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Cost-effectiveness analysis as a methodology to compare sanitation options in peri-urban Can Tho, Vietnam

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Abstract

It is challenging to make decisions about sanitation scale and technology choice for urban areas, however costing analyses have an important role to play in assisting determination of the most appropriate systems for a given context. The most appropriate technological system is the one that finds a locally acceptable balance between social (e.g., public health) outcomes, environmental (e.g., pollution, resource use and resource recovery) outcomes, and financial and economic outcomes (i.e. the costs and benefits for individuals, public and private organisations, and local society). There are many costing methods available. This paper describes the use of a cost-effectiveness analysis built on integrated resource planning principles. This method is suited to situations where the overall goal is already clear (in this case, that a wastewater service is required) and the analysis is conducted to identify the least cost solution to reach this goal. This costing method was used in conjunction with a deliberative sustainability assessment process that addressed non-monetary factors. The paper outlines the analytical approach adopted in the cost analysis as well as providing detailed discussion of the many decisions inherent in undertaking such an analysis. It describes how the analytical system boundaries were constructed, what level of detail was adhered to and how different cost perspectives and time value of money were taken into account. The explanation of the methodology is grounded in a case study undertaken in Can Tho Vietnam. The cost analysis results indicate that for the particular case study context, the 'least cost' solution was a combination of centralised and decentralised systems. Following discussion of the findings of this costing study, the challenges and limitations of the methodology employed are outlined. Finally, the authors note the need for a greater number of costing studies of this type to broaden the evidence base for decision-makers about the most cost-effective infrastructure options.

Keywords

Cost-effectiveness analysis: sanitation: urban development: wastewater management: Vietnam

INTRODUCTION

Decisions about the most cost-effective scale of treatment and fit-for-purpose configurations for wastewater treatment in cities are hampered by a lack of methods for robust comparison of alternatives. The aim of this paper is to describe a costing methodology that allows for sanitation options with very different characteristics to be compared on 'equal ground' – that is, using a method that does not inherently favour one or the other, but seeks to compare the societal costs for different alternatives that meet a specified objective. Illustration of the costing methodology is provided through examples from a case study site. This site is a newly developing peri-urban area in Can Tho, Vietnam. The site is currently home to approximately 40,000 people and contains a number of the poorest wards in Can Tho City. Based on current development plans, the future local population is likely to include wealthy and middle-class occupants as well as resettlement housing for poorer families relocated from 'temporary' housing during development of the area. The purpose of this paper is to focus specifically on the technicalities of the costing methodology, and hence other details of the overall approach undertaken in Vietnam, for instance the stakeholder engagement process, institutional analysis and sustainability assessment are reported elsewhere (Willetts et al., 2010).

The study builds on a well-established costing methodology developed by the Institute for Sustainable Futures (ISF) with five leading Australian water utilities and an environmental agency (Mitchell et al., 2007). The case study work was undertaken in collaboration with local Vietnamese partners at Can Tho University and Can Tho Water Supply and Sewerage Company, with support from AusAID through the Australian Development Research Awards program.

Costing methodologies – why cost-effectiveness?

There are many different costing analysis approaches, each with respective strengths and weaknesses and each suited to different decisions and informing them in different ways. The following introductory discussion explores the key principles of the approach taken (see Mitchell et al, 2006 for a full description), positions this approach in the field, and shows how it helps to promote both economic efficiency and resource efficiency, both of which are core sustainability concepts.

The costing approach described in this paper draws on integrated resource planning fundamentals (Beecher, 1996). Integrated resource planning promotes resource efficiency because it seeks an equitable comparison between quite different means of meeting the same service outcome, such as supply and demand side options for water service provision, or different scales of treatment plants (e.g., one large centralised plant versus a number of small decentralised plants) for sanitation service.

The fundamental idea is that the analysis sought to identify the least cost means of providing specified services, in this case, providing sanitation to a portion of Can Tho. It is therefore a cost effectiveness analysis, where the focus is the relative costs of different ways of providing those services. In order for these relative costs to be comparable, attention needed to be paid to which costs are included and excluded for each option under consideration.

The concept of systems thinking is useful as a framework to aid in defining the boundary of the analysis and which costs (and benefits) are to be included and excluded. Urban water infrastructure can be viewed as a 'complex system' which means that it contains many interconnected, interdependent parts that function together. According to systems theorists, one important concept in systems thinking is the boundary. Boundaries are defined by the 'observer' of a system, and hence are a subjective judgement based on certain values and assumptions, pointing to a need to critically reflect on choices made (Midgely, 2003). Ensuring the boundaries are consistent between alternatives under analysis is a critical systems principle that is often inadvertently overlooked.

There are a few key dimensions to system boundaries taken into account in the costing analysis presented in this paper. In very broad terms, these are the people dimension, the time dimension, and the service itself. The 'people' dimension concerns consistency in cost perspectives, or *whose* costs and benefits are included. Since sanitation is a public good, the cost to whole of society was of interest. This cost is made up of the costs of relevant key players, which may include government, utilities, developers and householders. Attention to the 'time dimension' means that alternatives were analysed across a consistent time span' and a life cycle perspective was taken, so all capital, operational, and replacement costs and benefits across the different life cycles were accounted for. In addition, it means that the time value of money was accounted for consistently, and that the staging of developments over time was taken into account. The 'service itself' dimension points to the need for consistency in the starting point and end point for alternative options, e.g., from a house's connection to the sewer and through treatment to final disposal into a waterway or reuse.

Different outcomes result from each option, for example in water quality terms, and these need to be acknowledged and accounted for in transparent ways, however were not monetised and included in the cost analysis. In the case study described in this paper, a deliberative stakeholder sustainability assessment process was instead used to address these and other areas of difference between the options under consideration (see Willetts et al., 2010). The costing analysis itself is focused on actual cash flows, rather than on monetising either positive or negative non-monetised, non-cash flow impacts. This is one of two features that distinguishes the method from cost benefit analysis. The other is quite simply that cost benefit analysis seeks to make a determination about whether the costs of a single option outweigh its benefits, whereas cost effectiveness is designed to compare options to meet a specified objective.

Background to case study

A costing analysis was conducted to compare wastewater infrastructure alternatives for an area identified by local stakeholders as lacking wastewater infrastructure and in need of analysis as to the best course of action. The case study area was a new development area in the south of Can Tho, a city in the Mekong Delta in Vietnam (Figure 1 **Case study area in Southern Can Tho**). It comprises an area of 2,080 hectares and has an intended population in official documents of 150,000 people, though according to development plans, the population may reach as many as 278,000 people. For further details about the case study area and the stakeholder engagement process, see Willetts et al., 2010.

Figure 1 Case study area in Southern Can Tho

Four options for providing a wastewater service to this area were considered (**Error! Reference source not found.**). Each option under consideration was technically able to meet the required quite stringent effluent discharge standard (QCVN 14:2008/BTNMT – National technical regulation on domestic wastewater). The technology for the centralised system was a trickling filter, and for the decentralised system in Options 2 and 3, it was an anaerobic baffled reactor followed by an anaerobic filter and a planted horizontal gravel filter (in a design followed by the non-governmental organisation BORDA) and in Option 4 was a re-circulating sand filter. In all options ultra-violet disinfection was applied in order to meet the required effluent standard with respect to coliforms. In Option 4, urine is collected locally and then transported beyond the city limits to be stored for 6 months according to WHO guidelines (WHO, 2006) before sale as agricultural fertiliser. Initially an option including separation of blackwater and greywater was included however this was discarded as impractical during the course of analysis. From a user perspective, the options all offer a similar level of service with the only exception being Option 4 which includes a requirement for urine-separating toilets within dwellings.

Option 1 Fully centralised: Connect all new developments to a wastewater treatment plant (which is currently under construction to serve another part of the city) and significantly upgrade the capacity of this treatment plant to accommodate the increased wastewater flows.

Option 2 Fully decentralised – separate systems for each development area: Install local decentralised wastewater treatment plants at all development lots. Each installation would service several hundred households within development precincts.

Option 3 Combination of centralised system and decentralised systems: Connect selected new developments (determined by spatial analysis of relevant parameters) to existing wastewater treatment plant. Provide decentralised wastewater treatment technologies for other developments.

Option 4 Combination of centralised system and decentralised systems with urine separation for decentralised components: Connect selected new developments to existing wastewater treatment plant (as for Option 3). Provide decentralised wastewater treatment technologies for other developments, including urine separating toilets. Collect and treat urine for agricultural reuse as fertiliser.

Figure 2 **Description of options considered in the cost analysis**

Features of the cost-effectiveness methodology

The sections below describe details of how the costing analysis was undertaken including an explanation of important features of the method of analysis.

Consistent system boundaries

The system boundaries for the cost-effectiveness analysis were composed of a geographical boundary, a time boundary, and a set of judgements about which types of costs to include and exclude. As mentioned earlier, attention was also paid to cost perspectives and whose costs were included.

The same geographic area was applied for all options and comprised an area of 2,080 hectares and a population projection of 278,000 people when fully developed and occupied assuming that all developer plans proceed.

There were two aspects to the time dimension for the analysis. First, a common time-period for analysis of 30 years was chosen. This time-period was chosen due to the long life-time of many wastewater infrastructure components, to ensure that the long-term operation and maintenance costs were made visible and to allow insight into some aspects of asset replacement. Second, the timing of developments within the overall case study area was taken into account. Since development of a new urban area happens over time rather than all in one go, it was important to have a common time-series analysis of *when* each development plot would most likely be developed and occupied. Professional judgements by local stakeholders informed the time-series of development staging, and sensitivity analysis was later performed to examine the effects of a slower, or faster, rate of urbanisation.

By including the staging of developments within the analysis, it was possible to model the decentralised wastewater options in a way that recognises the ability of decentralised systems to be built when required according to the pace of development, thereby closely matching supply of wastewater services with demand for those services. For example, if the analysis had simply taken the full population projection and costed both centralised and decentralised treatment systems for this population, it would provide a different answer to a cost-analysis that is able to take into account when different investments would actually need to be made.

The overall approach of the study was to ensure that as many capital and operation and maintenance costs as possible were included in the analysis. In addition, the life cycle costs and asset lives were taken into account for most major assets (by inclusion as annualised costs) where it was possible to make reliable cost estimates. An exception to this is the asset replacement costs for the pipe-network which were excluded from all options due to challenges in making a reliable estimate. **Error! Reference source not found.** indicates the main costs included and excluded from the analysis. In general, excluded costs comprised either costs that did not vary between the four options under consideration (e.g., household pipe networks, septic tanks and desludging costs), costs where it was difficult to make reasonable estimates (e.g., cost of land for treatment system sites, indirect management costs), costs that occurred beyond the geographical boundary (e.g., off-site sludge treatment costs) and costs that would be incurred for stakeholders other than those identified in the costing analysis (namely the water supply and sewerage company, the government and householders). So, for example, the costs of the urban works authority in septic tank desludging and the environmental agency in environmental monitoring were not included. Finally, environmental externalities such as the greenhouse gas emissions based on energy use were not included (however it would have been legitimate to do so as these are often included in cost analyses of urban water infrastructure, see Turner et al., 2008). Similarly, the costs of potential environmental impact were not included since these would be challenging to estimate and all options were designed to meet a fairly stringent environmental regulation.

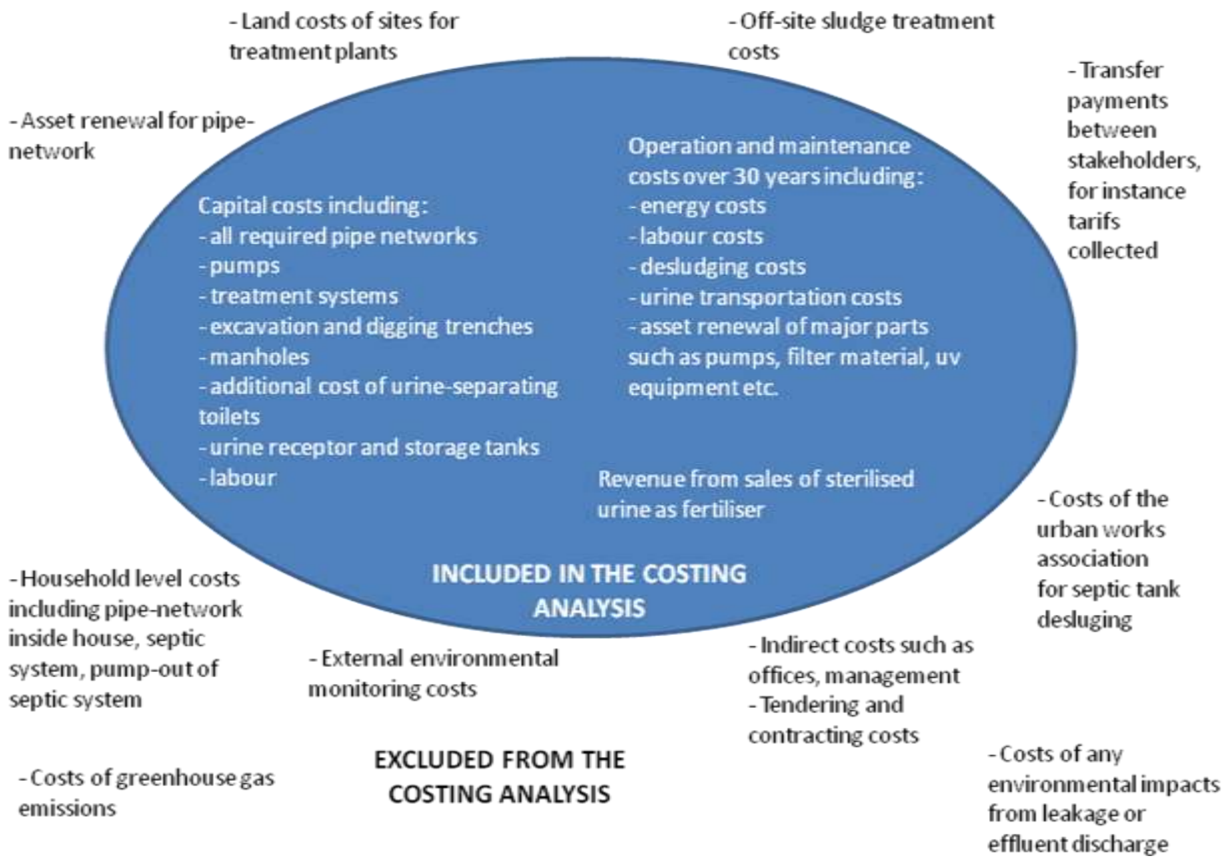

Figure 3 Costs included and excluded in the cost analysis

Comparison to a 'reference case'

As mentioned earlier, the overall pre-determined objective for the options being compared was to provide a reliable wastewater treatment service to a new development area that will protect public health and the environment. The cost-effectiveness analysis was therefore intended to compare a set of alternatives with the 'business as usual' course of action, which in this case would be to install fully centralised wastewater treatment infrastructure for the volume of wastewater likely to be generated by the projected population.

The three alternative options were included to provide insight into the relative cost of using decentralised infrastructure and resource recovery. It might also have been possible to include additional alternatives using the same analytical framework however these were beyond the scope within this project context. One such option would have been to consider the use of demand management (that is, water conservation programs intended to change water consumer behaviour) to reduce the overall wastewater flow. This would have offered a cost saving relative to options that treat a larger volume of wastewater.

Cost perspectives and focus on 'lowest cost to society'

The cost-analysis sought to identify the option that has the lowest 'cost to society' (Mitchell et al., 2007; Turner et al., 2008). This means that rather than individually considering the financial perspective of the water utility, or the financial perspective of a householder, a combined analysis is done in which costs (and revenue) for each of these groups is included. This means that costs such as tariffs paid by householders to a water utility) are considered 'transfer costs' that cancel each other out in the analysis.

The cost-analysis took into consideration the costs of four main stakeholder groups:

- Government (city or national government who are likely to provide the capital costs for wastewater treatment).
- The local water supply and sewerage company (who are likely to manage the system and hence bear the operation and maintenance costs, and in the future may also bear capital costs).
- Developers (who might, in the case of the decentralised treatment facilities, be called upon to install such systems as part of development of their land package).
- Householders (for instance the additional cost of a urine separating toilet as compared with a normal toilet for the fourth option, however as mentioned above, household level pipes and septic tanks were excluded as they are the same across all options).

Two other stakeholder groups were excluded since costs ascribed to them would likely be similar across the options, however could have potentially been included in the analysis – the urban works authority responsible for desludging septic systems and the environmental agency responsible for monitoring water quality.

The analysis added up the costs incurred and any revenue streams to these four stakeholder groups in order to generate a ‘whole of society cost’ in alignment with the methodology used in an integrated resources planning approach (Mitchell et al., 2007; Turner et al., 2008). In this methodology, once the least cost solution is confirmed, the individual financial perspectives can be considered for this option, and where necessary, adjustments can be negotiated in terms of ‘who pays for what’ to ensure that all stakeholders have an incentive to follow the ‘least cost’ solution. So for instance, if the result of the analysis was that a resource recovery option was the ‘least cost’ solution, then negotiations could be undertaken to determine who should pay for the additional cost of urine-separating toilets as compared with a normal toilet. Given that for this option the revenue stream from fertiliser sales would likely fall to the water utility, this negotiation could potentially see the water utility covering this additional cost of urine-separating toilets, rather than the householder, who may not see any return for that additional investment.

For the case study in Can Tho, the analysis identified the least cost option for ‘whole of society’ and then made clear the capital costs and operation and maintenance costs separately since they would likely be borne by different stakeholders. Capital costs are likely to be borne by the government, whereas the operation and maintenance costs (which include major asset renewal costs) would be borne by the utility. It is also possible that the developer’s financial perspective might be important for implementation of any options including decentralised components, since the capital cost of installing a decentralised wastewater treatment plant may be considered as part of the development of a package of land.

Basis of comparison

The basis of comparison of options using the ‘whole of society cost’ was undertaken using net present value. An additional analysis also assessed the average incremental cost (the unit cost) of options. Net present value is a commonly used criteria for investment analysis and is also a standard criteria used by many governments and organisations to evaluate, compare and prioritise projects (Turner et al., 2008). Net present value or net present worth accounts for the ‘time value of money’ through a discounting process. The net present value of an alternative is the value of the stream of costs and benefits (or avoided costs) associated with that alternative into the future, discounted back to the present based on a pre-determined discount rate (Hanley & Spash, 1993).

Discounting is the reverse of the standard compound interest calculation, so discounting is used to determine the present or current value of an identified cost or benefit incurred at a known time in the future. In the case study, a discount rate of 8% was used as an appropriate rate for government spending in Vietnam. Sensitivity analysis was also performed using 10% as a rate appropriate for private investment in Vietnam.

The present value (PV) of a cost incurred t years into the future is estimated as (Turner et al., 2008; p40):

$$PV(X_t) = \sum_{t=1}^{N} \frac{X_t}{(1+r)^t}$$

where

PV = present value
X_t = the cost incurred in year t
r = the annual discount rate
N = the period in years over which the analysis is undertaken

In addition, the levelised cost (or incremental cost) was calculated. This levelised cost concerned the cost of service per unit of water consumed and also per dwelling. In this calculation the time-series of either the volume of water consumed (or number of houses served) is used to generate a levelised cost. Calculating the levelised cost then takes into account the time-series of water consumed (or dwellings constructed), which changes during the period of development of a new urban area.

Use of sensitivity analysis

A few key parameters were chosen to undertake a sensitivity analysis on the results of the cost analysis. The parameters tested included the discount rate, the staging of developments, the time period of analysis and the population projection. These analyses gave insight into which of these factors played a key role in the results. Further sensitivity analysis, such as changing the unit costs of certain components where the cost estimates were less certain would have been useful however, this was not possible within the timeframe of the project.

Results and discussion

A detailed Excel® spreadsheet model was developed that included both the water balance as well as the costing analysis calculations. The sections below provide some of the core results of the costing analysis. For more detailed explanation of the implications of the analysis with regard to when and where centralised and decentralised wastewater systems are best employed, and also results of an associated sustainability assessment of the case study wastewater options, see Willetts et al. 2010. Following presentation of the results, we provide discussion of some of the key learnings through the use of the cost-effectiveness analysis methodology.

Presentation of results

The results of the cost-effectiveness analysis are presented as compared with a reference case (Option 1) which is the 'business as usual' case of a fully centralised wastewater system. **Error!**

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Cost of option in million VND (2010)	**Option 1** **Fully centralised**	**Option 2** **Fully decentralised**	**Option 3** **Centralised and decentralised**	**Option 4** **Centralised and decentralised with resource recovery in decentralised areas**
Present Value Capital Cost	517,000 (27m USD)	276,000 (14m USD)	256,000 (13m USD)	330,000 (17m USD)
Present Value Operation and Maintenance Cost	4,000 (210,000 USD)	1,900 (100,000 USD)	2,200 (120,000 USD)	2,300 (130,000 USD)
Present Value Revenue from Fertiliser Sales	-	-	-	11,800 (620,000 USD)
Net Present Value	-521,000 (-27m USD)	-278,000 (-14m USD)	-258,000 (-13m USD)	-321,000 (-18m USD)
Levelised cost per m^3 water consumed	0.064 (3.38 USD)	0.030 (1.55 USD)	0.029 (1.55 USD)	0.036 (1.88 USD)
Levelised cost per household	20 (1,000 USD)	11 (600 USD)	10 (500 USD)	13 (700 USD)

Figure 4 Results of the Cost-effectiveness analysis (full costs over 30 years)

Figure 5 below presents the net present value results graphically. The net present value for Option 1 is -27m USD, which means that to meet the objective of providing the wastewater service over 30 years using a centralised wastewater treatment approach, will require a cost of $27m. From the results, it is evident that this fully centralised solution is around double the cost of either using decentralised systems for the whole development area (Option 2) or for a mix of areas treated using centralized treatment and other areas serviced by decentralised systems (Option 3).

Figure 5 Results of the Costs-Effectiveness analysis-net present value of the four options

One of the reasons for the different net present value of Options 2, 3 and 4 relative to Option 1 is that the major investment costs are staggered over time in these options (see
). This demonstrates a benefit of the use of decentralised systems in allowing the delaying of capital costs and infrastructure operability until such time as that infrastructure is actually needed. In Figure 6, the peaks in costs relate to additional development plots becoming occupied and requiring a treatment service.

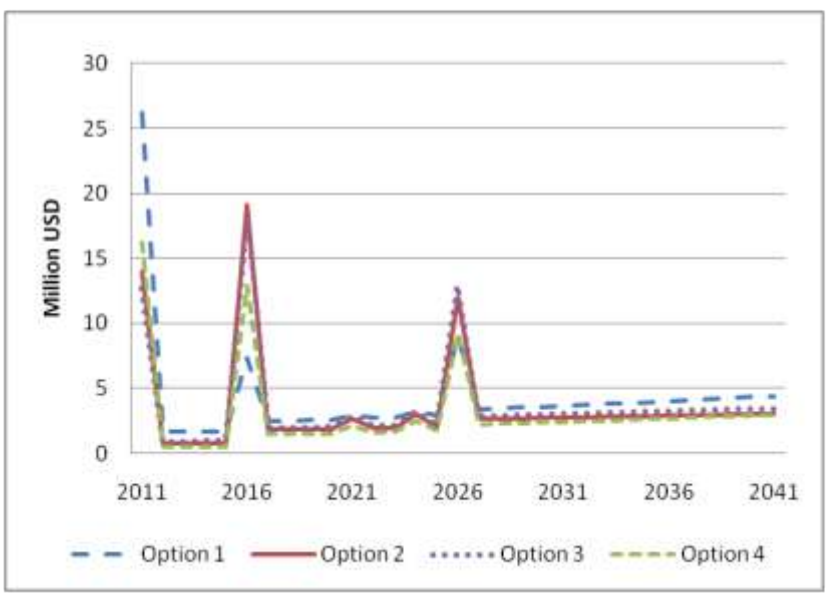

Figure 6 Cost of options over time

The results for the levelised cost of wastewater service provision (including all costs over 30 years) are shown in **Error! Reference source not found.**. These demonstrate similar relativities as the net present value figures. The findings for cost per unit volume of water consumed demonstrate how wastewater infiltration (a feature particularly of the centralised options) adds to the cost of treatment in these options.

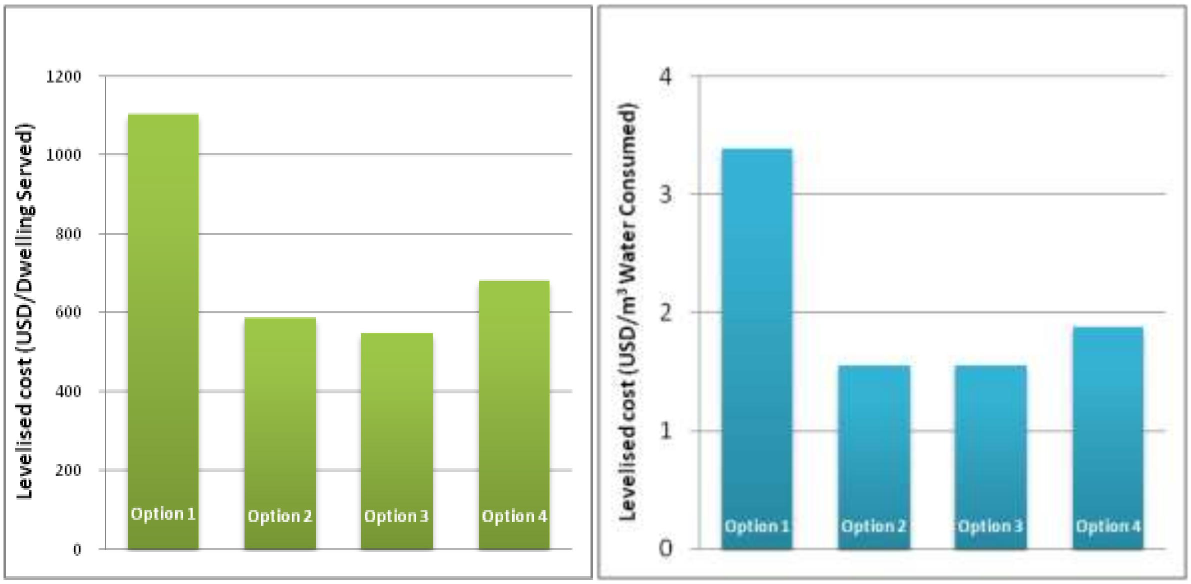

Figure 7 Levelised cost of wastewater service provision per dwelling and per unit of water consumed in UDS 2010

REFLECTIONS ON OUR USE OF THE COSTING METHODOLOGY

There were many lessons learnt in conducting this cost-effectiveness analysis. These included the significant scale of the challenge of building a 'bottom-up' picture of costs, the difficulties in sourcing unit costs, the intricacies in consideration of cost-perspectives (economic and financial) and the challenges in understanding the level of uncertainty in the final results.

Cost-effectiveness analysis requires building up the cost comparison from a detailed set of unit costs. In order to define these unit costs, it was important to fully design the four infrastructure options considered so that costs could be estimated at a consistent and appropriate level of accuracy. This entailed firstly a detailed stakeholder process to define technological options that made sense in the Vietnamese context, followed by a detailed technical design process for each option which represents a considerable amount of work and effort. For example, the entire network had to be broadly designed, including pipes, pumping stations and manholes as well as each of the treatment system components. Whilst it might have been possible to make rough estimates for some components, it was challenging to decide what level of detail was necessary to ensure sufficient reliability in the result, and hence the research team erred to greater detail rather than less to improve confidence in the final results. Given that this was one of the first costing research studies of its kind in Vietnam, it was felt to be important that the analysis had integrity. A higher-level, broad-brush analysis without accompanying detailed technical design may have failed to make clear some of the important differences between options and also may have held less weight with local stakeholders.

Secondly, once the technical design process was complete, it was challenging to obtain reliable unit costs. For some areas, costs were available – g for instance national norms for certain items such as sewer pipes etc exist, and in addition, BORDA was able to provide costs of anaerobic technologies and horizontal gravel filters in Vietnam. In other areas, such as for pumps, disinfection technologies and other treatment components, it was difficult and in some case impossible to obtain locally meaningful cost estimates. There are very few examples of wastewater systems already under operation at either centralised or decentralised scales that could be used as models, and there are very few companies with expertise in the design or costing of such systems in the Vietnamese context.

At the outset, we intended to conduct both an economic analysis (for the 'whole of society cost') as well as analyse each stakeholder's financial perspective. Including all of these cost perspectives proved challenging. We were able to examine and separate capital costs from operation and maintenance costs, which meant that the financial perspectives of the two main stakeholders (the government, responsible for capital, and the water utility, responsible for operations) could be defined. However, it was difficult to estimate and include realistic householder's costs since the two major cost contributors within houses (pipe networks and septic tanks) vary significantly. Specifically, septic tanks can be built to different levels of quality and there was no reliable easily available information about how often households empty their septic tanks. Anecdotal evidence suggests that they are not emptied often and they are often concreted into the foundations of houses. We therefore chose to exclude these costs from the overall analysis, which does not affect the relativity between different options as a cost-effectiveness comparison, but does mean that the overall 'cost to society' is not complete. The developers' perspective was also difficult to include sufficiently. We were not able to engage closely with developers in order to understand if and how they might invest in decentralised systems, and what proportion of their overall investment a local wastewater treatment system might represent.

Finally, whilst we undertook several sensitivity analyses, it would have been beneficial to conduct sensitivity analyses on a broader set of parameters at the end of the project in order to come to a clearer understanding of the level of certainty or uncertainty in the final results. Instead we have sought to report transparently the method of analysis as well as all unit costs used in the analysis.

As an overall conclusion, this paper demonstrates that is it possible and valuable to undertake a rigorous cost-effectiveness analysis to compare different infrastructure alternatives. The costing analysis undertaken ensured that key features of good practice cost analysis were taken into account. This included the use of a systems perspective; consistent boundaries of analysis between different scales of technology; transparent reporting of costs that were included and excluded; comparison with a reference case; explication of cost perspective and use of a 'whole of society' perspective for comparisons with the greatest extent that was possible; and finally, taking into account the time value of money through comparison using net present value and calculation of incremental cost.

The paper presented the results of such a cost analysis conducted for a case study in Can Tho, Vietnam. The research and findings have been formally endorsed by the Can Tho Peoples' Committee, however implementation of the selected option differs from current draft construction plans for South Can Tho which are based on centralised sanitation approaches and hence it is not yet clear the extent to which city authorities will draw on the findings of the study. The study nevertheless demonstrates that there is a strong case to examine decentralised systems as viable components of cost-effective urban wastewater infrastructure in the future, as well as the need for stronger consideration of resource recovery options that allow recycling of nutrients to agriculture.

The depth of the costing analysis was considerable and built upon detailed technical design of the four options. It is hoped that over time, with additional costing studies such as this one, a broader evidence base about the relative costs of different water and wastewater infrastructure options can be generated. This will make possible the use of more broad-brush costing analyses to assist decision-making in cases where a more detailed costing analysis is not possible or justified. An important area within such future costing studies would be to include options that include demand management (behaviour change towards better water conservation) that potentially serve to reduce the wastewater flow and thus the cost of its collection and treatment. This would contribute greatly to the knowledge base, enabling informed judgements regarding the choice of fit-for-purpose scales, configurations and technologies that can serve to increase access to these basic services for all.

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