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The Use of Public Resources for Water Supply and Sanitation Projects in Developing Countries

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Abstract: The use of public sector funds for water supply and sanitation projects in developing countries is often justified primarily on the basis of the anticipated impact of these projects on health. At present there is no satisfactory basis for comparing investments in water supply and sanitation projects, which have multiple impacts, with other health programs, which have more limited impacts. A methodology for making these comparisons is developed on the basis of a resource allocation framework. The implications of the framework for the use of public funds and for the choice of level of service for water supply and sanitation programs in urban and rural areas are assessed. It is suggested that in many circumstances use of public resources is appropriate for partially funding water supply and basic sanitation services in densely populated rural and urban fringe areas.

L'emploi des ressources publiques aux fins des programmes d'adduction et d'assainissement de l'eau dans les pays en voie de développement

Résumé: L'emploi des fonds du secteur public pour la réalisation des programmes d'adduction et d'assainissement de l'eau dans les pays en voie de développement est souvent justifié au premier chef par l'impact que ces programmes doivent avoir sur l'hygiène. Pour l'instant, il n'existe aucune base satisfaisante qui permette de comparer les investissements dans les programmes d'adduction et d'assainissement de l'eau, programmes aux impacts multiples, à ceux d'autres programmes de santé et d'hygiène aux impacts moins étendus. On élabore une méthodologie permettant de faire ce genre de comparaison en se fondant sur un cadre d'attribution des ressources. Les implications de ce cadre pour l'emploi des fonds publics ainsi que pour le choix du niveau du service dans les programmes d'adduction et d'assainissement de l'eau en zones urbaines et rurales sont évaluées. L'on pense que dans nombre de cas, l'emploi de fonds publics convient au financement partiel des services fondamentaux d'adduction et d'assainissement de l'eau dans les régions rurales fortement peuplées ainsi que dans les zones en bordure des agglomérations.

Introduction

In 1978 the member states of the World Health Organization committed themselves to implementing comprehensive Primary Health Care (including water supply and sanitation) programs so that the goal of 'Health for All by the Year 2000' could be attained.[1] In a related declaration in 1979, the General Assembly of the United Nations, citing the health improvements to be expected from water supply and sanitation programs, declared the 1980s to be the 'International Drinking Water Supply and Sanitation Decade', with the goal being the provision of adequate water supply and sanitation facilities for all by the year 1990.

No sooner were these declarations signed than it became apparent that only a fraction of the resources required for their implementation would be available. Attention was therefore immediately turned to the difficult questions of deciding whether limited funds should be used on, say, an immunization program or an improved water supply. A first approach to this resources allocation problem was to specify a primary objective (usually 'reductions in infant mortality'), to determine the cost-effectiveness of different programs in terms of this objective, and then to choose those programs which were deemed most cost-effective.[2] The group of activities which emerged from this analysis as 'cost-effective interventions' was exclusively biomedical in content, with environmental interventions specifically dismissed as 'not cost-effective.'[2]

In large part because the approach does provide a rational basis for making difficult resource allocation decisions, it has been used extensively, particularly by international agencies (including the United Nations' Children's Fund,[3] the United States Agency for International Development[4] and the World Health Organization.[5]) Since this has meant reduced priority for water supply and sanitation programs, the use of the methodology has been opposed by those who believe that environmental improvements have an important role to play in improving health in developing countries.[6,7] The central argument against the approach has been that such a narrowly-defined cost-effectiveness criterion is intrinsically biased against environmental interventions because these, unlike the biomedical programs, have multiple impacts.[6,8] It is pointed out, for instance, that improved water supplies are valued in most communities not because of the impact on infant mortality, but because of readily-perceived and important benefits such as time savings, the opportunity to grow gardens, brew beer, etc. These objections, however, have had little influence on policy makers because they have essentially been negative ('cost-effectiveness analysis should not be used in this setting') and have not provided an equally compelling and valid alternative resource allocation methodology.

Principles

The challenge, then, is to develop a practical method whereby programs with multiple benefits (such as water supply and sanitation programs) can be compared with programs (such as immunizations) which have health benefits only. The method proposed in this paper hinges on partitioning the costs of health-related programs into those which are properly funded out of public sources (through subsidies) and those which are properly funded out of private sources (through user charges). It is therefore instructive to review briefly some relevant principles of welfare economics.[9]

First, additional resources should be allocated to any given activity as long as the extra net benefit to society exceeds the benefit foregone from the best alternative use of the same resources. Second, under certain conditions (well-informed consumers enjoying perceived benefits which are not confined to the particular household) an aggregate measure of consumption benefits is provided by the sum of individuals' willingness to pay, with the demand curve providing a proxy measure for willingness to pay.[10] Finally user charges based on long-run marginal cost promote efficiency.[11]

It is often argued that market mechanisms are inherently incapable of ensuring the socially optimal allocation of resources available to the health sector because:

— for certain categories of service (such as immunizations) the benefits of participation are not limited to those who participate (i.e. externalities are often large);
— difficulties in evaluating and perceiving the effects of health-related services mean that consumers of health services often cannot make rational, well-informed choices;
— the possibilities for competition among suppliers of certain types of services (such as urban water supplies) are limited;
— certain groups (including the poor, women and children) are often inadequately represented in the decision-making process.

Conversely, it is also often argued that, for at least certain health-related activities, market mechanisms are preferable to mechanisms which rely on a strong public role because:

— the alleged market failures outlined above apply only to certain health-related services, not all;
— goods and services are produced more efficiently by the private sector;
— private markets may be more effective in mobilizing resources for health-related activities than mechanisms which rely chiefly on tax revenue.

Bearing in mind these arguments and the characteristics of different health-related activities, these activities can be classified (Table 1) into three broad groups, depending on the appropriate roles of the private and public sectors.

A simple resource allocation framework

The fundamental difficulty in comparing investments in, say, water supply facilities with investments in, say, a tetanus vaccination program is that water supply facilities have multiple impacts (economic, social, and health) while a vaccination program directly affects only health outcomes. Accordingly, the fundamental flaw in the cost-effectiveness approach presently used in the health sector[2] is that non-health benefits of programs are ignored. One approach to resolving this incomparability problem is to attempt to partition out the costs of the water supply program, and then to use that part of the total cost which is assigned to the health impacts as the numerator in the cost-effectiveness calculations. In general, this problem of joint cost allocation is a difficult one; in the particular case of water supply and sanitation programs, with a reasonable set of assumptions such partitioning can be done, thus making comparisons of water supply and sanitation projects with other health projects possible.

First, with regard to water supply, a detailed assessment of water use practices in Bangladesh[12] has shown that the choice of sources of water for domestic purposes is affected primarily by distance to the source and the social consequences of use of a particular source. Similarly it has been shown that health concerns do not affect water use practices in rural Africa[13] and in Latin America, where it has been concluded that 'the reduced incidence of disease . . . and the avoidance of death . . . apparently would not be reflected in the willingness to pay since in both cases these are fortuitous events on the future horizon and therefore difficult to perceive as directly useful to the consumers'.[14] Similarly, it has been shown in many settings that the reasons for using latrines in rural areas are primarily those of privacy, convenience and status, with perceived health benefits seldom being of importance, even after intensive health education efforts.[15–18] It may therefore be assumed that:

(i) amenity benefits (including time savings in the case of water supply and privacy, convenience and status in the

Table 1. Public and private sector roles in health programs

Group	Examples of activities	Characteristics	Implied major role for:	Appropriate overall role: Public sector	Private sector
A	Spraying against malarial mosquitos	Large externalities	Public sector	Major	Minor
		Uninformed consumers	Public sector		
		Often public goods	Public sector		
		Resource mobilization unlikely through user charges	Public sector		
B	Preventive maternal and child health services	Social benefits often exceed private benefits	Public sector	Some	Some
	Rural water supplies	Consumers' information imperfect	Public sector		
	Basic excreta disposal services	Disadvantaged groups needs might not be met	Public sector		
		Resource efficiency might be improved through competition	Private sector		
C	Curative medical services	Externalities small	Private sector	Minor	Major
		Consumers well informed	Private sector		
	Urban water supply	Production sometimes a natural monopoly	Public sector		
	Sophistocated excreta disposal services	Potential for resource mobilization high	Private sector		

case of excreta disposal) are perceived accurately;

(ii) health benefits do not affect household decisions both because these benefits are not perceived by the household and because the benefits are partially external to the household (i.e. they accrue to others who may not use the service);

(iii) the value placed on the vector of perceived benefits can be measured by willingness to pay.

As an aside, it should be noted that this partitioning is similar to that used in disaggregating the benefits of air pollution control in developed countries into perceived benefits (aesthetic, soiling and materials benefits) which are reflected in property values, and health benefits which do not affect property values.[19]

Where it is possible to estimate the costs of, the willingness to pay for, and the health impact of different levels of water supply and sanitation service, Table 2 can be constructed.

Table 2. Assessing the cost per unit of health impact of water supply and sanitation investments

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Service level (I)	Cost (capital + O&M)	Willingness to pay	Cost to govt.	Health impact	Marginal impact Marginal cost
1 (high)	C_1	W_1	$G_1=C_1-W_1$	I_1	$(I_1-I_2)/(G_1-G_2)$
2 (intermediate)	C_2	W_2	$G_2=C_2-W_2$	I_2	$(I_2-I_3)/(G_2-G_3)$
3 (low)	C_3	W_3	$G_3=C_3-W_3$	I_3	$(I_3-I_4)/G_3$
4 (no improvement)	0	0	0	I_4	—

From Table 2 it may be seen that where consumers are willing to bear a substantial portion of the costs of services, only a small part of the total cost becomes attributable to health, and the activity becomes relatively more cost-effective than would otherwise be the case. While the same logic applies to other health projects, in most situations consumers are only willing to pay for curative services (which have a limited impact on health). Thus, while full costs can be recovered from the consumers of urban water supplies, World Bank data (de Ferranti, personal communication) show that in most developing countries only about 5% of the recurrent costs of publicly provided health services in developing countries have been recovered through user charges.

From Table 2 it is apparent that, in determining the appropriate level of service in a particular community, there are two different 'solutions'. First, there is the 'market solution': without any public intervention, the level of service provided will be that for which the population is willing to pay (i.e. the highest level of service for which $W_n \geq C_n$). This 'solution' may be level 4, i.e. no improvement, in many cases. Second, there is the 'socially optimal' solution: if the marginal impact: marginal cost ratio for any level of service (say level 'n') is higher than the marginal impact: marginal cost ratio for all alternative programs in the health sector, then G_n units of public resources should be invested (along with W_n units of private resources) to ensure that the socially-optimal level of service ('n') is provided.

Components of the framework

Before discussing the implications of the framework for allocation of resources to water supply and sanitation projects, information which is available on each of the components of the model (viz. costs, willingness to pay, and health impact) is summarized.

(a) *Costs*

Adequate information on the capital costs of water supply and sanitation facilities is available. The World Bank[20] has estimated 'typical' per capita capital costs as follows:

Table 3. Typical capital costs (in 1976 $s) of water and sanitation projects

	Urban	Rural
Water supply through public standposts	$30	$25
Basic excreta disposal facilities	$20	$ 5

In any particular setting, however, the actual capital costs might be quite different from these 'typical' costs. In some settings (particularly arid areas) the costs of water supplies might be much higher, in others (such as in Bangladesh, where the groundwater table is high, where a low-cost drilling method has been perfected, and where handpumps are locally manufactured) the per capita costs are much lower. As indicated for water supply in Table 4 and for sanitation in Table 5, costs also increase sharply as the level of service is increased.

Table 4. Total investment costs (in 1983 $) per capita of a rural water supply (Source: World Bank data in Chandler, 1984)

Level of service	Cost
House connections	150
Standpipes	40
Handpumps	25

Table 5. Average annual investment and recurrent cost per household for sanitation technologies (after Kalbermatten *et al*[52])

	Mean total annual cost per household (1978 $)
Low-cost	
Pour-flush toilets	20
Ventilated improved pit latrines	30
Low-cost septic tank	50
Medium-cost	
Aquaprivy	170
Japanese vacuum-trunk cartage	190
High-cost	
Septic tank	370
Sewerage	400

Because the focus of development agencies has largely been on the construction of new facilities, relatively good information is available on the capital costs of water and sanitation facilities. Typically, however, recurrent costs have been considered to be the responsibility of the recipient government or institution and have been of little more than passing interest in the project preparation procedure. As in many other development sectors, "the sheer absence of data on the recurrent expenditure implications of projects . . . is extraordinary."[21] In the absence of such data, 'rules of thumb' (such as 'operation

and maintenance costs are assumed to be 3% of capital costs') are commonly used.

(b) *Willingness to pay*

(i) *Water.* A large number of studies of the impact of price on demand for water have been carried out in developed countries. These studies have shown that the demand for water is fairly inelastic with respect to price (with a 10% increase in price typically accompanied by a 2 to 4% reduction in the quantity of water used in the long run).[22,23]

There are few adequate published studies of the effect of price on demand for water in developing countries. In Malaysia the elasticity of demand with respect to price was estimated[24] by examining water use before and after a price increase was introduced. This method is likely to underestimate true short-run price elasticity for two reasons. First, in developing countries demand is often suppressed because the delivery system cannot provide the quantities of water which people wish to use. Price increases often correspond to the commissioning of new works and thus often correspond to an improvement in the service and in increase in the quantity of water used. Under such circumstances the apparent price elasticity would underestimate the true price elasticity. Second, apparent price increases are often no more than adjustments for inflation and not true price increases, again leading to underestimates of true price elasticity.[25] These factors notwithstanding, the short run price elasticity estimated in Malaysia was similar to the short-run price elasticities found in studies in the industrialized countries. Furthermore, as has been shown in the United States,[23] the long-run price elasticity is substantially greater than the short-run elasticity.

In a cross-sectional study in Nairobi, Kenya,[26] the price elasticity of demand was found to be about −0.5, a value similar to that derived from a cross-sectional analysis of national-level data by Meroz.[27] These studies and an extensive unpublished set of data collected by the Interamerican Development Bank for Latin America suggest that in the long run, water consumption in both urban and rural areas of developing countries is moderately responsive to price.

Development agencies use a simple notion of the concept of willingness to pay to assess the level of service which consumers might be willing to support. Most commonly it is assumed that consumers will be willing to spend no more than 5% of total income on water supply and sanitation services[14,28] thus setting a limit on the technologies which are considered to be 'affordable' in any particular setting. As the importance of the concept of willingness to pay has become more widely appreciated, and as more data on actual behavior have been gathered, it has become evident that income is but one of several factors determining willingness to pay, and that a more sophisticated understanding of the concept is required.

As an example of the shortcomings of the notion that willingness to pay is dependent on only the income of families, consider the experience of a series of USAID rural water supply projects in Northeast Thailand.[29] In the first of these projects handpumps were installed. After a few years it was found that many families were not using the (free) supplies, and that over 50% of the handpumps were not working, in part because the population was unwilling to cover the costs of maintenance and operation. In a second project piped water was distributed through public standposts. The fate of the project was little different, since the population again proved unwilling to pay for the costs of this service, but preferred to continue to use the traditional (often contaminated) surface water supplies. Finally, in a third project, USAID and the Government of Thailand decided to experiment with a higher (and more expensive) level of service. House connections were allowed, with connecting households required to pay the full costs of operation and maintenance of the system. The fate of this project was very different: although the rates were substantially higher than rates in Bangkok, a high proportion of the families were willing to, and did, make the necessary regular payments for the service. The project, unlike its two predecessors, was a success. The institutions necessary to run the projects developed, and, because the consumers were willing to pay for the recurrent costs of the project, the institutions were financially viable.

The key message of the Thailand project was that willingness to pay was not uniquely a function of the income of the population, but was also dependent on the perceived quality (including convenience, reliability and perceived — but not bacteriological — water quality) of the improved service relative to the traditional service.

A recent review of World Bank, Inter-American development Bank and US Agency for International Development rural water supply projects[30] shows that willingness to pay for an improved supply is greater: where water is supplied to the yard or house rather than to a communal facility[29,31] in arid rather than wet areas[32–34] and for high- rather than low-income people.[31,33,35,36] It appears, then, that the willingness to pay for water in rural areas may be as shown in Table 6.

(ii) *Sanitation.* The willingness to pay for sanitation facilities, too, depends on the perceived benefits of such facilities, and thus on the characteristics of the family and of the cultural, social and natural environment in which the family lives.

Data from many developing counrties,[15–18] have shown that improved excreta disposal facilities are valued by users because of the privacy, convenience and status which ownership and use of such facilities confer on the household and not because of perceived health benefits. Even in poor countries those living in peri-urban areas are willing to pay for the major portion of the costs of improved latrines,[37] while willingness to pay is often low in rural areas where traditional defecation alternatives are available.[38]

From available data it would appear that the effects of the major determinants of willingness to pay for improved sanitation facilities may be as shown in Table 7.

Table 6. Anticipated willingness to pay (as proportion of household income) for water services in different social and natural settings

		Income group	Urban		Rural	
			Wet	Arid	Wet	Arid
Level of service	High	Rich	+++++	+++++	+++	+++++
		Poor	+++	++++	++	++++
	Medium	Rich	++++	+++++	++	++++
		Poor	+++	++++	+	+++
	Low	Rich	+++	++++	+	++++
		Poor	++	+++	0	+++

Note: +++++ indicates very high and + indicates very low willingness to pay.

Table 7. Anticipated willingness to pay (as proportion of household income) for water services in different social and natural settings

		Income group	Urban	Rural	
				High density	Low density
Level of service	High	Rich	++++	+++	++
		Poor	+	+	0
	Medium	Rich	+++	++	+
		Poor	+	+	0
	Low	Rich	++	+	0
		Poor	+	0	0

(c) *Health impact*

The final requirement of Table 2 is information on the health impact of different levels of water supply and sanitation service under different social and natural conditions.

A recent, authoritative WHO study[39] has shown that water supply and sanitation programs typically have substantial direct impacts on diarrheal disease (Table 8) and even larger impacts on diarrheal mortality.

Table 8. Impact of water supply and sanitation interventions on diarrheal morbidity (after Esrey *et al.*[39])

Improvement in:	No. of studies	Median improvement (%)
Water quality	9	18
Water quantity	17	25
Quality and quantity	8	37
Excreta disposal	10	22

The usefulness of this literature is limited, however, because few studies have examined the critical policy relationship, namely the marginal effect of improving service levels. On the basis of *a priori* knowledge of the ways in which improved water supplies[13] and sanitation[40] affect health and limited empirical data[41–43] it is anticipated that:

— basic adequate water supply services (such as a handpump) may often be sufficient to reduce the transmission of water-borne diseases, but that reductions in water-washed diseases may require that water be provided through yard taps;
— while there are large health benefits to be gained through the use of basic excreta disposal facilities (such as pour-flush or ventilated improved pit latrines), the marginal health benefits of further improvements in level of service are probably usually small;
— the combined effects of improving both water supply and sanitation facilities is likely to be substantially greater than the sum of the effects of each of these improvements alone.

Until recently it had been assumed that epidemiologic studies of the effect of the impact of different levels of water supply and sanitation service on health were impractical 'because of the high cost, limited possibility of success and restricted application of results'.[44] Over the last decade, however, there have been major advances in knowledge of the etiology of diarrheal diseases[45] and in the methodology of case-control studies.[46] It now appears[43,47] that while it will never be simple to interpret health impact evaluations[48] this method offers a real possibility for assessing, rapidly and at modest cost, the effect of different levels and combinations of water supply and sanitation service in any particular setting.

Implications of the framework

For the agencies involved in water supply, sanitation and other health programs, two principal questions need to be answered in any particular social and natural setting. First, within the water and sanitation sector, what are the levels of service which are most cost-effective in terms of achieving health goals? And, second, how does the cost-effectiveness of these 'optimal' water supply and sanitation programs compare with other Primary Health Care programs (such as immunizations and oral rehydration therapy)?

Although definitive answers await the development of a far richer set of empirical information, this analysis suggests that the following conclusions will often be reasonable.

(a) *Urban water supplies*

The costs of water supplies (column 2 in Table 2) increase sharply as level of service increases. However, as evidenced by the fact that low-income dwellers of many third world cities (e.g. Lima,[49] Surabaya,[50] Port au Prince[51] spend more than 20% of total income on purchasing water from vendors, willingness to pay (column 3) for basic services in urban areas is high, even among the poor. Willingness to pay for high level services (house connections) is generally high among the middle and upper classes. Accordingly, most well-run urban water supplies can achieve full cost recovery through user's charges, meaning that the required subsidy from public funds (column 4) is usually small. Because there is likely to be a positive marginal impact on health as service level increases (column 5), it is likely that the use of health sector funds (either to provide credit at low interest rates, or to provide subsidized services to the poor) will be a highly cost-effective use of health funds.

The major qualification to this conclusion is that such investments are cost-effective only in well-run utilities. Many urban utilities in developing countries continue to draw large subsidies from public funds because of poor fiscal, administrative and technical management. Evidently the provision of public funds to such utilities should be contingent on improvements in the operation of the utility.

(b) *Rural water supplies*

As in urban settings, the costs of rural water supplies increase sharply as the level of service improves. From available information it appears that, where the improved service represents a marked improvement (in terms of convenience, reliability and perceived quality) over the existing service, willingness to pay is higher than has previously been assumed. In arid areas a more convenient and reliable borehole fitted with a handpump would constitute an 'improved service', while in wet areas only water piped into yard taps might be considered a real improvement. As in urban areas, there is likely to be a positive impact on health as level of service increases.

Because of the synergistic effect of water supply and sanitation improvements, it is in settings where sanitation improvements are likely that the health impact of improved water supplies will be greatest. This means that it is in relatively densely populated rural areas (where there is a real demand for improved sanitation) that the health impact of improved water projects is likely to be greatest.

Where costs are not exorbitant (usually in densely populated areas), willingness to pay for water is high (i.e. where income is relatively high, the opportunity cost of women's time is high,

and the level of service represents a marked improvement over the existing service), and there exists a real demand for improved sanitation (in higher density areas), rural water supplies will often represent cost-effective health interventions.

(c) *Urban sanitation and sewerage*

As with water supplies, the costs of sanitation services increase sharply as the level of service increases. Available data on willingness to pay suggest that even poor people are willing to pay a major portion of the costs of basic but adequate excreta disposal services. It appears that the major health impact is gained when basic sanitation facilities are used and that the additional health benefit from higher levels of service is small. Accordingly, limited use of public funds for basic sanitation facilities in urban areas will generally be cost-effective. There appears to be little justification in committing public resources to higher levels of sanitation (such as water-borne sewerage) in most circumstances.

(d) *Rural sanitation*

The costs of basic rural sanitation facilities are usually substantially lower than the costs of similar services in urban areas. Willingness to pay is dependent on population density, culture and level of development. In many poor, sparsely populated areas of Asian and African countries willingness to pay is very low, with facilities often not used even if provided free; in more higher-density and more developed areas willingness to pay for basic services may be substantial. As in urban areas, there are likely to be substantial health benefits from the use of adequate basic facilities, but little further health benefit as the level of service is increased.

Where willingness to pay is high, rural programs for the provision of improved latrines will often be cost-effective investments of health resources, particularly where improvements in water supply are made simultaneously. Where willingness to pay is low, facilities are unlikely to be maintained and the programs would accordingly be both more costly and less effective. As in urban areas, public funds should not be used to subsidize higher levels of sanitation service.

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