schemes.

12.6. Cost Estimation Methods in Drinking Water Technologies (WBS Approach)

Different models are used for estimating drinking water treatment system costs. Most of them has been developed for the evaluating cost and performance of the best available technologies for drinking water. To estimate treatment costs, EPA (United States Environmental Protection Agency) developed new cost modeling approach to developing unit costs for drinking water technologies The technique uses a work breakdown structure (WBS) methodology, which involves dividing technology into discrete components for the purpose of estimating unit costs. The models provide unit cost and total cost information by component.

The models also contain estimates of:

- Add-on costs (such as permits, pilot studies and land acquisition)
- Indirect capital costs (such as site work and contingencies)
- Annual operation and maintenance costs (EPA 2014)

As with any technology treatment plant cost and operation scheme shown as follows Figure 12.4 under the model of the Work Breakdown Structure (WBS)[6].

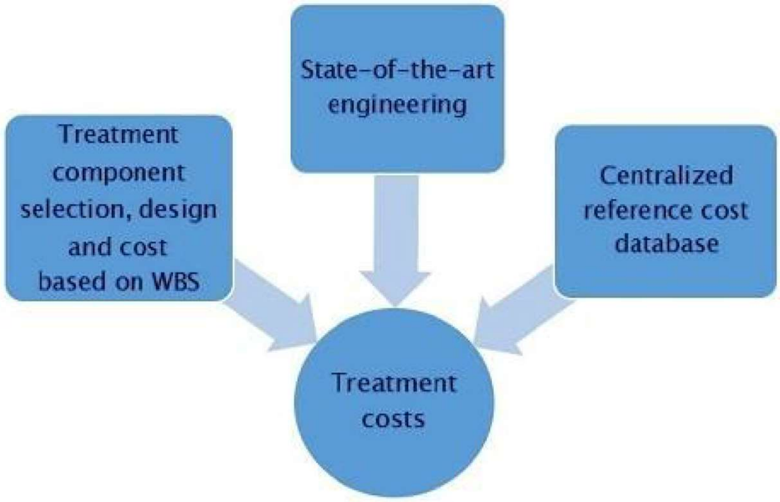

Figure 12.4 The structural features used to generate treatment costs in the WBS models (EPA, 2014)

Framework for Developing the WBS-Based Models

Step 1: Identify the treatment requirements based on the contaminant requiring removal, the flow for which treatment is required, the influent water quality and treated water quality requirement, and then select a treatment technology or combination of technologies capable of meeting the requirements.

[6] A work breakdown structure (WBS), in project management and systems engineering, is a deliverable-oriented decomposition of a project into smaller components. A work breakdown structure is a key project deliverable that organizes the team's work into manageable sections. The Project Management Body of Knowledge (PMBOK) defines the work breakdown structure as a "deliverable oriented hierarchical decomposition of the work to be executed by the project team." https://en.wikipedia.org/wiki/Work_breakdown_structure

Step 2: Develop the general design assumptions that apply to all the technologies (e.g., chemical storage capacity).

Step 3: Develop site- and technology-specific design assumptions that might affect treatment performance and, thereby, design requirements (e.g., assumptions related to influent water constituents such as alkalinity or water quality parameters such as pH).

Step 4: Construct a typical process flow diagram or P&ID showing the main unit processes for the technology and identify equipment requirements.

Step 5: Calculate the equipment requirements, including dimensions and quantities, for the core elements of each unit process. At each component (or group) level, identify choices of material (e.g., stainless steel or PVC pipe material).

Step 6: Link the treatment equipment requirements to a database that contains unit costs by equipment type, size and material. Multiplying the unit costs by the dimension and quantity requirements developed in Step 5 provides the component-level design costs.

Step 7: Tally the costs of the selected components to determine direct capital cost.

Step 8: Develop and add indirect and add-on costs to determine total system capital cost.

Step 9: Develop operation and maintenance cost estimates.

12.7. An Overview of Treatment and Sanitation Costs

The economic costs of providing a household with modern water and sanitation infrastructure services are the sum of seven principal components:

1. Opportunity costs of diverting raw water from alternative uses to the household (resource rents)
2. Storage and transmission of untreated water to the urban area
3. Treatment of raw water to drinking water standards
4. Distribution of treated water within the urban area to the household
5. Collection of wastewater from the household (sewerage collection)
6. Treatment of wastewater (sewage treatment)
7. Any remaining costs or damages imposed on others by the discharge of treated wastewater (negative externalities).

Table 12.5 use some rough calculations to illustrative average unit costs for each of these seven components. The cost estimates in Table 12.5 include both capital expenses and operation - maintenance expenses. Annual capital costs are calculated using a capital recovery factor of 0.09, assuming a real discount rate of 6% and an average life of capital equipment and facilities of 20 years.

The unit costs of these different elements could vary widely in different locations. For example, in a location with abundant fresh water supplies. Opportunity cost of raw water supply and Damages associated with discharge of treated wastewater costs may, in fact, be very low or even zero (Whittington et al., 2009).

Table 12.5 Cost Estimates Improved water and Sanitation Services (Whittington *et al*., 2009)

Cost Component	**US$ per m^3**	**% of total**
Opportunity cost of raw water supply	0.05	3%
Storage and transmission to treatment plant	0.10	5%
Treatment to drinking water standards	0.10	5%
Distribution of water to households (including house connections	0.60	30%
Collection of wastewater from home and conveyance to wastewater treatment plant	0.80	40%
Wastewater treatment	0.30	15%
Damages associated with discharge of treated wastewater	0.05	3%
Total	2.00	100%

On the other hand, some cost components are typically subject to economies of scale, particularly storage and transmission treatment of raw water to drinking water standards (item 3), and treatment of sewage. This means that the larger the quantity of water or wastewater treated, the lower the per-unit cost. Other cost components are subject to diseconomies of scale. As large cities go farther and farther away in search of additional fresh water supplies and good reservoir sites become harder to find, the unit cost of storing and transporting raw water (item 2) to a community increases. There are also tradeoffs between different cost components: one can be reduced, but only at the expense of another. For example, wastewater can receive only primary treatment, which is much cheaper than secondary treatment; but the negative externalities associated with wastewater discharge will then increase (Whittington et al., 2009).

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QUESTIONS AND ANSWERS FOR CHAPTER 12

Q1. Which of the following could not be considered a financial analysis of Water Treatment Plant project?

a) accounts for benefits and costs realized by a project proponent
b) inclusion of environmental and other external costs and benefits
c) the discount rate to be used should reflect the opportunity cost of capital
d) when calculating the discount rate, inflation is included which uses nominal prices.

Q2. Which one of the following sentences is false about economic analysis for Water Treatment Plant project?

a) this is the next step after the financial analysis
b) accounts for all benefits and costs to whomsoever they shall accrue
c) conversion of market prices into accounting prices, which reflect social costs and benefits.
d) financial prices are used which are include the effects of government intervention

Q3. Which of the following is a component of the use value of water

a) existence value
b) bequest value
c) indirect use value
d) option Value

Q4. How do we quantify the economic values that clean water provide to people if there are no explicit market prices?

a) economic valuation method
b) nonmarket valuation method
c) total economic valuation method
d) indirect valuation method

Q5. Which of the following is a component of Revealed Preference Method?

a- hedonic pricing method
b- contingent valuation method
c- choice experiment method
d- hypothetical method

Q6. Which of the following is not a component of Full Economic Cost?

a) full Supply Cost
b) opportunity Cost
c) environmental externalities
d) economic externalities

Q7. What is the opportunity cost of the water resource?

a) is the alternate use of the same water resource.
b) the cost of damage that water users impose on the environment and ecosystems and those who use the environment
c) means all actual cash operation, maintenance and administrative costs relating to the projects

the cost that includes purchase of equipment, land, construction charges

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