

DO TRANSPORT AND WATER SUPPLY INFRASTRUCTURE HAVE THE SAME BENEFITS?

Anna Robak, Opus International Consultants

Dr Henning Bjornlund, University of South Australia and University of Lethbridge

Abstract

Water supply infrastructure will be upgraded for drinking water standard compliance purposes, but with economic evaluation methods that are commonly being employed in water supply it may be difficult to show whether or not the benefits of proposed solutions outweigh the costs. Water supply projects will begin to compete for funding with other infrastructure types. Hence, it will be invaluable to be able to compare them using similar calculation methods. Transportation economics in particular is a well established field with rigorous guidelines for calculating costs and benefits, so we investigate the elements of transportation economics to identify areas for development in water supply economics.

Key Words: Benefits, water supply, transportation, infrastructure

Introduction

As engineers we select water infrastructure projects whose financial benefits outweigh financial costs but generally we do not quantify the social, cultural, environmental, and wider economic costs and benefits. How can we evaluate the health, welfare, and productivity benefits of a proposed new, maintained, or upgraded water supply system?

Water supply infrastructure will be upgraded for drinking water standard compliance purposes, but with economic evaluation methods that are commonly being employed in water supply it may be difficult to show whether or not the benefits of proposed solutions outweigh the costs. Drinking water standards are generally targeted at using treatment that has a certain level of assurance (e.g., 95 percentile) that the determinand will be removed or reduced to acceptable levels, but there tends to be no valuation of the benefits. As one drinking water programme coordinator said, “we know what upgrading water supplies need to do...but we know less about the benefits and generally assume there are benefits (personal communication 2007).” The aim of

this paper is to identify calculation methods for valuing the benefits of water supply projects. Transportation economics in particular is a well established field with rigorous guidelines for calculating costs and benefits, so we investigate the elements of transportation economics to identify areas for development in water supply economics.

The importance of water supply infrastructure

The purpose of water supply infrastructure is to provide reliable access to enough water of adequate quality. Any improvement that reduces the costs associated with providing this level of access, reliability, volume, and quality is a benefit.

Worldwide there are 2.2 million deaths annually due to diarrhoeal disease, due to unsafe drinking water, a lack of sanitation, and/or a lack of hygiene (WHO 2008). It is difficult to separate out the portions that are due to poor quality or inadequate water supply compared to those that are due to inadequate waste disposal or poor hygiene practices. However by looking at statistics from a part of the world that presumably have adequate sanitation and hygiene, which

should largely be left with the impact of water supply issues. The World Health Organisation (WHO)'s 'Western Pacific A' region comprises Australia, New Zealand, Japan, Brunei and Singapore. In Western Pacific A, 2,000 deaths and 45,000 disability affected life years (DALYs) annually are due to diarrhoeal disease (Table 1).

Table 1. Deaths, incidences and DALYs of diarrhoeal disease compared to road traffic accidents

(adapted from *WHO Global Burden of Disease: 2004 update database*)

	Deaths ('000)	Incidences ('000)	DALYs ('000)
World			
Diarrhoea	2,200	4,620,400	72,800
Road traffic accidents	1,300	24,300	41,200
Western Pacific			
Diarrhoea	108	1,255,900	5,200
Road traffic accidents	336	4,100	9,600
Western Pacific A (high income)			
Diarrhoea	2	29,700	45
Road traffic accidents	12	145	270

To provide a rough estimate of the costs associated with diarrhoeal disease, we use a fraction of the costs from the most recent significant *E coli* outbreak and make some conservative assumptions. As part of the Walkerton Inquiry of 2001, Livernois (2002) estimated the economic costs of an E coli outbreak that affected an estimated 2300 people at \$CAD64.5M, without including the statistical value of life. Approximately half of these costs were due to studies, reports and legal costs. Only using the costs arising from a typical incidence of diarrhoeal disease, including the costs of travelling to the chemist, purchasing an over the counter medication, and missing one day of work, the cost of one diarrhoeal incident may be around \$119 (Table 2). This corresponds with the cost of US\$116 for a mild illness estimated by Corso et al,(2003) . At \$119 per

incident, the total cost of diarrhoeal incidences in Western Pacific A would be in around \$3,530M, assuming only minor cases, with no permanent disability.

Table 2. Cost estimation of one diarrhoeal incident

Cost item	Rate	Cost	Rate source
Round trip to chemist 5km	\$0.34/km	\$1.70	NZTA base vehicle operating cost, 1-3% grade, 31-50km/hr, 2008 NZ dollars
Over the counter medication	\$9.90	\$9.90	Online chemist – Diastop tablets (lowest price treatment) http://www.healthchemist.co.nz/category/anti-diarrhoea.html
One day of work hours - 8	\$13.42	\$107.40	Statistics New Zealand median wage June 2008 (http://www.stats.govt.nz/products-and-services/hot-off-the-press/nz-income-survey/nz-income-survey-jun08qtr-hotp-revised.htm)
Total		\$119.00	

In New Zealand, the Ministry of Health (Ball 2007; MoH 2006, 2007) have reported an average of 173 cases of waterborne outbreak, and 18,000 to 34,000 cases of gastro-intestinal disease per year during 2001-2007. The exact number is difficult to estimate as water-related illnesses are often not severe in developed countries and are therefore not reported in a manner that clearly identifies the cause of the illness (Ball, 2007). Cost of illness studies (Livernois 2002; Corso et al. 2003; Baker et al. 1977) (Table 3) suggest that the consequences of outbreaks caused by poor water quality include:

1. life lost or years with disability;
2. lost personal time;

3. the need for medical treatment (travel to doctor, doctor's fees, pharmaceuticals);
4. preventive (water) treatment (costs associated with boiling water) or securing other sources (travelling to and purchasing from vendor);
5. replacement of contaminated food and/or costs of purchasing from a restaurant;
6. replacement of damaged clothing (and travelling elsewhere to wash clothing, take showers and baths);
7. lost business opportunity (obtaining safe drinking water, replacing and disinfecting equipment, diverting human resources deal with the water crisis);
8. lost productivity (sick days);
9. a decrease in property value;
10. long-term health costs;
11. opportunity costs of hospital days
12. legal expenses, investigations, and public relations;
13. water quality testing, monitoring and reporting; and
14. remediation and repair.

Table 3. Cost of illness calculated for four major outbreaks

(sourced from: Livernois 2002, Corso et al 2003, ETC 2007)

	Fatalities	Non-fatal illnesses	Estimated cost
Walkerton (2000)	7	2300	\$CAD65-155M*
Milwaukee (1993)	69	403,000	\$US96.2M**
Sydney (1998)	0	0	\$AUD37-137M***
Queenstown (1984)	0	3500	NA
*2002 dollars. \$64.5M includes items 3 listed above. \$155M includes statistical value of life. **1993 dollars, medical and lost productivity ***1998 dollars. \$37M includes media response; \$137M includes contingencies.			

For small systems such as Walkerton, a small investment in the water supply system would have proven cost effective, as the remedial works only cost in the order of \$9M,

and preventive costs would likely have been much lower. The USEPA (2005) has undertaken an economic analysis of its proposed surface water treatment rule, and has valued the benefits at between \$US497M and \$US2,047M annually, compared to annual costs of \$US111M to \$US160M. This analysis focused only on expected reductions in the numbers of *Cryptosporidium* oocysts and the associated cost of illness avoided by implementing a particular type of treatment.

Why compare benefits of water supply infrastructure to benefits of transportation infrastructure?

Clean and adequate water is essential for life, yet in New Zealand and in many other parts of the industrialised world, water supply infrastructure has been left to deteriorate. In New Zealand, \$424M was spent on local government water supply services in 2006 (LGRI 2007), whereas local government ten-year plans project average annual expenditures of \$815M (NZCID 2008). Approximately one-third of the \$815M is targeted at compliance with the New Zealand Drinking Water Standards 2005 (NZCID 2008), although it is debatable whether the \$271M reported is strictly for DWSNZ compliance, or whether local authorities are taking the opportunity to address significant backlogs. The non-DWSNZ proportion is nearly 30% higher than previously suggesting there are significant backlogs in the water supply sector.

While it is widely believed communities benefit from new or improved water supply or treatment systems, the net present value (NPV) tends to be negative and the benefit cost ratio (BCR) tends to be less than 1.0, because most of the benefits are social,

There seem to be a larger number of guidelines on benefit cost analyses for transportation projects. We therefore know the benefits of roads and are able to make appropriate investments. If we could similarly understand the true costs and benefits of water supply investments, we would be more confident in making appropriate investments. The water supply sector might therefore be able to learn lessons from Transportation.

Strength of transportation economics as a discipline

The strength of transportation infrastructure economics is likely due to a combination of factors, including the following:

- **Commercial.** The main purpose of roads and highways is to trade goods and services, which means they are driven by economic benefits which are easier to put into monetary terms than are social and environmental benefits. Conventional transportation project appraisal captures the most significant economic benefits through time travel savings (Department for Transport 2006). Water supply projects, are generally driven by social needs, and are more difficult to quantify.
- **Recognised academic discipline.** Due to its commercial nature, transportation economics is a well-funded discipline, with much of the research and development funded by organisations that benefit from supplying roads. Organisations supplying water infrastructure, do not appear to have pooled resources in a similar way.
- **Growth.** New roads promote increased economic growth by increasing trade linkages and reducing travel times so that more and/or lower cost trips are possible. Water are mainly concerned with *sustaining welfare*. New treatment facilities are likely to be put in place because the source water quality has degraded; water supplies are therefore more for preventive purposes than for 'progress'. For some reason, progress pulls more weight than sustenance.
- **Visibility.** We can see when the condition of a road surface is deteriorating, or when there is an accident due to surface condition (slippery surface) or road alignment. With water supply, we generally cannot see that pipes are leaking and we often are not aware of water-related illnesses in the community.
- **Limited number of variables – 'ease' of predictive modelling.** As roads are visible, it is easy to collect a significant amount of temporal data on their surface conditions for predictive modelling. While underlying pavement strength and construction quality add some uncertainty,

in water supply the uncertainties are far more plentiful, including i) likely pollutants in the source, ii) effective plant operation, iii) potential growth in the reticulation, iv) likely virulence, and v) likely health effects. In addition, whereas road performance can be predicted primarily through a single discipline, civil engineering, understanding water supply performance requires an understanding of civil engineering, biology, chemistry, electrical engineering, and epidemiology.

- **Political.** Transportation projects – being so visible to the public – makes them ideal for political grandstanding with great electoral potential. In water supply the public does not see a problem until there is a catastrophic break or an outbreak.
- **Economies of scale.** Road projects are less susceptible to economies of scale than are water supply projects. Road projects can often be developed in sections and still provide user benefits. Water supply requires a significant capital outlay because it requires development of a source, treatment facilities, storage facilities, and reticulation. Much of the capital cost is in site establishment; installing the intake, digging the trenches, and erecting the treatment building and reservoir. Smaller populations tend to have a lower population density resulting in high cost per beneficiary.
- **Inter-regional use.** Road projects are used by more than just the local population; they encourage external use, bringing in trade from other regions. As the cost of some roads is shared across regions, even poorer communities may have high quality roads.
- **Low operation and maintenance costs.** Compared to water infrastructure, annual operation and maintenance costs for roads are low. Roads may require small patching jobs and a reseal every 6 to 20 years resulting in annual expenditures at approximately 2.5% of replacement value. A water treatment plant can generate 10% of its initial capital outlay annually in operating and maintenance costs.

Examining project-level transportation infrastructure benefits

The New Zealand Transport Authority (NZTA) has developed an Economic Evaluation Manual (EEM) to evaluate BCR's for transportation projects (NZTA 2008). Table 4 shows our proposed analysis categories for water infrastructure based on each category in Volume 1 of the EEM.

Table 4. Standard analysis procedures

Transportation (existing)	Water supply (proposed)
<u>Maintenance costs</u> Historical and projected maintenance costs compared to projected maintenance	<u>Maintenance costs</u> Same, incorporating operators' attendance and travel time
<u>Structural bridge renewal</u> Travel time benefit of heavy vehicle access	<u>Time value and equipment costs (access)</u> Time and equipment costs of procuring and treating own water
<u>General road improvements</u> Use of quick reference tables for vehicle operating costs	<u>Operating costs</u> Produce lookup tables for pump costs or chemical dosing alternatives
<u>Seal extension benefits</u> Comfort benefit value per kilometre and productivity gains for farms	<u>Time value and equipment costs (access)</u> As above
<u>Isolated intersection</u> Travel time, vehicle operating costs and accident reduction as discussed elsewhere in this table	Not applicable
<u>Travel time (improved flow / reduced congestion)</u> Time value of time lost in speed cycle changes, shorter duration trips	<u>Time value and equipment costs</u> Time value and equipment costs of backup plans or reduced business productivity due to routine low flow or pressure
<u>Travel time (reliability)</u> Time value of predictability of trip duration	<u>Time value and equipment costs (service disruption)</u> Time value and equipment costs of

Transportation (existing)	Water supply (proposed)
	backup plans or reduced business productivity due to unplanned service interruptions or water quality excursion, plus frustration costs on time value
<u>Vehicle operating cost</u> Additional running costs (fuel, etc) due to surface roughness, speed, terrain, congestion	<u>Energy, chemical dosing, operations costs</u> Additional operating costs due to pump start-stops, choice of chemical dosing
<u>Accident cost savings</u> Medical costs, standard value of life, legal fees, property damage	<u>Cost of illness, accident cost savings, damage</u> Same costs related to illness
<u>Vehicle passing lane benefits</u> Travel time savings as address above	Not applicable
<u>Other impacts (noise)</u> Based on median property value and decibel noise increase	<u>Other impacts (noise)</u> Applicable mainly to noise effects of pumps and equipment on operators
<u>Other impacts (Vehicle emissions)</u> Based on particulate matter	Not applicable
<u>Other impacts (external, ecological, visual, community severance, overshadowing, isolation)</u> No specific guidance	Not applicable

We propose to apply the EEM model to water supply infrastructure as follows:

Maintenance costs

Maintenance cost = replacement parts + operators' attendance time + response to public + additional treatment costs + property damage

Replacement parts + operators' attendance time. The maintenance cost method is based on the cost savings derived from maintaining a proposed option compared to maintaining the do-minimum scenario. Standard maintenance cost curves can be developed

for expected replacement parts and attendance time for different pipe materials, sizes, flows, water quality, and suspected water hammer.

Response to public. If the need for maintenance is brought to the supplier's attention by a member of the public then there will be administrative costs associated with responding to the complaint.

Additional treatment costs may result from water that is treated and subsequently lost from the reticulation. We recommend valuing the treatment and pumping costs associated with the additional water.

Property damage. Maintenance or replacement costs may be incurred by the user if a break damages property or if the water quality causes more rapid deterioration of the customers' fittings or businesses' equipment, and the damage caused by salinity.

Access costs

Access costs = equipment / vendors' fees + travel time

The costs associated with access would be alternative methods of procuring water, such as wells, vendors (including the costs associated with travelling to vendors), and/or household treatment. In developed countries there may be no cost savings associated with household access to water supply; however, there may be cost savings to businesses or plants that use significant amounts of water. According to PWC (2004), only 58% of water supplied by local authorities in New Zealand is used domestically. Conversely, industry sources only 66% of its water needs itself.

In developing countries much time is spent collecting water. Traditionally this time has been described as difficult to value, but the Genuine Progress Indicator (GPI) recognises the value of domestic work, based on the rates that would be paid by hiring someone to do household or childcare (Talberth et al 2006). People – generally children and women – who fetch water could be otherwise occupied doing housework, productive labour, or gaining an education. The time travel savings can be based on the opportunity cost associated with these other

activities, or on the sum that would have to be paid to a water vendor.

Operating costs

Operating costs = energy + chemicals + operators' attendance time

In water supply, normal running costs may include energy costs associated with pumping, treatment and controls; chemical costs associated with treatment; and operation. These costs are affected by pipe roughness and head losses, number of pump start-stops, pumping time of day, and level of automation. As for maintenance, lookup tables could be developed for different cases.

Service disruption costs

Service disruption = preventive equipment or reactive water procurement

Service interruptions, their duration as well as fluctuations in pressure and supply rate can be costly and inconvenient to water users. The potential cost savings associated with improved reliability will depend on to what extent people or businesses rely on water at a particular time, and to what extent it affects their daily life and productivity. If a water supply is known to be unreliable, people might purchase storage tanks or other preventive measures so that their daily life remains unaffected. For supplies serving households and businesses that do not have backup plans, the cost savings would include reduced responses to public complaints, reduced reactive works, and reactive arrangements people need to make to obtain water. These events might also carry frustration costs.

Cost of illness

Cost of illness = Probability of illness * {medical treatment + travel time (for doctors' visits, clean water, etc) + lost productivity + other items identified in (1) through (14) above}

The first-world outbreaks of Walkerton, Sydney, Milwaukee, and Queenstown are a few of the significant incidents that stress the importance of secure and robust drinking water supplies. The water supply community does not have a robust database of illness,

hence, the probability of a drinking water related illness being reported over the past five years is unlikely. Yet there are 200 times more incidences of diarrhoeal disease than road traffic accidents in Western Pacific A, and the social costs are likely to be similar.

Above we calculated the cost of diarrhoeal disease at about \$3,500M. We can use MOT (2008)'s statistics to calculate the cost of road traffic accidents to compare the magnitude of social costs. The weighted average per-injury road traffic accident cost was \$52.5k. The cost of road traffic accidents in the Western Pacific A would be in the region of \$7,600M. Thus, a very conservative estimate of the social costs of water supply suggests that improved quality of water supply has at least similar benefits to improved road safety.

USEPA (2005) and Chapman and Wellington (2004) estimate cost of illness savings as part of the treatment decision making process before implementing the project by attributing a probability to a particular occurrence based on the type of treatment. The cost savings associated with a higher level of treatment would be the likelihood of occurrence without the treatment less the likelihood of occurrence with the treatment times the likely cost of illness.

Accident and damage costs

Cost of accident = Probability * {Medical fees + lost productivity + legal fees + damages due}

In transportation, accident cost savings are based on the average annual number of accidents over the previous five years. Each accident falls into a particular severity category of fatal, serious, or minor, and each severity category has an associated under-reporting factor that recognises that not all serious and minor injuries are reported. The numbers of serious and minor accidents are bumped up by their under-reporting factor, and all accident types are multiplied by their expected costs, which are based on reported costs associated with various injury types and severities, and based on a large accident database.

There may be particular problem areas in the network – particularly in pump stations or water treatment plants – where operators or members of the public have a tendency to become injured. We propose a simplified version of the NZTA accident cost model which recognises the number of injuries over the past five years, and the costs associated with them. The prevalence of falls as a cause of injury should not be underestimated; in 2004, falls represented 0.5% of total deaths in the Western Pacific A subregion (WHO 2004), whereas road traffic accidents represented 0.8%. This could be an area for improvement.

A pipe break has the potential to cause significant property damage – in such an event, the cost would be the value of the property damage and business losses.

Other impacts (Noise)

The EEM proposes a value of 1.2% of property value per dB noise increase per property affected by the noise, and uses the New Zealand median house price. In water supply, operators may be subjected to high noise levels frequently due to maintenance and operations duties at pump stations and treatment plants. We propose applying the same value as the median household divided by the median number of people per house, although the monetised benefits will be small as the number of operators will be small.

National strategic factors

National strategic factors are benefits that are valued by water supply users or communities, but are not captured elsewhere in the project evaluation. These may include agglomeration benefits, security of access, and investment option values. Many economists attempt to capture the broader economic benefits of projects through Computable General Equilibrium (CGE) models and input-output models, but Wallis (2009) argues that most of the benefits for transportation projects are already captured through travel time and vehicle operating cost savings. Agglomeration, for example, is captured through the lower costs associated with proximity.

In developing countries, while we can value the time a household member could spend productively taking care of the children, it is more difficult to value the potential for community livelihood to improve as a result of that additional time, and harder still to value the children's time that could otherwise be spent obtaining an education. In smaller communities worldwide, it is difficult to evaluate the potential effects of innovation and technical diffusion due to operation and maintenance of complex water treatment and supply equipment.

Conclusion

The NZTA Economic Evaluation Manual appears to provide guidelines that cover a significant proportion of social and economic benefits. There seems to be significant scope and need for more specific guidance on economic evaluation for water supply projects, paper pulls together the elements required for such procedures.

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