The Secret Life of Water Systems: Least Cost Planning Beyond Demand Management

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Abstract The water industry in Australia and international is involved in a period of significant change. The conventional roles of water and wastewater utilities are being redefined with the objectives of resource conservation and sustainable development added to existing responsibilities.

Least cost planning (LCP) has emerged as the way forward for water utilities in regions where water conservation has become an objective or where ongoing supply expansion is constrained. It involves techniques for the design and evaluation of demand management programs and aims to compare demand- and supply-side options on an equivalent basis. The approach is based on the key ideas that: demand is for the services water provides rather than the actual volume supplied; and that a drop of water saved is equal to a drop supplied.

This paper contends that LCP has much to offer the water sector beyond demand management. It is an approach that has potential for options assessment across the water cycle and can aid planning towards more sustainable outcomes within the sector. The paper concludes that LCP concepts and techniques will have worth in addressing the challenges of sustainable development for both urban water systems and catchment management.

Keywords Backcasting, Economic analysis, End-use modelling,

Introduction

Least cost planning originated in the energy sector in the United States during the 1980's for comparing energy conservation programs to increased generation as sources of supply (Beecher, 1996). It was based on the realization that a kilowatt of electricity saved through demand management was the equivalent of an increased kilowatt of supply. More recently LCP has emerged as a way forward for water utilities looking for ways to provide for new customers in regions where opportunities for the expansion of bulk supply are constrained.

Least cost planning for water supply involves a suite of techniques for the design of demand management options and programs, the estimation of water conservation outcomes, and the evaluation of costs. These assessment techniques aim to identify the lowest cost means of providing customers with the water-related services rather than the water itself (Howe and White, 1999).

The conceptual distinction between supplying water services rather than water is critical to how LCP differs from conventional 'supply-side' approaches. Based on this idea, a water supply and distribution system should not be designed or managed in order to meet a simple projection of increasing bulk water demand, but should be designed to satisfy the water-related service needs or end-uses. The key focus of LCP is then on what is normally the 'secret life' of our water systems: how water systems interact with system users to deliver the water-related services that people actually want and how the demand for specific end-uses such as clean clothes, hot showers, amenable landscapes is likely to change in the future. As well as this focus on end-use services, LCP is characterized by the deliberate linkage of demand forecast to backcasting, and by a distinctive approach to option evaluation.

In the water industry the usefulness of LCP in the design and evaluation of demand management options has been recognised. Beyond demand management, however, LCP has much to offer the water sector as an approach for planning towards more sustainable outcomes. This paper describes the key LCP concepts and techniques and explores a number of ways these might be applied more generally and with further development LCP has a significant role as an approach for identifying sustainable outcomes for both urban water systems and catchment management.

Service provision and end-use modelling

Least cost planning is based on the understanding that demand for water is in fact demand for the services water provides. As an approach it shifts the focus of analysis from the quantity of water delivered to the quality of the service provided. This change means that the conventional rationale of continuing supply expansion is no longer appropriate. Instead taking an LCP approach water utilities should consider demand management, source substitution and bulk supply options in unison, with the aim of identify how best to provide water-related services to system users (the customers).

The focus of LCP is at the point of interaction between system users and water systems. This is where end-use occurs. Both the characteristics of the water using equipment employed and user behaviour are then of interest. The end-use of household sanitation, for example, can be provided by single flush 12 litre, dual-flush 9/4.5 litre or 6/3 litre and now 4.5/3 litre dual-flush toilets or even with no water by a composting system. The amount of water required to provide household sanitation also depends on how the equipment is used. For example, do users flush both before and after use and is the half flush facility utilised?

The foundation of assessment in LCP is end-use analysis and end-use modelling. These methods epitomize the principle that demand is for water-related services rather than bulk supply. End use analysis and modelling disaggregate water demand into individual sectors (i.e. residential, commercial, industrial, institutional and unaccounted for or non revenue water), and end uses within these sectors (i.e. toilets, showers, clothes washers). End-use analysis builds up a picture of water use through customer meters, surveys of water using equipment (i.e. showers, clothes washers, toilets) and water using practices (i.e. frequency of shower use and clothes washing), and evaluation of industry sales statistics from manufacturers (White, 1998). End-use models combine this technical and behavioral data with demographic and land use change projections to produce detailed forecasts.

An end-use model forecasts both the future demand for water services and the resulting bulk supply demand. Detailed end-use modelling provides a much more rigorous basis for demand forecasting than simple demand trend models and this improves estimates of timing and costs of conventional supply augmentation (White and Fane, 2001). End-use models also allow the water savings from demand management and other conservation measures to be estimated. Both water efficiency and source substitution options can be better designed and evaluated using end-use models. Increased water efficiency can be achieved by either replacing water using equipment in existing properties or regulating the sales of new equipment. Source substitution options such as rain tanks and effluent reuse can be targeted at specific end-uses. Examples include, roof water being used for the laundry and garden watering and greywater diversion for toilet flushing. The focus of LCP on end use services allows options for providing the same end-use with less water or lower grade of water to be explored.

Forecasting and backcasting

Backcasting studies involve describing a desired future end-point and then working back from that point, to determine the feasibility and what would be required to reach that goal. Backcasting is useful when problems are complex, there is need for major change and/or dominant trends are part of the problem (Dreborg, 1996). It is an approach for exploring means by which specified future states might be attained (Robinson, 1982).

Forecasting in comparison involves projecting into the future based on what are perceived as the current dominant tends. Forecasting conceives of the future as immutable and a derivative of the present and the past while backcasting addresses the potential for people to change significant aspects of the future as it occurs. The future is of course both of these things, being in part derived from the present and in part the result of deliberate shaping.

Mitchell and White (2003) contend that forecasting and backcasting are complementary in planning for the future of water systems. Forecasting can tells us important information about the near future. This allows us to optimise the existing system in the short term. Backcasting is in contrast much more powerful as a means of reflecting on the medium to long term. This is because it allows assumptions about how systems might be configured in the future to be challenged and reconsidered.

Detailed forecasting is the basis of insightful backcasting. Since forecasting in LCP is based on understanding the underlying trends driving the demand for water (demographic change and the need for water-related services) rather than crude predictions based on the past volumes supplied, it opens the potential for backcasting. It is this kind of careful identification of which variables represent the underlying tends and which variables are mutable to future action that characterises a powerful backcasting study. The focus on service provision in LCP allows the source, quality and quantity of water used for each end-use to be variables in the analysis.

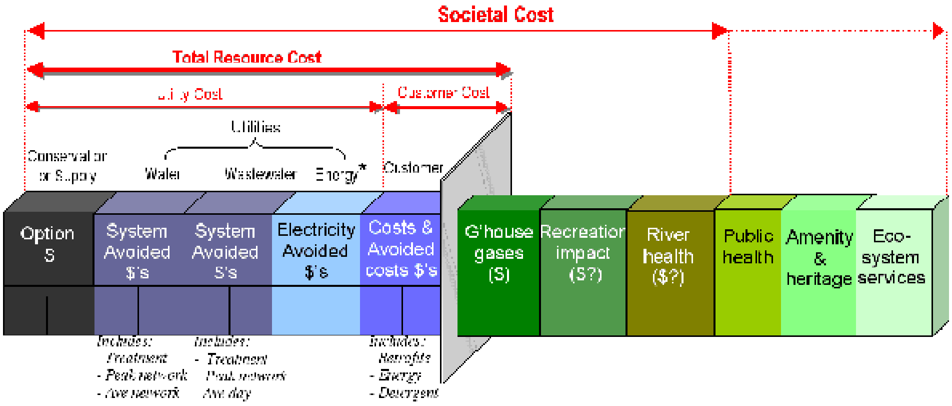
Least cost planning studies can focus on either forecasting or backcasting. Studies can use LCP to identify the immediate benefits from demand management programs or identify the current least cost suite of options. Alternatively an LCP approach can be used to design programs that aim to meet designated water conservation targets over time. Australia has a number of examples of such targets, which would be amenable to backcasting. The Victoria Government has recently established a target to reduce Melbourne's per capita water use by 15 per cent by 2010, Sydney Water Corporation has a long standing regulatory requirement to reduce demand per capita by 35% by 2011 from 1991 levels in per capita terms and the ACT Government has targets to reduce per capita demand by 12% and 25% by 2013 and 2023 respectively compared to 2003 levels.

The least-cost evaluation framework

Cost analysis in LCP is distinctive. Firstly, the focus on service provision in LCP allows demand-and supply-side options to be compared on an equivalent basis. The use of levelised cost, calculated in the manner described by Fane *et al* (2002), compares options in terms of their relative unit cost based on the potential to satisfy projected demand. As demand can be satisfied through either increasing the water supplied, or reducing the quantity required, demand management, source substitution, and bulk supply options are treated equally.

Secondly, the concept of cost avoidance is important for LCP (Beecher, 1996). In LCP for water supply, the avoided costs are those costs of supply that are not incurred when water is conserved. Accounting for these costs, which include the direct operating costs of supply, the deferred cost of future augmentation, and the indirect cost savings to consumers (i.e. energy and detergent) are critical in making the case for water conservation.

Finally, LCP for water supply utilises various ‘cost tests’ which explicitly inform decision-making by and about water utilities (White, 1998). These tests address the ‘whole of society’ standpoint as well as the financial perspective of stakeholders in supply planning (see Figure 1). The total resource cost and societal cost tests are used in LCP to evaluate the cost effectiveness from a whole of society perspective while the utility and customer cost tests address financial interests (Cal Public Utilities Commission, 2001). For each test, both the costs and benefits (avoided costs) are included.



** to avoid double counting, exclude energy costs from Water, Wastewater and customer operating costs.*

Figure 1 Least cost planning cost tests : Spectrum of cost and avoided cost

The total resource cost includes all costs and benefits to the utility and its customers. The societal cost test is a better approximation of the whole of society perspective including all those elements in the total resource cost as well as externalities. Transfer payments from governments such as tax credit benefits are excluded. The societal cost is more difficult to estimate because while the economic value of some externalities can be assessed (i.e. greenhouse gas emissions, recreational impacts) a defendable valuation of other impacts of water supply (i.e. river health, public health, heritage) are more difficult or impossible to quantify.

The financial cost tests from the utility and customer group perspectives are used decide how best to roll out programs and to allocate costs fairly amongst stakeholders. They address issues of equity between customer groups and the financial viability of the water utility. This allows the least cost solution to be pursued even when it is not in the water supply utilities current financial interest (Cal Public Utilities Commission, 2001).

Least cost planning for sustainable water management

This section considers the potential of LCP concepts and techniques beyond the design and evaluation of demand management programs.

End-use modelling and the provision of services across the water cycle

The concept of end-use modelling can be extended from it's current application to demand management. In urban water, both wastewater and stormwater infrastructures can be addressed by end-use models. Existing water end-use models can be readily adapted to give estimates of average dry weather sewage flow. As Howe and White (1999) illustrated, end-use models can be used to inform planning for sewer networks and wastewater treatment. For wastewater planning, end-use models could also be enhanced to included pollutant loads. Wastewaters can be conceived as being generated at multiple sources (the end-use services) with each source having various quantity and quality characteristics. Similar to water, aggregate dry weather wastewater flows and pollutant material loads can be derived by combining the end-use or end-source information with data on pollution generated per person or household or from measured concentrations of pollutants present in each stream or source.

End-use models can be combined with stormwater modelling to examine the impact of rain tanks and stormwater capture on both potable demand and stormwater infrastructure requirements. Complete urban water infrastructure scenarios can also be designed around an end-use/end-source models. This has significant advantages over other total water cycle approaches because it focuses scenario design on the actual services to be provided.

For water supply, models which incorporate both daily and seasonal timing for particular end-use demands can also be envisaged. Such an advance would improve projection of peaks demands and facilitate better capacity planning in distribution networks. In some instances, targeted demand management programs could be designed to 'shave' the peaks to within existing system capacities, thus optimising the system. This approach, called 'local integrated resource planning' (Pupp *et al.* 1995) or time and area specific costing (Swisher and Orans, 1995) has already been developed for the electricity sector.

Beyond urban water, end-use models can include agricultural (irrigation demands) and ecological services (environmental flows). Such models could be utilised in catchment management. End-source modelling for water quality planning on a catchment basis is also being developed. In each case an end-use or end-source model will enables water conservation and pollutant source control options to be fully explored and considered equally alongside capital works augmentations.

Backcasting from a sustainable future

As Mitchell and White (2003) state, the development of sustainable water service provision will require the application of both forecasting and backcasting. Backcasting from a sustainable future in relation to an infrastructure system first requires the definition of sustainability goals. At the same time forecasts would be made based on underlying service provision and material flow generation trends. Given the goals and the known trends, interim steps could then be developed. This process is iterative, working backwards to determine the necessary steps towards the desired future, while also working forward based on trend forecasts. By working in this way a number of possible physical and behavioural paths connecting the preferred future with the present could then be developed.

The backcasting concept can readily be extended to address wastewater goals as well as catchment water quality and environmental flow targets. Ideally backcasting would be used to address multiple sustainability goals in a process of planning sustainable development pathways for urban water infrastructures and catchments. Goals might include: water quality targets in catchments, water and nutrient recycling, resource usage, and greenhouse gas intensity.

Backcasting for water systems could also apply deliberative processes in setting sustainability goals. This would ensure that the targets set were both reasonable and acceptable to the community. A deliberative process requires a forum such as citizen juries, consensus conferences, or planning cells. Such techniques assess community opinions and act to educate these opinions through briefing materials (Carson and Gelber, 2001). Critically these techniques also allow citizens to discuss and deliberate on the issues in question.

Challenging the assumption that future urban water systems will follow the conventional model of centralised networks and supply of one quality of water, backcasting can be used to generate alternative scenarios. Alternatives might be based on distributed wastewater and stormwater systems as well as utilise distributed source of supply (such as neighbourhood run-off and the local reuse of effluent). Such scenarios could then be compared to more conventional systems that might also provide future service demand and meet the sustainability goals set.

Extending the least-cost framework

As with LCP for water supply, designing options around an end-use demand projection model can change the relative costs of options for wastewater, stormwater and whole infrastructure scenarios. The concept of levelised cost, which in water supply LCP is the unit cost of water conserved or supplied, can be applied to both wastewater and stormwater volumes. Building alternative infrastructure scenarios for water in a new urban development around an end-use model of forecast demand also has advantages at both the scenario design and life cycle costing stages of an evaluation.

The concepts of avoided costs and the utility of various ‘cost tests’ can likewise be extended and applied to infrastructure planning across the water cycle. For example, cost tests which consider the public sector as a whole and the developer’s perspective would be of benefit for State Government planning of new development areas. As Figure 1 illustrated, the spectrum of avoided costs for an option also extends beyond those externalities which are simple to value and include in the societal cost. Moving along the spectrum, more difficult to value externalities, such river health, are followed by impacts where reasonable and non-contentious monetary valuation is not possible (such as public health or ecological services).

As O’Conner (2000) contends, not all impacts can be translated into dollar term. A frontier of monetisation exists beyond which monetary evaluations are not meaningful. Crossing the frontier people can not consider impacts in a solely economic manner and information on impacts needs to be organized in a non-monetary form (O’Connor, 2000). At this point we argue that further aspects must then be accounted for qualitatively. This could be as an absolute constraint on the options considered or as sustainability goals for backcasting. Such an approach would treat critical criteria for water system sustainability as limits on the options or goals for scenario development. Less critical criteria (although not necessarily less important) would be treated as costed externalities within the societal cost test.

Conclusions

Least cost planning is based on the key idea that demand for water is in fact derived from the demand for the services that water provides. Least cost planning concerns itself with how water systems mediate resource usage and environmentally impact in producing these water related-services for system users. In LCP, options and scenarios are constructed around an end-use model. This exemplifies the focus on service provision. Importantly, end-use models allow demand management, source substitution and pollutant source control measures to be full considered.

In LCP forecasting and backcasting are complimentary. When LCP is used in a backcasting study, various means of moving from where we are to the determined desirable future state where we want to be are compared. The LCP approach permits this exploration of alternative pathways only because of the detailed forecasting based on underlying service provision trend embodied in the end-use model.

Options evaluation in LCP is characteristic because of the focus on service provision in modelling and analysis. The evaluation framework in LCP also moves beyond cost benefit analysis. An extended LCP framework can account for the qualitative aspects of sustainability together with cost analysis. It provides alternative means for incorporating externalities and sustainability criteria together with cost.

An LCP evaluation framework also accounts for the various financial perspectives of stakeholders. This means cost sharing arrangements can be considered based on the partitioning of costs between parties relative to the benefits. The LCP framework thereby allow an exploration of which stakeholders will benefit and how much it will cost to move along the different pathways towards sustainability.

In conclusion, because of its various distinctive and beneficial attributes it is our contention that LCP concepts and techniques have significant potential for use in assessing sustainable outcomes across the water cycle.

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