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Costing improved water supply systems for developing countries

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The aim of this paper is to present a practical manual prepared for the World Health Organization (WHO) on how to identify, collect, estimate and compare costs of the available technical options to provide access to safe drinking water in low-income communities. In order to cost – from a social point of view – an improved water supply technology that is likely to secure access to safe drinking water (as defined by the WHO–Unicef joint monitoring programme for water supply and sanitation), an analytical approach is used that disaggregates the technology process according to its essential components, singled out by an engineering description. Questionnaires were developed to identify the main resources invested in a water supply project and to collect, at different disaggregation levels, four types of costs: investment, operation, maintenance and other relevant costs (e.g. administration). Comparability of these different cost elements is achieved by discounting expenditures at different times to the same reference time. Full and unit cost indicators that allow a least-cost analysis can then be derived from this cost picture. To successfully apply the method to actual projects, a spreadsheet was developed using Microsoft Excel to enable user-friendly implementation of all the costing tasks.

1. Introduction

The United Nations millennium declaration confirmed the central role of water in sustainable development and efforts to eradicate poverty. Increasing water supply (WS) coverage is essential in overcoming poverty through reduction in water-related diseases.

This paper presents a practical manual prepared by Carlevaro and Gonzalez (2009) for the World Health Organization (WHO) on how to identify, collect, estimate and compare costs of available technologies to provide low-income (i.e. rural and slum) communities access to safe drinking water. The manual intends to contribute in a meaningful way to assessing the social cost of achieving one of the main targets of the millennium development goals (MDGs) – namely, to halve the number of people without sustainable access to safe drinking water and basic sanitation by 2015. The main aim of this paper is to inform decision makers and professionals involved in the drinking water sector in developing countries of the existence of an operational tool that can be used to assess the social cost of achieving sustainable access to safe drinking water.

Although limited to the process of costing safe WS technologies, the methodology is intended to be part of a more comprehensive socio-economic evaluation of the basic services that are instrumental in fostering human development and quality of life in developing countries. In the context of this sustainable development perspective, the developed methodology allows identification and costing of the technical alternatives for performing least-cost analyses in order to identify the best social alternatives. For this purpose, a practical manual has been conceived to facilitate and standardise the implementation of this methodology. Inspired by former guidelines of the World Bank (Kalbermatten *et al.*, 1982) and the Asian Development Bank (ADB, 1999), it systematically explains the process by which relevant data should be collected and processed for costing improved drinking water technologies as defined by the WHO and United Nations of International Children's Emergency Fund (WHO/Unicef, 2006) joint monitoring programme (JMP) for water supply and sanitation (WS&S).

To successfully apply this method to actual projects, an Excel spreadsheet – referred to as a water supply costing processor (WSCP) – has been developed. This enables user-friendly collection and processing of the relevant information needed to assess a specific project, providing detailed as well as consolidated cost figures for decision makers.

2. Improved WS technologies for low-income communities

The essential components of a WS process in low-income communities are as follows.

(*a*) Water source. This represents all the freshwater that comes from evaporation/precipitation; types of water source are surface water, groundwater and pluvial water.

(*b*) Collection. Intake using pumping facilities is required if water is to be collected from a surface water source. Dug wells are common for the use of groundwater and a permanent roof is needed for rainwater collection.

(*c*) Conveyance. Water is normally conveyed by gravity or pumping; dedicated structures carry water from source to storage before treatment or consumption.

(*d*) Storage. Reservoirs have a storage capacity for anticipated water demand before treatment and distribution.

(*e*) Treatment. The more common method includes sedimentation, aeration, filtration, demineralisation and disinfection.

(*f*) Distribution. The means of delivery of water to individual consumers varies. It may be piped or carried in containers by various means of transport by household members or middlemen (water vendors, tank carriers, etc.).

Figure 1 shows how the components of a WS process can be combined to generate an actual WS system for low-income communities.

The WS technologies considered here are those compatible with the MDG target of improving the access to safe drinking water in low-income communities. To be operational, the WHO/Unicef JMP for WS&S has defined drinking water as water used for normal domestic purposes, including consumption and hygiene, and has classified existing WS technologies as either 'improved' or 'unimproved'. The former are those that are more likely to secure a safe supply of drinking water and therefore achieve the MDG WS&S target. These technologies include

(*a*) piped water into dwelling, plot or yard

(*b*) public taps/standpipes

(*c*) tube-wells/boreholes

(*d*) protected dug wells

(*e*) protected springs

(*f*) rainwater collection

(*g*) bottled water (only considered improved when the household also uses water from an improved source for cooking and personal hygiene).

Unimproved technologies include

(*a*) unprotected dug wells

(*b*) unprotected springs

(*c*) carts with small tanks/drums

(*d*) bottled water without an improved source for cooking and personal hygiene

(*e*) tanker-trucks

(*f*) use of surface water (rivers, dams, lakes, ponds, streams, canals, irrigation channels).

Only some of the available improved WS technologies will be suitable for use in the setting of specific projects. On the basis of local conditions, the use of some available technologies can be ruled out as they will be incompatible with prevailing constraints or will entail unacceptable risks (e.g. arsenic levels in groundwater). Therefore, before tackling the costing of available technologies, it is important to identify all local risks and constraints and to discard those technologies that are unable to overcome these constraints or pose unacceptable risks. The technologies remaining after this elimination process are referred to as 'appropriate' for the project under assessment and are those on which a least-cost analysis should be conducted.

To identify the risks and constraints facing a particular WS project, it is useful to consider a set of guiding criteria. The main screening criteria are related to local resources, financial, technical, environmental, institutional, cultural and social constraints, and health risks. Physical/technical and socio-economic questionnaires have been designed in order to collect basic relevant data to test the appropriateness of available WS technologies.

3. Costing rationale

The primary intent of the costing method is to develop an economic value of the opportunity cost of providing a given WS service to the national economy that can fit in a more comprehensive social cost–benefit analysis (SCBA). The SCBA then aims to compare all the socially scarce resources invested into a WS project with the complete set of project outcomes contributing to improve the quality of life and health conditions of project beneficiaries. Therefore, as far as a SCBA looks at the impacts of a project for the whole community and not just for a single agent

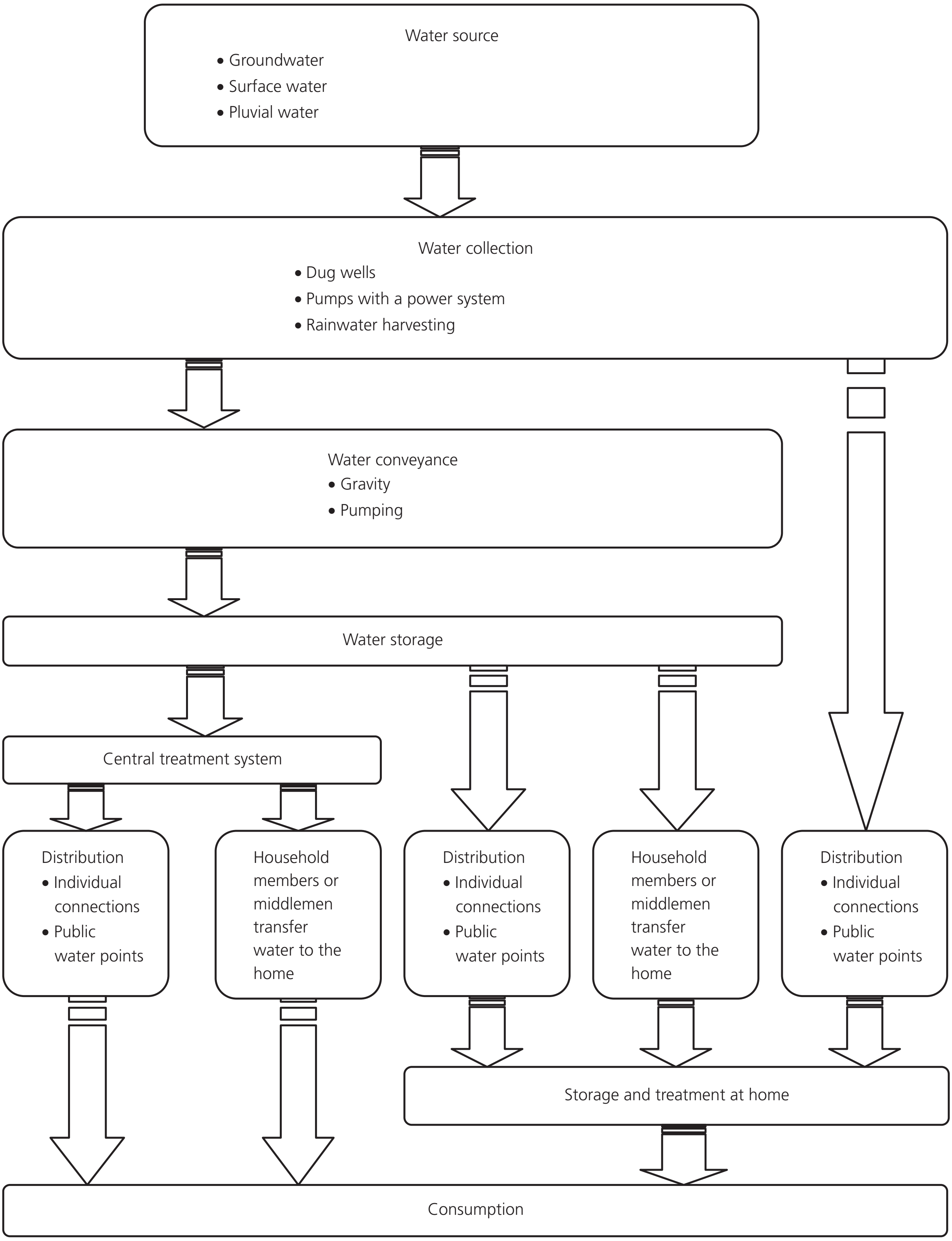

Figure 1. Components of a WS process

(the private investor), the social costs and benefits may differ significantly from those of a private economic evaluation of the same project.

The valuation of market costs and benefits is different. In an SCBA, the prices of marketed goods and services should be set to motivate users to individually choose less expensive solutions that generate less expensive community solutions. These prices – including interest rates, wage rates and foreign exchange rates – should be those prevailing in a competitive economy. Hence, when actual market prices involve significant distortions arising from market imperfections, they should be replaced by 'shadow prices', assessing the cost of scarcity for the community, of the marketed resources invested in a social project.

Furthermore, the costs and benefits taken into consideration are not the same. In an SCBA it is advisable to also account for non-market costs and benefits of a project (entailing no explicit exchange between economic actors) such as those generated by external effects or the use of public goods. In particular, from this perspective, costing a WS project from a social point of view will need to take into account

(*a*) external costs arising from environmental damages

(*b*) the opportunity costs of the foregone benefits of diverting raw water from productive activities such as agriculture to non-productive ones such as basic domestic uses

(*c*) depletion premiums that value the cost of water source conservation such as groundwater aquifers (reservoirs).

Given the difficulties of obtaining unquestionable values of such non-market costs, it was decided to delimit the costing method to the realm of marketed costs (cost of the resources used in a WS project that can be provided by markets) of a WS project regardless of who (utility, households, government, etc.) incurs them. By limiting the domain of the analysis to marketed costs, the method may be used, with any relevant changes being made, to perform financial costing of a WS project (based on actual non-competitive market prices) that would be relevant to assess the finances required to implement, operate and maintain the project over its life cycle.

The proposed method of identifying, collecting and analysing cost data of appropriate WS technologies relies on an analytical approach that disaggregates the WS process according to the main components listed in Section 2. For each activity, four types of costs are considered.

(*a*) Investment costs include those that can be identified in the construction of infrastructure, for example the costs of preliminary studies, equipment, local material, imported material, labour, other investment costs and contingencies.

(*b*) Operation costs comprise all expenditures that are required to keep a system in operation. They include expenses for personnel, chemicals, electricity, fuels, materials, office supplies and building rents.

(*c*) Maintenance costs are those required to keep a system in good condition while it is being operated; these include expenses for running maintenance plans and for repairs to infrastructure, equipment, vehicles, etc.

(*d*) Other relevant costs encompass the operational costs of a WS technology providing correct functioning of the system. In this context the most important are administrative costs of the system, training costs, promotional and educational costs.

These costs are identified through a set of costing questionnaires describing the main marketed resources (materials, equipment, labour, power services, etc.) invested in the project. Each questionnaire describes the use of a given resource within one of the above-mentioned four cost categories by detailing the use of the resource for each main component of the WS technology (i.e. collection, conveyance, storage, treatment, distribution). Three levels of aggregation are provided for each description

(*a*) an item level corresponding to the methods that can be used to perform a single activity of an improved WS technology (e.g. water collection can be carried out using different methods according to the water source – a gutter for rainwater or a well for groundwater)

(*b*) a sub-item level corresponding to the particular technical device that can be used to practically implement a technology (e.g. wooden, galvanised or PVC gutter for collecting rainwater)

(*c*) an input level that breaks down the sub-item description of a device according to a more detailed level at which cost data can be collected (e.g. 'wood gutter structure' and 'nails' as local materials necessary to install a wood gutter for collecting rainwater).

Once the resources involved in the realisation of a WS project have been identified, the next step is to look for data sources to quantify the resources invested. Depending on the data sources available, this quantification can be performed at a disaggregated level (input level breakdown) or at a more aggregated level (sub-item, item or item breakdown).

(*a*) The use of the disaggregated level option requires physical measurement of the invested resources described at the input level breakdown. This level of disaggregation is recommended in order to provide insight and transparency of the process of valuing economic resources in monetary terms and, eventually, enabling portability to other settings.

(*b*) The sub-item or item aggregation level option has been devised for those situations where historical or bid data sources lack the detailed information required for performing costing at a disaggregated level. In these cases only the monetary value of a cost component at sub-item or item level is required.

The final step in costing a WS project is to value the quantified invested resources using prices that represent the national opportunity costs of these resources at a reference date (conventionally chosen to represent either the date of project completion or the beginning of the project life cycle). As available data sources on prices and costs usually rely on actual historical market data, two types of adjustments should be performed on this primary data.

(*a*) Historical prices and costs must be inflated at the overall price level of the reference date using a price index of the priced resource or, in the absence of such a specific price index, by means of a gross domestic product (GDP) deflator or consumer price index.

(*b*) Actual market prices and costs that do not reflect the scarcities of the priced resources within the national economy (because they differ significantly from competitive market prices) should be converted into virtual competitive market prices through 'shadow factors' that express the ratio of an economic efficient or 'shadow' price to its actual (economic inefficient) market price. In most developing economies such price distortions represent an endemic phenomenon. This is particularly the case regarding the wage rate of unskilled labour because of a substantial amount of 'structural unemployment' and the foreign exchange rate as a result of barriers set by governments to free foreign trade through quotas, taxes and subsidies. Of course, assessing these shadow factors in a specific national setting requires the expertise of economists with experience in macroeconomic policy and planning of social projects. For an introduction to this issue, readers are referred to the work of Young and Haveman (1985).

4. Cost indicators for least-cost analyses

Application of the above costing rules then leads to setting up the time path of expenditures to implement, operate and maintain an appropriate improved WS technology over its life cycle. To perform least-cost analyses of alternative appropriate improved WS technologies that provide a stream of services during a design lifetime, it is necessary to consolidate this time sequence of expenses in the full cost of the project by computing the present value of these expenses at the reference date of the project, using an appropriate discount rate for social projects.

By assuming a design lifetime of the project of T years and assigning C_t as the total costs incurred in year t of the project life cycle and i the annual real social discount rate, the full cost present value (FCPV) of the project is computed from

$$\text{FCPV} = \sum_{t=1}^{T} \frac{C_t}{(1+i)^{t-1}} \qquad (1)$$

which implicitly assumes that annual costs all occur at the beginning of the year.

The choice of the social discount rate is an issue of considerable debate (Pannell and Schilizzi, 2008; Zhuang *et al.*, 2007). In an ideal competitive economy without market imperfections and a perfect financial market where any economic agent can lend and borrow any amount of money at a unique rate of interest, the social (as well as the private) discount rate is equal to the rate of interest; for an economic agent it is equivalent to holding two different cash flow time sequences having the same discounted value, at the current interest rate. This unique rate of interest also equals both

(*a*) the rate of time preference (RTP) (the rate of return on loans, which motivates a consumer to save by postponing a marginal unit of current consumption in exchange for more future consumption)

(*b*) the opportunity cost of capital (OCC) (the rate of payment on loans, which motivates an investor to borrow a marginal unit of capital to fund a productive activity that generates a higher future return).

Market imperfections imbalance this equality by creating a gap between the RTP and the OCC (with the former generally lower than the latter) and making both differ from the market rate of interest. In such circumstances, which rate should be used to discount future benefits and costs in an SCBA?

The use of a social rate of time preference (SRTP) has been advocated on the grounds that, contrary to a private discount rate, the social discount rate should not merely express the average cost of capital invested in social projects but also the inter-temporal substitution rate in consumption used to trade off the level of present national consumption against that of investments increasing future consumption. This social rate of discount may be revealed by the formulation of a development plan for the national economy as, by means of a macro-econometric growth model, it is possible to simulate the impact of policies aiming at marginally increasing investments during one year (by decreasing the consumption) to foster future production and consequently future consumption.

The use of the social opportunity cost of capital (SOCC) has been suggested for those situations where public and private sectors compete for the same pool of funds. Under such circumstances, where social projects can inflict a loss to the national consumption by diverting funds from more socially profitable private investments, public investments should yield at least the same return as private investments. It has been suggested that the SOCC could be approximated by the marginal pre-tax rate of return on riskless private investments, like the real pre-tax rate on top-rated corporate bonds. Attempts to reconcile these two approaches have also been developed. For a recent survey on the theoretical and practical dimensions of this issue, see Zhuang *et al.* (2007).

Cost comparisons based on the FCPV can also be performed by a cost indicator of easier interpretation, namely the full annual equivalent cost (FAEC). This is defined as the constant annuity to be paid during the project life cycle to refund the FCPV of the project at the annual real social discount rate i

$$\sum_{t=1}^{T} \frac{\text{FAEC}}{(1+i)^{t-1}} = \text{FCPV} \tag{2}$$

leading to

$$\text{FAEC} = \text{FCPV}\,\frac{i(1+i)^{T-1}}{(1+i)^{T}-1} \tag{3}$$

When the level of services provided by the appropriate WS technologies varies in time and across technologies, the FCPV or the FAEC are not the most suitable indicators to use for least-cost comparisons because the value of these full-cost indicators varies according to the level of services provided. In these situations, a service or production indicator of the WS system is needed to compute a cost measure per unit of service provided during a year.

In the general case where the WS facility is not utilised at full capacity upon construction but its use increases gradually over time to meet the designed level of service only after a period of utilisation growth, an appropriate definition of a unit cost is provided by the so-called average incremental cost (AIC)

$$\text{AIC} = \text{FCPV} \Big/ \sum_{t=1}^{T} \frac{S_t}{(1+i)^{t-1}} \tag{4}$$

where S_t is the annual level of services provided in year t. This formula defines a unit cost indicator calculated by dividing the FCPV of the WS system by a measure of its life-cycle production that values services provided in the future less than services provided at the present time (just as costs incurred in the future have a lower present value than those incurred at the present time). This way of measuring the life-cycle production of a WS system that is operated over time in a non-stationary way expresses the present economic value of life-cycle production if the value of the services provided is constant over time.

To quantify the service or production of a WS system in each year t of its life cycle, three alternative indicators are considered

(*a*) the size of the population served, denoted by P_t

(*b*) the number of household water connections, H_t

(*c*) the quantity of water supplied, Q_t.

For designing consistent life-cycle scenarios of these production indicators, we start by specifying independent scenarios for the population served and for two further variables

(*a*) the average size of the household served, N_t

(*b*) the average per capita consumption of water of the population served, q_t.

These two variables allow the derivation of consistent life-cycle scenarios for the number of household water connections and for the quantity of water supplied from the population served scenario simply by dividing P_t by N_t and by multiplying P_t by q_t.

The life-cycle scenario of P_t, N_t and q_t can be entirely designed by the user by setting the value of these quantitative indicators for each year of the project life cycle. It may also be modelled in a more parsimonious way by means of

$$X_t = X_1 + (X_{\theta+1} - X_1)F(t-1;\, \alpha, \beta, \theta) \tag{5}$$

where X_t denotes the variable to be modelled, X_1 is its initial value at the start date of the WS system use (beginning of year $t = 1$), $X_{\theta+1}$ is its final value (beginning of year $t = \theta + 1$), which corresponds to the full capacity use of the WS system reached after $\theta \leqslant T$ full years of the T-year project life cycle, and $F(\tau;\, \alpha, \beta, \theta)$ is a beta cumulative distribution function of the continuous time variable τ defined in the interval $[0;\, \theta]$. This function expresses the shape of the time trend followed by X_t, reaching after θ full years its final value $X_{\theta+1}$ from its initial value X_1. Therefore it depicts a growth scenario if $X_1 < X_{\theta+1}$, a decline scenario if $X_1 > X_{\theta+1}$ and a steady scenario if $X_1 = X_{\theta+1}$.

The profile of this time trend is determined by the values of α and β, which rule the shape of the beta cumulative distribution function and its underlying density function that expresses the instantaneous rate of change (speed) of this time trend. By choosing appropriate values of α and β, a wide range of time trend profiles can be generated (linear, S-shaped, J-shaped or rotated J-shaped).

It is worth noting that in the particular case where the WS facility is utilised at full capacity as soon as it is built, the AIC indicator becomes the ratio of the FAEC of the system to the annual production at full capacity; this is here called the unit annual equivalent cost (UAEC). For a project designed to provide drinking water to a growing population or to satisfy a growing water demand, the UAEC understates the cost of producing a unit of service by an amount determined by the time path of unused production capacity. Therefore, the differential between UAEC and AIC will assess the opportunity cost of spare capacity during the design lifetime of the project.

5. The water supply costing processor

To implement the costing method described in Section 3 and compute the full and unit cost indicators defined in Section 4, an Excel spreadsheet (called the water supply costing processor (WSCP)) was developed. This enables user-friendly identification, collection and processing of the relevant quantitative information to assess the life-cycle social cost of a specific WS project. The WSCP comprises 31 sheets, 21 of which are used to input data, 9 to provide output results and 1 contains a glossary of the technical terms displayed in the WSCP. The labels and functions carried out by these sheets are presented in Table 1. The tool is illustrated using a case study of a rural WS project intended to provide potable water to the population of Guantánamo, San Martín, Peru, carried out by a local consultant (Lampoglia, 2007) to test and assess both a previous version of the guidance manual and the WSCP.

The WSCP costing of a WS project starts with the choice of an improved WS technology and the design of its use over its life cycle. The WS project of Guantánamo-San Martín (GSM) was designed to provide drinking water to a population of 50 families by transporting, through one collector, water taken from a river located in a gorge to a sedimentation system and then to a slow sand filter and reservoir. From the reservoir, a line of adduction transports the water into the distribution network and domiciliary sinks. The initial population benefiting from this project was estimated at 300, but the infrastructure was laid out to supply water to a design population of 408 inhabitants reached after 7 years of growth at an average annual rate of 4·5% (based on historical growth rate during 1993 to 2003). The expected utility life of the system was estimated to be 20 years.

Label	Function
Scenario design (1 sheet)	Selecting an improved WS technology to be assessed and a time trend shape of the quantitative indicators used to design the life-cycle production growth of the WS system
Numerical scenarios (1 sheet)	Providing data to define the time trend shape of the above quantitative indicators, when a free beta-shape profile or a free trend scenario is selected within the 'scenario design' menu of trend shapes; displaying annual values and changes of these time trend indicators
Population scenario (1 sheet)	Displaying the time trend graph of the population size supplied with water jointly with that of its annual changes
Household scenario (1 sheet)	Displaying the time trend graph of the number of household water connections jointly with that of its annual changes
Water scenario (1 sheet)	Displaying the time trend graph of the quantity of water supplied by the system jointly with that of its annual changes
Investment costs (7 sheets)	Identifying the main resources in local or imported materials, local or imported equipment, local labour, incidentals and others, required to set up the WS technology; providing data for costing these resources
Maintenance costs (5 sheets)	Identifying the main resources in local or imported materials, local or imported equipment and local labour, required to maintain the WS technology; providing data for costing these resources
Operation costs (5 sheets)	Identifying the main resources in local and imported materials, local or imported power services and local labour, required to operate the WS technology; providing data for costing these resources
Other relevant costs (1 sheet)	Identifying the main resources invested in administration, training, and health and hygiene promotion and education; providing data for costing these resources
Economic pricing (1 sheet)	Providing data for performing an economic costing of the resources invested in the WS project, reflecting the national opportunity cost of these resources
Costing summary (6 sheets)	Displaying the full and unit cost indicators of the resources invested in the whole WS project and each of its components
Glossary (1 sheet)	Glossary of the technical terms used in the WSCP

Table 1. Labels and functions of the WSCP sheets

Consequently, as shown in Figure 2, from a menu of improved WS technologies on the scenario design sheet, piped water into dwelling, plot or yard was selected for costing over a design lifetime of 20 years. From a menu of pre-programmed time trend shapes, a symmetrical S-shaped ($\alpha = \beta = 2$) trend was selected to design the trend scenario of the population served by the project (from 300 to 408 in 7 years). As the size of the population served was the unique indicator used to quantify the services provided by the WS facility, the N/A (not available) option was selected from the menus of time trend shapes for average household size and average per capita consumption of water indicators. This prevents the WSCP computing scenarios for the number of household water connections and the quantity of water supplied. Note that a free (non pre-programmed) trend scenario, entirely designed by the user by setting the population size for each year of the project lifecycle could have also been chosen: for example, an exponential population growth scenario at the historical average annual rate of 4·5% during the first 7 years of the project lifecycle, instead of the selected pre-programmed symmetrical S-shaped trend. This scenario must be entered in numerical form by using the numerical scenarios sheet. Once these data are input, the WSCP displays the time trend scenario of the WS project use in numerical and graphical form (Figure 3).

The second step consists of identifying and costing, at the aggregation level compatible with the available data sources, the main resources invested in the project by means of the questionnaires presented in the appropriate WSCP sheets. Realisation of the GSM WS project required only the use of local materials, equipment and labour; no power services or imported resources were used. Therefore, the corresponding costing data were input into the following WSCP sheets: investment costs in local materials, equipment and labour (three sheets); maintenance and operation costs in local materials and labour (four sheets); other investment costs and other relevant costs (two sheets).

Investment costs for local materials and equipment were quantified at a disaggregated (input) level, while the available data sources allowed an assessment of investment costs for local labour at a more aggregated level (i.e. total wage costs at a sub-item or item level). To show what kind of data are required to complete the questionnaires, Figure 4 shows the investment cost data used to quantify (at disaggregated (input) level) the resources in local materials and Figure 5 shows those used to quantify (at aggregated (sub-item or item) level) the resources in local labour invested in the implementation of the tap and private connection infrastructures of the GSM WS project. Other investment costs (preliminary studies, administration, promotion and training, and education/instruction of the project staff and users) were assessed as a share of the construction costs or simply as a lump sum.

Maintenance and operation costs are recurrent costs evaluated on an annual basis. The relevant questionnaires needed to collect

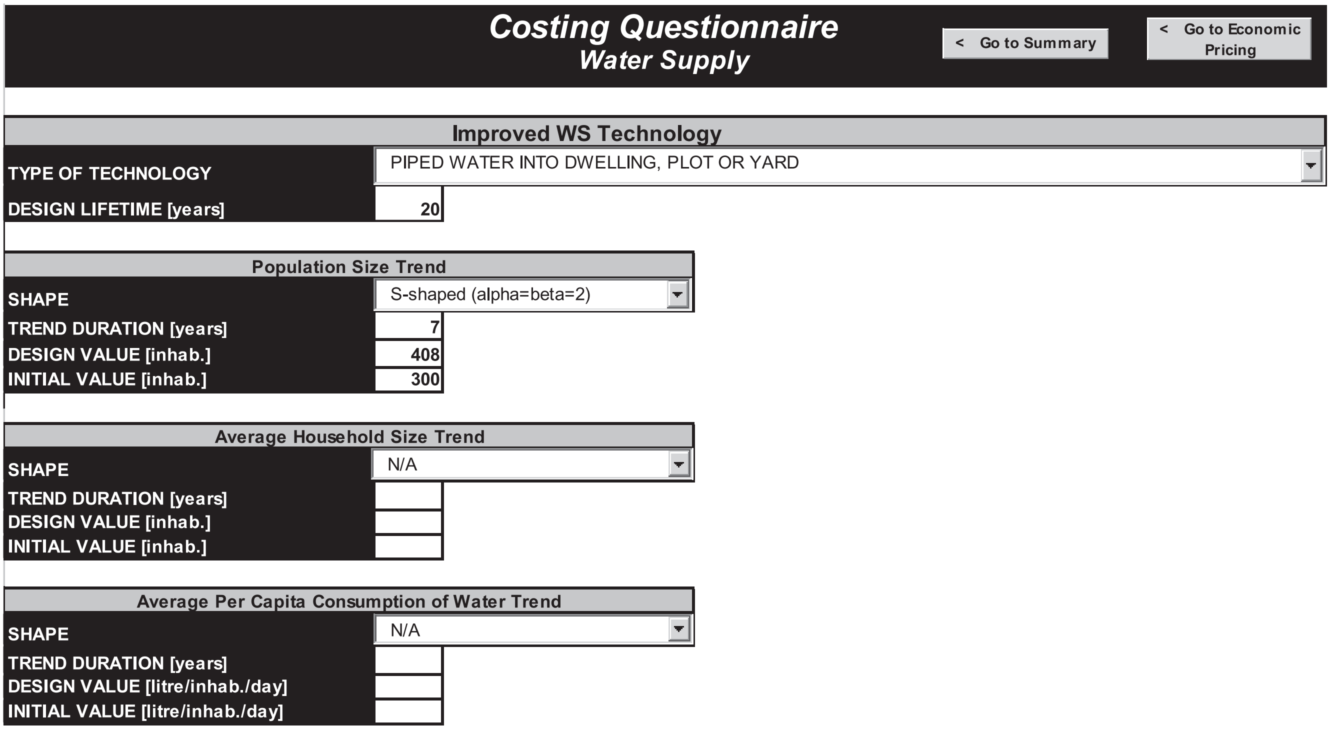

Figure 2. The scenario design sheet of the GSM WS project

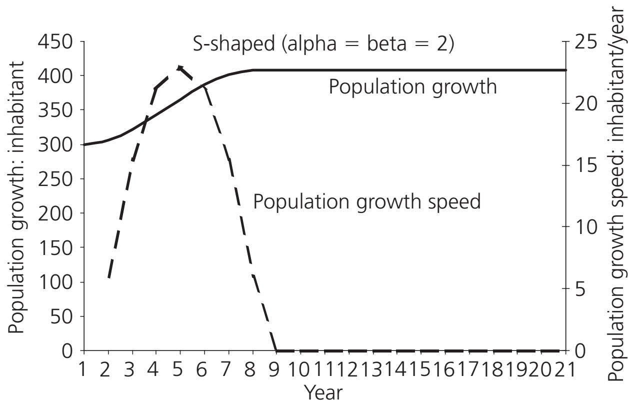

Figure 3. Growth scenario of the population of users for the GSM WS project (S-shaped with $\alpha = \beta = 2$)

these annual costs were designed using the same model as for investment costs, as far as cost breakdown by activity, item, sub-item and inputs is concerned. These project costs for local materials and labour were reported at an aggregated level, with labour costs entirely allocated to maintenance when the same person was appointed for both tasks. Other relevant costs encompass several recurrent costs assessed on an annual basis, among which the most important are costs for administration, training (in administration, maintenance and operation), and promotion and education in health and hygiene. These costs were difficult to evaluate at such a disaggregated level and were therefore assessed as a global lump sum.

The final step of costing a WS project is to value and discount the quantified invested resources using prices that represent the national opportunity costs of these resources (social costing). To perform this task, an economic pricing sheet was designed to

I. Investment Costs (in local currency unit, LCU)

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by disaggregated level (Input)

by aggregated level (Sub-item)

Fill out the following table. Consider all **Local Materials used in Investment.** The table contains pre-classified items, which may be changed if it exists other items or sub-items. Please, keep the same form of the table when you include new items.

INVESTMENT COSTS									
Item	Sub-item	Input	Acquisition Cost in LCU	Month/year of acquisition	Useful life (years)	Qty	Unit of measurement	Present Acquisition Costs in LCU (12.2006)	Annual Equivalent Cost in LCU (12.2006)
		Materials	88,649					96,281	10,892
		Water Collection	5,299					5,755	651
		Water Conveyance	786					854	97
		Water Storage	4,818					5,232	592
		Water Treatment	5,876					6,382	722
		Water Distribution	71,870					78,057	8,831
Tap Connection			17,691					19,214	2,174
	Connection							-	-
		Tap (with standpost and reservoir)	11,054	01/2003	20	50	Unit	12,006	1,358
		PVC pipe and installation	6,637	01/2003	20	910	m	7,209	816
		Other______	-					-	-
								-	-
	Other______							-	-
		Other______	-					-	-
								-	-
Public Standpipe			-					-	-
	Connection							-	-
		5 taps and one suction handpump						-	-
		Tap	-				Unit	-	-
		PVC pipe	-				m	-	-
		Cement	-				kg	-	-
		Sand	-				m³	-	-
		Other______	-					-	-
								-	-
	Supporting							-	-
		Wood	-				kg	-	-
		Brickwork	-				kg	-	-
		Dry stone masonry	-				kg	-	-
		Concrete	-				kg	-	-
		Globe or self-closing tap	-				Unit	-	-
		Concrete slab or apron	-				kg	-	-
		Regulating Valve	-				Unit	-	-
		Other______	-					-	-
								-	-
	Other______							-	-
		Other______	-					-	-
								-	-
Private Connection			54,179					58,843	6,657
	Connection							-	-
		PVC pipe	24,448	01/2003	20	5659.3	m	26,553	3,004
		Valves of air and purge (with box)	446	01/2003	20	2	unit	484	55
		Valves and accessories	1,556	01/2003	20		global	1,690	191
		Aerobical pass 15 m	8,066	01/2003	20	3	unit	8,761	991
		Aerobical pass 60 m	11,208	01/2003	20	1	Unit	12,173	1,377
		Hydraulic test	2,674	01/2003	20		global	2,904	329
		Other______	5,781	01/2003	20		global	6,278	710
								-	-
	Other______							-	-
		Other______	-					-	-
								-	-

Figure 4. Investment costs sheet for local materials of the GSM WS project filled in at disaggregated level

I. Investment Costs (in local currency unit, LCU)

< Back to Summary | by disaggregated level (Input) | by aggregated level (Sub-item)

Fill out the following table. Consider all **Local Labour used in Investment**. The table contains pre-classified items, which may be changed if it exists other items or sub-items. Please, keep the same form of the table when you include new items.

INVESTMENT COSTS									
Item	Sub-item	Input	Hourly wage (LCU/hour)	Quantity (hours)	Date of wage payment (month/year)	Total working costs	Useful life of investments (years)	Present wage in LCU (12.2006)	Annual Equivalent Cost in LCU (12.2006)
		Labour				**41,889**		**45,496**	**5,147**
		Water Collection				**1,237**		**1,343**	**152**
		Water Conveyance				**742**		**806**	**91**
		Water Storage				**802**		**871**	**98**
		Water Treatment				**2,054**		**2,231**	**252**
Household Treatment						**-**		**-**	**-**
Central Treatment						**2,054**		**2,231**	**252**
	Small filter					-		-	-
						-		-	-
	Storage and sedimentation				01/2003	1,493	20	1,622	184
						-		-	-
	Up-flow roughing filters					-		-	-
						-		-	-
	Slow sand filtration				01/2003	561	20	609	69
						-		-	-
	Chlorination in piped systems					-		-	-
						-		-	-
	Other______					-		-	-
						-		-	-
		Water Distribution				**37,055**		**40,245**	**4,553**
Tap Connection						**8,130**		**8,830**	**999**
	Connection				01/2003	8,130	20	8,830	999
						-		-	-
	Other______					-		-	-
						-		-	-
Public Standpipe						**-**		**-**	**-**
	Trench					-		-	-
						-		-	-
	Connection					-		-	-
						-		-	-
	Supporting					-		-	-
						-		-	-
	Cement fence					-		-	-
						-		-	-
	Wood fence					-		-	-
						-		-	-
	Collecting spillage					-		-	-
						-		-	-
	Other______					-		-	-
						-		-	-
Private Connection						**28,924**		**31,414**	**3,554**
	Trench					-		-	-
						-		-	-
	Connection				01/2003	28,924	20	31,414	3,554
						-		-	-
	Other_____					-		-	-
						-		-	-

Figure 5. Investment costs sheet for local labour of the GSM project filled in at aggregated level

input the relevant information. This WSCP sheet, filled in with the data used to assess the GSM WS project, is shown in Figure 6.

From the content of this sheet, it can be seen that the social market cost of the marketed resources invested in the GSM WS project was valued in Peruvian currency (nuevo soles) at the shadow prices of 1 December 2006 by using a real annual discount rate of 11%, corresponding to the real social discount rate published by the Dirección General de Programación Multi-anual del Sector Público (DGPMSP, 2006) of Peru, and a shadow factor for unskilled labour of 0·49, reflecting the existence of a substantial amount of structural unemployment for unskilled labour in Peru. As no imported equipment or materials were used, a value for the shadow factor of the rate of foreign exchange was not provided. The monthly series of the consumer price index was used to convert the investment cost components, inputted in the costing questionnaire sheets at the historical values of January 2003, to the soles value of the reference date of 1 December 2006, conventionally chosen as the starting date of the WS system use.

Once all the input data sheets have been provided with the relevant information, the WSCP computes the consolidated cost indicators of the project defined in Section 4. These cost indicators are displayed in a series of costing summary sheets, designed to cost the whole project as well as each of its components.

As shown in Figure 7, the FCPV of the GSM WS project was evaluated (at the soles value of 1 December 2006) at 254 953 soles/life cycle, of which 74·4% is due to investment costs, 12·2% to maintenance costs, 5·2% to operational costs and 8·2% to administrative costs. This FCPV is converted into an

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Valuation parameters	
Month/Year of actualization [mm.yyyy]	12/2006
Currency [local currency unit, LCU]	Soles
Shadow factor of unskilled labour wage	0.49
Shadow factor of foreign rate of exchange	
Real annual social discount rate [%]	11

Consumer Price Index		
Date	*Base (=100)12.2001*	*Base (=100) 12.2006*
01/12/2001	100.00	110.51
01/01/2002	99.48	111.09
01/02/2002	99.44	111.13
01/03/2002	99.98	110.53
01/04/2002	100.70	109.74
01/05/2002	100.84	109.59
01/06/2002	100.62	109.83
01/07/2002	100.65	109.80
01/08/2002	100.75	109.69
01/09/2002	101.23	109.17
01/10/2002	101.96	108.39
01/11/2002	101.55	108.82
01/12/2002	101.52	108.86
01/01/2003	101.75	108.61
01/02/2003	102.23	108.10
01/03/2003	103.37	106.91
01/04/2003	103.32	106.96
01/05/2003	103.28	107.00
01/06/2003	102.80	107.50
01/07/2003	102.64	107.67
01/08/2003	102.66	107.65
01/09/2003	103.23	107.05
01/10/2003	103.28	107.00
01/11/2003	103.45	106.82
01/12/2003	104.04	106.22
01/01/2004	104.60	105.65
01/02/2004	105.73	104.52
01/03/2004	106.22	104.04
01/04/2004	106.19	104.07
01/05/2004	106.57	103.70
01/06/2004	107.17	103.12
01/07/2004	107.38	102.91
01/08/2004	107.37	102.92
01/09/2004	107.39	102.91
01/10/2004	107.36	102.93
01/11/2004	107.67	102.64
01/12/2004	107.66	102.65
01/01/2005	107.77	102.54
01/02/2005	107.51	102.79
01/03/2005	108.21	102.13
01/04/2005	108.34	102.00
01/05/2005	108.48	101.87
01/06/2005	108.76	101.61
01/07/2005	108.88	101.50
01/08/2005	108.68	101.68
01/09/2005	108.58	101.78
01/10/2005	108.74	101.63
01/11/2005	108.81	101.56
01/12/2005	109.27	101.13
01/01/2006	109.81	100.64
01/02/2006	110.42	100.08
01/03/2006	110.92	99.63
01/04/2006	111.49	99.12
01/05/2006	110.90	99.65
01/06/2006	110.75	99.78
01/07/2006	110.56	99.95
01/08/2006	110.72	99.81
01/09/2006	110.75	99.78
01/10/2006	110.79	99.75
01/11/2006	110.48	100.03
01/12/2006	110.51	100.00

Figure 6. Economic pricing sheet of the GSM WS project

AIC by dividing the FCPV by the present value of life-cycle production evaluated (at the production value of 1 December 2006) at 3295 year-inhabitant/life cycle, where the unit 'year-inhabitant' represents the services provided by the WS system to an inhabitant during a full year. This leads to an AIC of 77 soles/year-inhabitant.

To assess the opportunity cost of spare capacity, a unit cost at full capacity is computed by dividing the FAEC of 28 444 soles/year by the system production at full capacity evaluated to 408 year-inhabitants/year. The ensuing UAEC is 70 soles/year-inhabitant. Compared with the former AIC, these figures lead to an opportunity cost of spare capacity of 7 soles/year-inhabitant.

6. Conclusions

To assess the scope and limits of the proposed costing method in a real setting, a series of field tests were designed and performed by local practitioners in selected countries. These tests, carried out in Peru (Lampoglia, 2007) and in six countries of south-east Asia and the Western Pacific (WHO, 2008), were primarily intended to identify practical issues (limitations, difficulties, adaptability, friendliness) in the use of the manual and the water supply costing processor (WSCP). The results provided practical recommendations that have been implemented in the current version of the manual (Carlevaro and Gonzalez, 2009) and the WSCP (notably implementation of the methodology presented in Section 4 for designing scenarios of project life-cycle production and a glossary of technical terms used in the WSCP) and identified the following issues, which deserve special attention in application of the method.

(*a*) Although the local conditions of a WS project often provide overriding arguments in favour of a single technological option, within that option an insightful least-cost analysis can be conducted as different technology components can be implemented according to different economic alternatives.

(*b*) Successful implementation of the method requires a multi-disciplinary team and the creation of a partnership between sanitary engineers and economists.

(*c*) To support widespread utilisation of the method, it is important to complement the manual and the WSCP with a database of real-life case studies to present reliable estimates of both investment and recurrent costs and to illustrate justified choices of shadow factors and social discount rate.

(*d*) An expansion of the costing methodology to non-market costs and benefits would be suitable for assessing WS projects from the sustainable development perspective. This calls for an extension of the costing method to a more comprehensive social cost-effectiveness or social cost–benefit analysis framework. Research is continuing in this direction.

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Selected improved technology: *PIPED WATER INTO DWELLING, PLOT OR YARD*
Currency and day of actualization: *Soles of 01/12/2006*

TOTAL COST TYPOLOGY	FULL COST			UNIT COST PER					
	FCPV		FAEC	INHABITANT		HOUSEHOLD		litre/inhab./day WATER SUPPLY	
	[Soles]	[%]	[Soles/year]	AIC [Soles/year]	UAEC [Soles/year]	AIC [Soles/year]	UAEC [Soles/year]	AIC [Soles/year]	UAEC [Soles/year]
TOTAL INVESTMENT COSTS	**189,664.16**	**74.4**	**21,160.02**	**57.56**	**51.86**	**N/A**	**N/A**	**N/A**	**N/A**
Local Materials	97,632.12	38.3	10,892.40	29.63	26.70	N/A	N/A	N/A	N/A
Imported Materials	-	0.0	-	-	-	N/A	N/A	N/A	N/A
Local Equipments	103.39	0.04	12.80	0.03	0.03	N/A	N/A	N/A	N/A
Imported Equipments	-	0.0	-	-	-	N/A	N/A	N/A	N/A
Local Labour	46,134.07	18.1	5,146.98	14.00	12.62	N/A	N/A	N/A	N/A
Other Investment costs	45,783.22	18.0	5,107.84	13.89	12.52	N/A	N/A	N/A	N/A
TOTAL CONTINGENCIES COSTS	**-**	**0.0**	**-**	**-**	**-**	**N/A**	**N/A**	**N/A**	**N/A**
Incidental costs	-	0.0	-	-	-	N/A	N/A	N/A	N/A
TOTAL MAINTENANCE COSTS	**31,004.15**	**12.2**	**3,459.00**	**9.41**	**8.48**	**N/A**	**N/A**	**N/A**	**N/A**
Local Materials	18,464.46	7.2	2,060.00	5.60	5.05	N/A	N/A	N/A	N/A
Imported Materials	-	0.0	-	-	-	N/A	N/A	N/A	N/A
Local Equipments	-	0.0	-	-	-	N/A	N/A	N/A	N/A
Imported Equipments	-	0.0	-	-	-	N/A	N/A	N/A	N/A
Local Labour	12,539.70	4.9	1,399.00	3.81	3.43	N/A	N/A	N/A	N/A
TOTAL OPERATION COSTS	**13,310.54**	**5.2**	**1,485.00**	**4.04**	**3.64**	**N/A**	**N/A**	**N/A**	**N/A**
Local Materials	761.88	0.3	85.00	0.23	0.21	N/A	N/A	N/A	N/A
Imported Materials	-	0.0	-	-	-	N/A	N/A	N/A	N/A
Local Power Services	-	0.0	-	-	-	N/A	N/A	N/A	N/A
Imported Power Services	-	0.0	-	-	-	N/A	N/A	N/A	N/A
Local Labour	12,548.66	4.9	1,400.00	3.81	3.43	N/A	N/A	N/A	N/A
TOTAL OTHER RELEVANT COSTS	**20,974.19**	**8.2**	**2,340.00**	**6.37**	**5.74**	**N/A**	**N/A**	**N/A**	**N/A**
Administration	20,974.19	8.2	2,340.00	6.37	5.74	N/A	N/A	N/A	N/A
Training	-	0.0	-	-	-	N/A	N/A	N/A	N/A
Promotion & Education	-	0.0	-	-	-	N/A	N/A	N/A	N/A
TOTAL COST	**254,953.04**	**100**	**28,444.02**	**77.37**	**69.72**	**N/A**	**N/A**	**N/A**	**N/A**

	[year-INHABITANT]	[year-HOUSEHOLD]	[year-litre/inhab./day]
PRESENT VALUE OF LIFE-CYCLE PRODUCTION	3,295	N/A	N/A
FULL CAPACITY PRODUCTION	408	N/A	N/A

Figure 7. Costing summary sheet of the GSM WS project

and support in achieving this project and introducing its results to potential users.

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