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Financial and Economic Aspects of Water Demand Management in the Context of Integrated Urban Water Management

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Abstract
Water Demand Management is considered in the framework of Integrated Resource Planning, as a suite of options for managing users' demands for water-related services, to be compared with supply-side and source-substitution options. These options are compared using levelised costs, and the paper describes the use of Average Incremental Social Costs (AISC) for this, including how environmental, social and carbon externalities can be included, referring to recent guidance used in the UK water industry. AISC provides a common approach for comparing options of all types, and could be applied to other SWITCH workpackages.

Demand management options to reduce water consumption include use of tariffs, and an example is presented from Zaragoza of the design of stepped tariffs and the use of incentives for customers to reduce consumption.

At the utility level, the concept of Non Revenue Water is a key indicator of performance. This takes account of both commercial losses and physical losses. The concept of Economic Level of Leakage provides a target for leakage control to aim at, and is the focus of current research in Zaragoza, including sensitivity to changing energy costs. The incorporation of environmental, social and carbon costs into the Economic Level of Leakage is also discussed.

Keywords: Costs, Tariffs, Leakage, Externalities, Carbon

1 Introduction

This paper focuses on the financial and economic aspects of Water Demand Management (WDM), in particular cost estimation, the use of tariffs and economic targets for leakage, but these need to be seen in context. WDM is an interdisciplinary issue, combining engineering, management, financial, social and environmental perspectives. Within the urban water cycle WDM has various linkages to Water Supply, Wastewater and Stormwater. Following the International Water Association Task Force on the International Demand Management Framework (IWA Task Force), it is helpful to consider these wider

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perspectives within the framework of Integrated Resource Planning (IRP) as presented previously (Kayaga and Smout, 2007a).

IRP is an approach that was first applied in the energy sector in the United States in the early 1980s, after the limitations were recognised of focusing on meeting increased demand only through construction of power supply infrastructure. It has since been applied in the water sector by organizations such as the American Water Works Association, the Water Services Association of Australia and the Institute for Sustainable Futures (Turner et al, 2008) and the IWA Task Force. The UK water industry uses a similar approach to resolve the supply-demand balance by considering both demand and supply options in the same framework (Environment Agency, 2007).

IRP may be defined as a comprehensive form of planning that uses an open and participatory decision-making process to evaluate least-cost analyses of demand-side and supply side options against a common set of planning criteria (Turner et al, 2006). The guiding philosophy for IRP is that utility customers do not necessarily demand a resource itself but rather they demand the services that the resource provides, often called end uses. Hence in the water sector, IRP shifts the focus of attention from the quantity of water delivered to the quality of service provided. In this way, consumer demand can be disaggregated into demands for various end uses, such as clothes washing or toilet flushing, rather than a demand for litres of water.

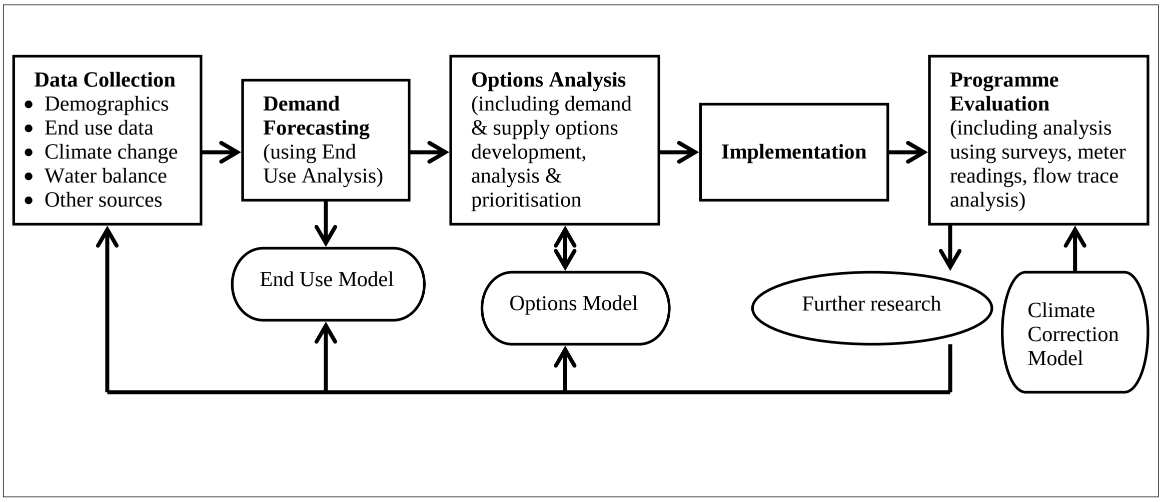

Figure 1: Simplified process chart for Integrated Resource Planning (Adapted from Turner et al, 2008)

Figure 1 shows a simplified process chart for IRP. The key steps of the IRP process include:
(i) collecting data to enable accurate water demand forecasting and detailed options development;
(ii) demand forecasting using a detailed end use analysis (also called a component analysis) which considers demand by sector, individual end uses and how they change over time, considering projected behavioural, technological and demographic changes;
(iii) developing the response to resolve the supply-demand balance by (a) carefully considering various types of demand management, increased supply, source substitution and reuse options, (b) analysing individual and grouped options/scenarios using a common metric, (c) carrying out a sensitivity analysis, and (d) optimising the response;
(iv) implementing the response, and
(v) monitoring, evaluation and review of the programmes and IRP process.

2 The Unit Cost of Water

2.1 Approaches

Integrated urban water management requires an agreed and consistent way to calculate the unit cost of water so as to compare various types of options, whether related to supply, demand (water saved), or reuse (source substitution).

From an Australian perspective, Mitchell et al (2007) compare different approaches to estimating the unit cost of water supplied or saved by a project, in particular
i. annualised unit cost;
ii. present value per total volume saved or supplied;
iii. average incremental cost (AIC) or levelised cost.

They recommend the AIC approach as more easily applied to both water supply and water efficiency projects which may have varying quantities of water supplied or saved each year, and because it is directly comparable to the marginal cost of water supply. This has made the AIC approach a standard for water supply and water demand management strategies in the UK water industry.

The power of this approach is demonstrated by Figure 2 which shows various options for supplying or saving water for a hypothetical city using Australian data. The options are ranked in terms of the unit costs, and plotted to show the cumulative water saved and supplied, assuming the cheaper options are implemented first.

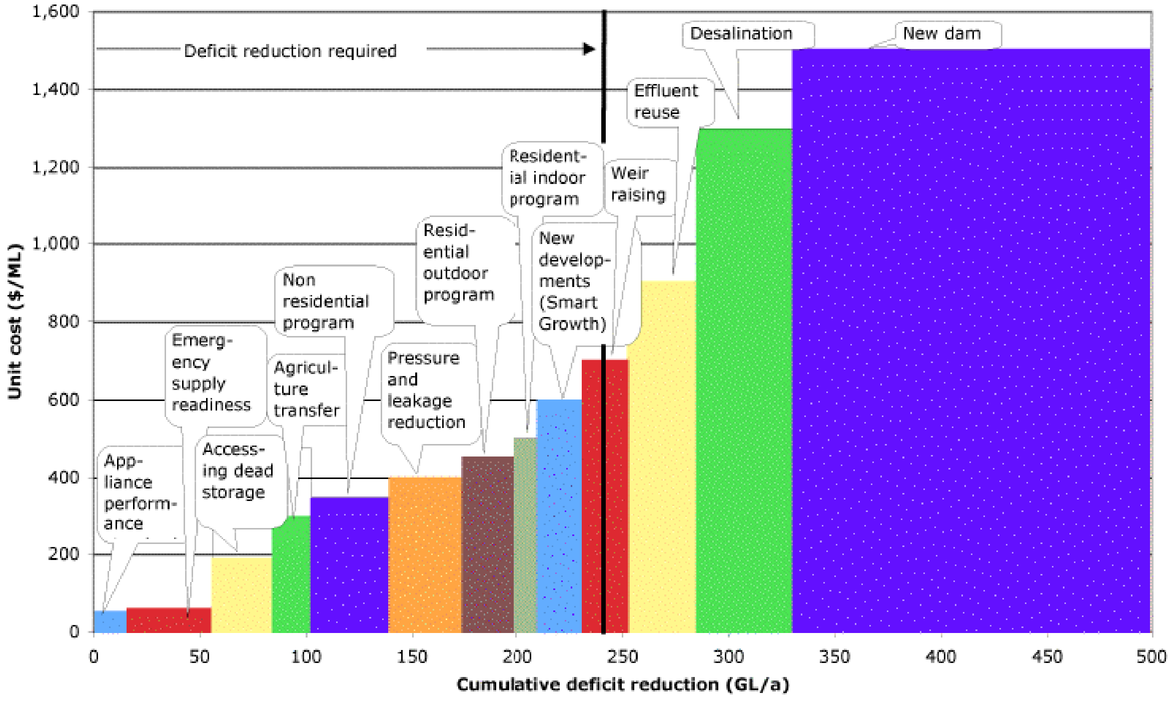

Figure 2: Example of assessing supply and demand options (Turner et al, 2008).

2.2 Average Incremental Costs

Average incremental costing is a forward-looking estimation, using a Life Cycle Analysis approach. It is essentially a cost per volume of water, based on the stream of future costs including both capital and operational (management, operation and maintenance) expenditures and the stream of future volumes consumed. The Net Present Value approach is used to discount future costs and volumes to a baseline time.

The Average Incremental Cost (AIC) is calculated by dividing the net present value (NPV) of all the costs by the net present value of the volume of water consumed each year.

$$AIC = \frac{PV\ of\ Costs\ over\ 25\ years\ (€)}{PV\ of\ Water\ Consumed\ over\ 25\ years\ (m^3)}$$

The average incremental cost therefore represents the average cost of water over the entire life of a project, assumed here to be 25 years. Using a longer time period is unlikely to make a significant difference to the cost, depending on the discount factor used. All costs need to be included whether capital cost (C) or operating costs (O) but no consideration needs to be made for inflation and exchange rate depreciation.

The AIC method can be used to compare different water supply options, for example abstraction from groundwater or surface water or a desalination plant.

The AIC can also be applied to investments in saving water for example through reduced leakage or reduced consumer demand. In this case, the calculation includes the savings in operating costs by not producing the water saved by the scheme (OS) as well as the capital (C) and operating (O) costs of the water saving project.

$$AIC = \frac{PV(C) + PV(O) - PV(OS)\ over\ 25\ years\ (€)}{PV\ of\ Water\ Consumed\ or\ Saved\ over\ 25\ years\ (m^3)}$$

The Average Incremental Social Cost (AISC) extends this approach to include “externalities” - the social and environmental costs and benefits (E).

$$AISC = \frac{PV(C) + PV(O) + PV(E) - PV(OS)\ over\ 25\ years\ (€)}{PV\ of\ Water\ Consumed\ or\ Saved\ over\ 25\ years\ (m^3)}$$

These social and environmental costs (E) should include the social cost/benefit of increased or decreased greenhouse gas emissions from the project.

The above approach is followed in the UK water industry planning process (Environment Agency, 2007) using a discount factor of 4.5% for comparing options.

A lot of attention has focused on estimating the cost of greenhouse gas emissions and guidance on this has changed frequently. The basic approach in UK is to express emissions as carbon dioxide equivalent (CO2e), priced at £25 per tonne of carbon dioxide equivalent (CO2e) in 2007 prices.

In these ways, the UK water industry attempts to monetarise the externalities of water supply or water efficiency projects, reflecting the UK's strong focus on financial regulation of the water industry.

3 Tariffs and other Economic Incentives

Tariffs are the charges paid by the users for their water service. As well as enabling the water service provider to recover their costs and finance the service, tariffs can also influence demand. In particular a high charge per unit of water provides an incentive to consumers to limit their consumption.

Kayaga and Smout (2008) described an example of the use of tariffs for demand management from Zaragoza, Spain where research is being conducted under SWITCH WP3.1.

Following a serious drought, Zaragoza City Council, the water service provider, initiated a long-term programme in 1995 to reform the tariff and raise prices to economic levels in a step-wise fashion. Until then the water tariffs were mainly driven by financial and political considerations, rather than economic considerations, to provide revenues that covered a politically acceptable part of the costs of providing water services (Arbués and Villanúa, 2006). The tariff comprised a fixed fee based on the street category where the building was located and a volumetric-based rate on an increasing block system, as shown in Table 1.

Table 1: Zaragoza variable tariff in 1993 (Source: Key informant, Zaragoza Finance Department, 2007).

Consumption Range per property per month	Price in Pesetas* per m^3	Equivalent price in Euros (at 2002 exchange rates)
0 - 6 m^3	12	0.07
6.1 – 13 m^3	25	0.15
13.1 -35 m^3	40	0.24
Over 35 m^3	56	0.33

*The Spanish Pesetas was replaced by the Euro in 2002 at an exchange rate of 166.4 pesetas to 1 Euro.

Key shortcomings of this system were

- the fixed portion of the tariff was relatively high and based on non-economic criteria.
- the tariff levels were relatively low, and could cover only a fraction of the operating costs,
- a significant number of properties did not have consumption meters, and were charged on a flat rate
- there was no differentiation between domestic and non-domestic tariffs.

As part of the reform programme, an empirical study was carried out by the University of Zaragoza from 1996 to 1998, to test short-term sensitivity of water demand to changes in price and key socioeconomic variables. (Arbués and Villanúa, 2006). The results were used to design a tariff aimed at incorporating optimization of economic efficiency; horizontal and vertical equity (i.e. same benefit, same cost, and different benefits, different costs); universal access and transparency.

Tariff structures that have operated since 2005 have been designed to match the socioeconomic attributes and consumption habits of the population. The tariff is based on a model household using an average basic amount of 3.5 m^3 per month to maintain the common good in the home, plus an additional 2.5 m^3 of water per month for each member of the household as shown in Table 2.

Table 2: Zaragoza domestic variable tariff at end of 2005 (Source: Key informant, Zaragoza Finance Department, 2007).

Breakdown	Consumption Range (per property per month	Price* (€/m^3)
(A) Fixed consumption (3.5 m^3 per household) plus 1 person's 2.5 m^3 per month	0 – 6.0 m^3	0.32
(B) Fixed consumption (3.5 m^3 per household) plus 6 persons' consumption at 2.5 m^3 per person per month	6.0 – 18.5 m^3	0.768
(C) Excess consumption	> 18.5 m^3	1.536

*Price includes sewerage charges

Whereas consumption falling in blocks (A) and (B) is subsidised, the tariff in block (C) is designed to cover full supply costs.

Furthermore, Zaragoza Municipal Council has been offering economic incentives to households that reduce their consumption rates. If households reduced their consumption by at least 40% in 2002, they were entitled to a 10% discount on the bill. After one years' trial, it was realised that 40% reduction in household water consumption was rather unrealistic, as can be seen from the low number of people (1,708) who achieved the target. In subsequent years, the target was reduced to 10% reduction in consumption rate per year. Following this change, more households participated and managed to achieve the target.. Table 3 shows the number of households that have made water savings, and who have benefited from the economic incentives.

Table 3: Number of households benefiting from the economic incentives for water saving (Source: Key informant, Zaragoza Finance Department, 2007).

Start Year	Households with new commitments	Further subsequent savings of 10% in the Year			
		2003	2004	2005	2006
2002	1,708	375	66	2	1
2003	27,741		5,331	487	123
2004	24,331			2,956	721
2005	27,929				4,635
2006	33,274				

Table 3 also shows that some households have the capacity to continue making savings in subsequent years. For instance, of the 1,708 households that reduced their consumption by 40% in 2002, 375 of these made a further 10% reduction in 2003. A further 10% savings were achieved by 66 households in 2004, two households in 2005 and one household in 2006, respectively. As can be seen from column 2 of the table, the scheme is being embraced by an increasing number of households, which has contributed to overall reduction in water consumption in Zaragoza described in Section 6.2.

4 Non Revenue Water and Economic Level of Leakage

Non Revenue Water (NRW) represents the difference between the volume of water delivered into a network and billed authorized consumption. This difference comprises unbilled authorized consumption, apparent losses and real losses, i.e. both commercial and physical losses.

NRW represents water which the service provider extracts from the source, treats and pumps into the network, incurring costs but getting no revenue in return. NRW values exceed 20% in many cities, and may be much higher. For example Kayaga and Smout (2007b) report that the estimated NRW for four utilities in sub-Saharan Africa that participated in a project on reduction of NRW ranged between 30% and 70%, a large fraction of which was suspected to be physical losses in the distribution network. Reduction of water loss in the water distribution network is not only important for financial accountability, but also reduces the risk of water re-contamination, improves service quality, and contributes to overall economic/environmental sustainability.

Actions to control NRW are therefore important, but they also have a cost and practical limits to what can be achieved, which has led to the concept of the Economic Level of Leakage as a target. As shown in Figure 3, the cost of leakage control is low when real losses are high, but these costs increase disproportionately as losses are reduced. The ELL is the level of leakage where the marginal benefits of the reduction of water losses are equal to the marginal costs associated with the reduction of water losses. Reducing the water losses further would cost more than the savings derived from those reductions.

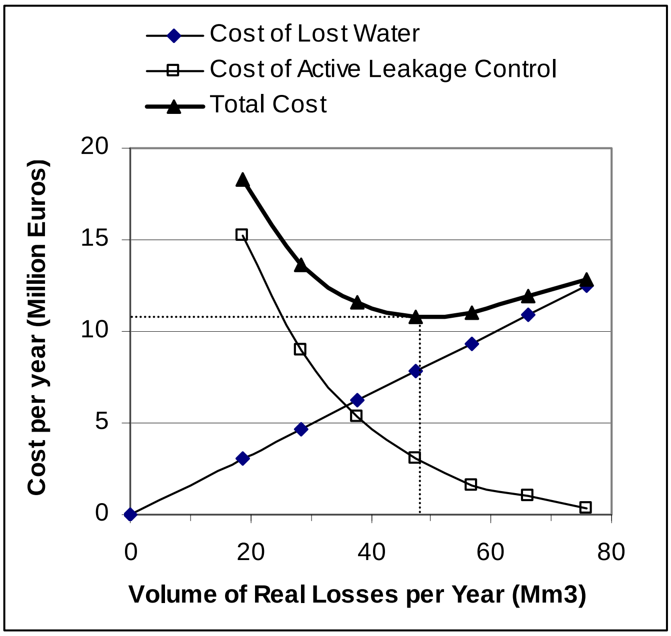

Figure 3: Derivation of the Economic Level of Leakage

Research is being undertaken on ELL in Zaragoza under WP3.1, including the energy component (which is a major component of the cost of water) and the impact of changing energy prices in future on the ELL.

As with the Average Incremental Cost calculation described in Section 2, externalities can also be monetarised and included in the ELL, to take account of the environmental, social and carbon impacts of leakage and leakage control activities. This is the approach being adopted in the UK water sector, though guidance on this is still evolving (RPS Water 2007). Taking account of these externalities is likely to increase the economic cost of lost water more than the economic cost of leakage control, leading to lower levels of ELL than would be calculated from the narrower financial perspective of the water service provider.

5 Conclusions

The Average Incremental Social Cost methodology can be applied across the whole water cycle, to compare different types of urban water management options, taking account of social and environmental costs, including the cost of carbon.

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