Journal of Hydroinformatics | 06.2 | 2004

EVAPRO: economic and financial evaluation of water supply projects

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ABSTRACT

The present paper describes a computer-based system for water supply project appraisal called EVAPRO, standing for EVAluation of water PROjects. The aim of EVAPRO is to facilitate economic and financial assessment of water supply projects under different investment and operating scenarios, and changes to initial system configuration. The software consists of automating the feasibility study of water projects using information about population and water demand forecasts, potential water resources, investment decisions, financial resources and water pricing policy. It embodies a set of tools, including linear programming techniques, numerical methods and financial calculations, and combines operational optimization with financial analysis to assess the feasibility of water supply projects.

The software is intended for water production and distribution agencies and aims to assist engineers and decision-makers in water supply project evaluation and feasibility assessment.

Key words | economic and financial assessment, feasibility study, water supply projects

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INTRODUCTION

A project in a water system aims to supply a region with water or to increase the supply in an existing system. Hence, it can be a project for a new supply or an extension project. Such a project involves the use of a number of limited resources to produce water for consumers. Economic evaluation aims at assessing whether the value of the project output exceeds the value of the resources used. In economic terms, the values of the output are designated as benefits of the project and those of the resources are known as the costs of the project.

The purpose of economic and financial assessment is to identify the benefits and costs and hence to determine whether carrying out the project is justified on economic and financial grounds. The main objective of economic evaluation is to ensure the best use of limited resources to satisfy current or future needs. Financial analysis has more specific boundaries and answers the question of whether the project is viable as a unit action, i.e. if the funds to be invested generate enough cash-flow corresponding to a reasonable internal profitability.

Due to the scarcity of both water and financial resources, there is a need to evaluate and optimize all related engineering projects on a common basis. A water supply system is a set of interconnected components, which takes water from external supplies, such as dams, lakes and rivers, and distributes it to consumers. Engineers and managers are faced with the challenge of coming up with water systems to provide water as economically as possible.

In this paper, a new software package called EVAPRO is presented. It enables the user to automate feasibility studies of water projects using information on population and water demand forecasts, potential water resources, investment scheduling, financial resources and water pricing policy. It embodies a set of tools including linear programming techniques, numerical methods and financial calculations.

The software is intended for water production and distribution agencies and aims to assist engineers and decision-makers in water supply project evaluation and feasibility assessment. EVAPRO is currently being used by

ONEP (Office National de l'Eau Potable), the Moroccan office for potable water.

EVAPRO FEASIBILITY STUDY PROCESS

The abbreviation 'EVAPRO' stands for EVAluation of water PROjects. It aims to assist managers in water project appraisal by carrying out feasibility studies. The purpose of this feasibility study is to assess whether or not the project can be carried out successfully. The procedure is to seek out a range of alternative approaches and then to investigate each in turn to determine which are feasible (Dandy & Warner 1989).

Figure 1 summarizes the EVAPRO feasibility process. An initial water supply project is proposed. The results of the software allow the decision-maker to assess whether the project is feasible or not and to choose the best among different project alternatives (Bakkoury *et al*. 1998). The process is iterative: at each step, a new project alternative is obtained by altering information from the input data. The following sections present the most relevant input and output data for EVAPRO. The calculations leading to different results are detailed.

Data required by EVAPRO

The project is first identified by general information, including name and location, reference year, first year of running and last year of operation.

The reference year is used for present value calculations. All investments and works related to the project occur after the reference year. The first year of running represents the first year of service for the first stage of the project. The last year of operation is the last year taken into account in the calculations. The main objective of the project will usually be expressed as satisfaction of a varying demand for a duration from the first year of running to the last year of operation.

EVAPRO is a typical Windows application usable by any operator familiar with the Windows interface. The list of input data includes population, water demand, potential sources of water production, investment commitment and scheduling, financial resources and pricing policy. Other information is also specified including discount rate and inflation.

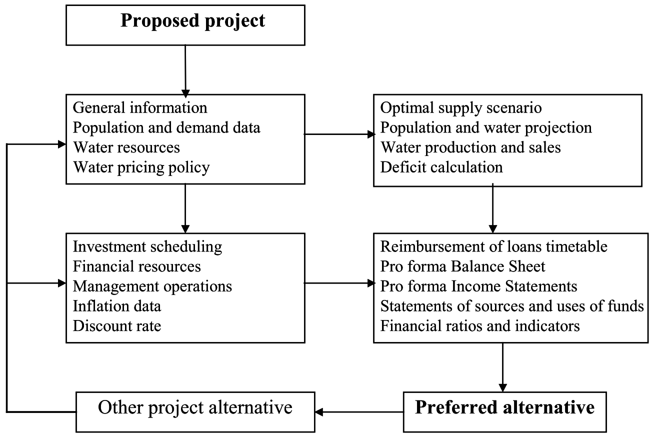

Figure 1 | EVAPRO feasibility study process.

Population

Population is a relevant factor in predicting water demand. Several methods have been proposed for population projection and determining how it influences demand forecast (Rodriguez & Beteta 1991). EVAPRO provides the choice between two methods: using a population growth rate or a number of estimations. In the first case, the growth rate may be variable; in the second case, population projection is based on a set of values interpolated according to an exponential function.

Growth rate. When using this figure, the software determines the population using a growth rate and an estimation for a reference year. Equation (1) is used in this case to calculate the value of population served (or to be served) by the project for any year n through the duration of the project:

$$P_n = P_1(1 + Gr)^n \quad (1)$$

where:

P_n represents population for year n in millions of inhabitants,

P_1 population estimated for the reference year in millions of inhabitants,

Gr the population growth rate.

The growth rate may be variable. In this case, *Gr* in Equation (1) is replaced by Gr_n, the population growth rate in year *n*.

Interpolation. Population is estimated for a number of years (at least for the reference year and the last year of the project) and calculated for any other year over the project horizon. The following formula considers an exponential growth:

$$Pn = \frac{P_i}{P_{i-1}} \exp\left(\frac{year(n) - year(i-1)}{year(i) - year(i-1)}\right) \qquad (2)$$

For a year *n*, two known values P_i and P_{i+1} are used to calculate P_n such as

$year_i < year_n < year_{i+1}$.

In Morocco, population forecasts and growth rate are estimated from surveys or statistics given by CERED (Centre de Recherche et d'Etudes en Démographie) (CERED 2002).

Water demand

Water needs fall into a number of categories including domestic, industrial, commercial, public and other activities. Planners are concerned with predicting long-term needs so that they can plan works to be executed in time at least cost.

Forecasts are divided between those that are aggregate and those that are disaggregate in their characterization of water use (Boland 1983). An aggregate forecast calculates total water use directly; disaggregate methods address defined sectors of water use separately, e.g. residential, commercial, industrial and institutional categories, later summing forecasts by sector to produce a total water use forecast. Various levels of disaggregation are possible.

EVAPRO offers two options. Water demand can therefore be given according to different types of consumers or it can be calculated globally, depending on the level of detail desired and the available information. Average annual estimations are given in l/sec. Demand modulation is introduced using the peak and the minimum coefficients characterizing, respectively, the peak and the least water demand during a year (ONEP & PNUD 1989). This approach allows the use of minimum information to take account of demand modulation.

Disaggregated water demand. Water needs are considered separately for every category of consumer and based on the per capita requirement method where future water requirements are estimated by multiplying the adjusted per capita use by the projected population.

In Morocco, categories of potable water needs include population connected to the water network, those not connected to the network, plus administrative and industrial consumption. Table 1 explains the use of the per capita requirement method within EVAPRO to establish water needs. Every item represents the average annual demand in l/sec.

Aggregated water demand. These forecasts represent the average values of annual water demand in l/sec without distinguishing between different types of consumers.

Demand modulation. When using average annual demand without taking into account the daily demand variation during a year, substantial errors may arise in calculating water production. Within EVAPRO, water demand modulation is characterized by a peak coefficient *Cp* given by the following formula (ONEP & PNUD 1989):

Cp = average demand of three successive peak days/ average annual demand

and *Cm* as the coefficient that characterizes the least demand of the year using the following:

Cm = average demand of the three successive days with least demand/average annual demand.

For ONEP projects, *Cm* is usually estimated approximately by $Cm = 2 - Cp$. Typically, $Cp = 1.3$ and $Cm = 0.7$.

Table 1 | Disaggregated water demand.

Year	N
Total population (millions)	①
Connection rate (%)	②
Connected population	③ = ① × ②/100
Non-connected population	④ = ① − ③
Per capita requirements (*l*/*d*/*capita*)	
Connected population	⑤
Non-connected population	⑥
Administrative	⑦
Demand (m^3/d)	
Connected population	③ × ⑤/1000
Non-connected population	④ × ⑥/1000
Administrative	① × ⑦/1000
Industrial	⑧
Other	⑨
Total	

Potential sources of water production

When undertaking a water project feasibility study, water sources which are potentially available need to be identified. Therefore, information concerning these sources should be specified as input data for EVAPRO. If it is an extension project, data about existing facilities is also required. Information regarding sources comprises the following data: flow in l/sec, first and last year of running, unit cost of chemicals (in Dirhams for Morocco) and, for pumped systems, additional information is given concerning the pressure head at nodes, efficiency in % and unit cost of energy for day and night (in Dirhams/kWh). The first and last year of running indicate that additional production units can be gradually included in the project over the time horizon considered. These data are used to compute energy requirements for the supply optimization model using the following energy expression:

$$\frac{\rho g Q H}{\eta} \qquad (3)$$

where ρ represents density, g gravity, Q the flow, H the head and η the efficiency.

Information on potential sources of water production is particularly relevant in determining the best scenario for operation and assessing if the project will present any deficit in satisfying water demand.

Investment commitment and scheduling

Water projects are usually staged over a long-term duration. The duration of the project is divided into phases. Water system components can be installed in several stages while satisfying a varying water demand over the project duration. Information is specified regarding the necessary investment for each component in the project, e.g. civil engineering, pipelines, electrical and mechanical equipment, land acquisition and other components. For every item, the following are detailed:

- investment schedule;
- annual depreciation;
- the life span, which indicates the horizon of equipment exploitation; and
- the percentage of total investment devoted to annual maintenance costs if necessary.

Investment schedule. Planning a water system implies determining the first year of running for each component as well as an investment schedule providing information on different construction periods or stages.

For every stage, the following information is specified:

- start year of work;
- first year of running; and
- the investment committed to this stage and its schedule from the start year of work until the first year of running.

Investments are expressed in Dirhams related to the reference year specified in the 'general information'.

Bakkoury (2002) presents an approach based on genetic algorithms to investment sheduling that may be coupled with EVAPRO. The GA technique determines the optimal staging of a water project based on minimizing total present cost while satisfying water demand.

Depreciation. Two methods are used by EVAPRO for depreciation calculation: linear and degressive. Linear, or straight-line, depreciation is considered to be the most common method of depreciating assets. The annual depreciation expense employing the straight-line method uses the following formula:

$$A_d = \frac{I}{D} \tag{4}$$

where A_d represents the annual depreciation, I the investment spent on the asset and D the useful life of the same asset. In this case, A_d remains constant.

A_d represents a depreciation expense that is reported on the project income statement under operational expenses at the end of each year.

Some financial managers, usually for tax purposes, prefer to use degressive methods, accelerating depreciation in order to record larger amounts of depreciation in the early years of the asset so as to reduce tax bills as soon as possible. Degressive depreciation is given by the following formula:

$$Ad_n = I(1 - Dr) \tag{5}$$

where Ad_n represents the depreciation expense for year n, I the investment spent on the asset and Dr a depreciation rate.

Financial resources

Once the necessary investments are known, an inventory of different available financial resources is made. In the case of ONEP projects, these include government subventions, internal funds or equity capital, loans and donations from international institutions. For every sponsor, information is required regarding interest rates, duration of loan, reimbursement calculation method and other relevant factors.

Water price structure

EVAPRO offers two main options for pricing policy, including uniform rate and multiple block rate pricing.

Uniform rate pricing (flat rate pricing). A single unit price for water applies to all users and is applied regardless of the amount consumed. All units of water purchased are charged at the same price. This rate is appropriate in locations where water customers have similar water use characteristics.

When applying a flat rate pricing within EVAPRO, the volume of water distributed within a year is multiplied by the unit price to determine the annual income from water sales. The unit price in this case may be variable over the project duration.

Multiple block rate pricing. The aim of applying block rates is usually to discourage excess water consumption. This tariff policy imposes a higher rate for water use that occurs over a certain level. Thus, the customer pays more money per unit for water in excess of what is considered normal use.

The block pricing option offered by EVAPRO allows three levels for domestic and public use and distinguishes between industrial and tourist tariffs, which use uniform rates. The first block is charged at the base rate, the second block is charged at the base rate plus an additional fee per unit and the third block is charged at the base rate plus a higher additional fee per unit. In this case, calculations are based on attributing a consumption percentage to domestic, administrative or public use along with industrial and tourist consumption, as shown in Table 2. The category 'Other' may be used for a demand corresponding to a specific activity not included in the proposed classification, or if there is a need to separate one or many customers such as big industrial consumers.

OUTPUT

EVAPRO enables the trapping of as many input errors as possible prior to calculation runs. The tabular and

Table 2 | Multiple block pricing for year *n*.

Type of use	Tariff structure	Percentage of consumption ①	Demand for year *n* ②	Volume of water ①×②=③	Tariff rate ④	Sales ③×④
Domestic and administrative	First block	10%				
	Second block	—				
	Third block	—				
Industrial	—	—				
Tourist	—	—			—	—
Other	—	—			—	—
		100%			**Total sales**	

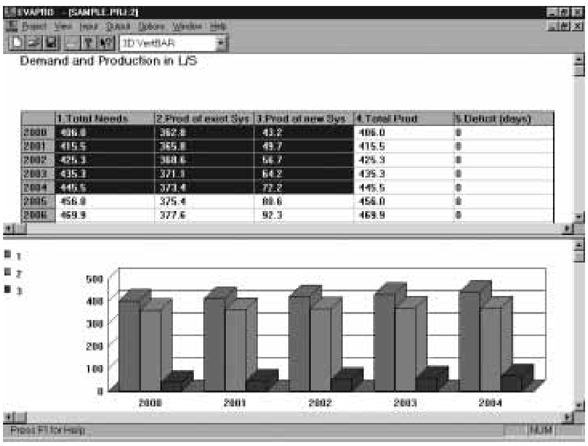

Figure 2 | Screen capture of EVAPRO.

Figure 3 | Report generation within EVAPRO.

graphical display of results and the reporting make the software user-friendly. The user specifies the type of graphic for a selection from tabular results. Figure 2 shows the graphic display of interpolated data representing population and demand along with the results of water production calculations performed by the software for a sample project. Water production calculations are based on optimizing the water supply, as detailed in the next section.

EVAPRO generates an output file with all the results specified by the user, who may choose a full report with all calculations performed by the software as shown in Figure 3.

The list of output data comprises population and water demand projections, water production and sales, along with deficit calculations if any exist. These calculations are based on optimization of supply from available water sources. The software also gives a complete financial report, including financial statements, along with a set of ratios and indicators.

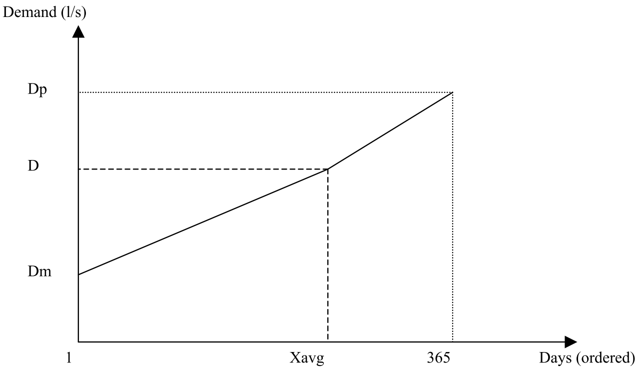

Figure 4 | Classified curve of daily needs.

Supply optimization

Supply is optimized to meet demand by using linear programming techniques. Water resource operation has to be controlled so that total costs of energy and chemicals will be minimal.

Demand modelling

Information available concerning demand represents average annual needs. Calculating water production and sales while ignoring demand variation may lead to considerable errors. The procedure used in this case is similar to the one described in ONEP & PNUD (1989). The demand variation during a year can be represented as a growing curve of daily needs between the minimum value *Dm* and the peak value *Dp*. The curve of classified flows is then approached by two linked segments as follows: the first segment is for flows below average demand *D* with the minimum flow *Dm* of the year as its origin, while the second segment represents flows greater than the average demand with the highest demand *Dp* of the year as its end.

The calculation of annual water production from different sources will be based on the curve of daily needs ordered from minimum to peak demand during a year. Ordering the demand curve makes the calculations easier and improves their accuracy.

Since information available regarding demand does not include daily needs, the required curve is modelled using average demand and the coefficients *Cm* and *Cp* as illustrated by the curve presented in Figure 4. The coordinates corresponding to the average value of demand *D* are given by $Xavg = 365(Cp-1)/(Cp-Cm)$ and $Yavg = D$. This method presents the advantage of modelling demand variation with minor error and of only using information on minimum, average and peak demand values.

Problem formulation

The linear optimizer calculates the amount of water and the time of day for its operation for every available resource. If the demand cannot be satisfied, the program calculates the value of the deficit.

By using the curve of classified flows, the software determines the best daily timing for water sources operation, minimizing the cost of energy and chemicals.

Assuming that:

Di = the demand of day i (in l/sec),
Qj = output of source j (in l/sec),
Cj = production cost for energy and chemicals of one cubic meter using source j in Dirhams,
Tj = operation time of source j (in h),

the expense is given by

$$Out = \sum_{1 \leq j \leq n} CjQjTj. \quad (6)$$

For each day (i) two constraints should be introduced:

$$\sum_{1 \leq j \leq n} Tj \leq 24(\text{hours}) \quad (7)$$

$$\sum_{1 \leq j \leq n} TjQj = D_i \times 24. \quad (8)$$

The problem formulated above is solved using the simplex algorithm described in Gondran & Minoux (1995). In this formulation, the decision variables are *Tj* while *Qj* are constants for all available sources.

Input data specifies, for every source, the first and last year of running, allowing the program to determine the available sources for every year.

Having more than one source to meet the day's demand often gives good economy during that day. A source means, in this formulation, either a unique resource or a set of resources that can operate in parallel. Calculation of the resultant sources for all possible combinations is carried out. These sources are then sorted by increasing capacity and non-competitive regimes are eliminated. As a result, the demand is supplied by the two resultant sources such as

$$Q_j < D_i \le Q_{j+1} \quad (9)$$

The LP optimizer within EVAPRO aims at minimizing Equation (6) under constraints (7) and (8) using sources j and $j+1$ to satisfy D_i. When $D_i > Q_j$ for all sources, a deficit is recorded.

Equation (7) indicates that the total time of operation in a day cannot exceed 24 h and Equation (8) expresses that supply should equal demand. Energy costs for day and night are taken into account and the problem is solved for day and night separately to find the best operation. The duration in hours of day and night is specified in this case. Reservoir damping is neglected for feasibility analysis.

The result of supply optimization allows calculation of annual production by summing optimal daily output to meet water demand. The amount of water sales is then determined according to the tariff policy adopted. Supply optimization also helps in calculating production cost, which is useful for water tariff establishment or adjustment.

The LP procedure within EVAPRO calculates the production capacity on a daily basis. Providing daily curves or approaching the classified curve given in Figure 4 by more than two segments to have a better accuracy in the results is therefore possible.

Financial analysis

The financial analysis report established by EVAPRO presents *pro forma* balance sheet, income statement, statement of sources and uses of funds along with reimbursement of loans timetable and calculations of present values. It also offers a set of financial ratios and indicators, providing a convenient way to summarize large quantities of financial data in order to compare the performances of various projects.

One of the main objectives of the financial analysis report established by the software is to get acceptance by development partners to obtain government grant support or any other financial means.

Reimbursement calculation methods

The debt service comprises the amount of money allocated to the reimbursement of loans. It largely comprises the principal and interest. The principal represents the reimbursement of the amount of loan, and is thus subtracted from the loan. The interest, also called financial fees, is usually calculated by applying a percentage of the due amount. The interest rate may be constant or variable.

In some cases, a period of grace is applied to a loan, during which the borrower only pays the interest. This occurs when return is not important during the early years of a new project, keeping the debt service to interest.

Several cases are possible for debt service calculations.

- During the period of grace. During the years corresponding to the period of grace, the borrower only pays interest:

  Debt service = Capital × Interest rate.

- After the period of grace (which may be zero). Two methods are implemented within EVAPRO. The first is based on a constant annuity and the second on a constant principal. The application of a commitment fee is also considered.
- *Constant annuity*. Annuities represent the debt service during a year, including a part of the capital and the amount of interest. In this case, the debt service, including interest plus principal, is constant during the duration of loan and the reimbursement calculations are based on the formulae given in Table 3. In these formulae, *TI* represents the interest rate, *M* the amount of capital and *D* the duration of loan in years, excluding the grace period. When the

Table 3 | Reimbursement with constant annuity

	Year *n*	Total
Interests	$\frac{TI \times MF[(1+TI)^{D} - (1+TI)^{n-1}]}{(1+TI)^{D} - 1}$	$\frac{M \times [D \times TI - 1 + (1+TI)^{-D}]}{1-(1+TI)^{-D}}$
Principal	$\frac{TI \times M(1+TI)^{n-1}}{(1+TI)^{D} - 1}$	M
Annuity	$\frac{TI \times M}{1-(1+TI)^{-D}}$	$\frac{D \times TI \times M}{1-(1+TI)^{-D}}$

Table 4 | Reimbursement with constant principal

	Year *n*	Total
Interests	$\frac{TI \times M(D-n+1)}{D}$	$\frac{M \times TI(D+1)}{2}$
Principal	$\frac{M}{D}$	M
Annuity	$\frac{M[TI(D-n+1)+1]}{D}$	$M\left[\frac{TI(D+1)}{2}+1\right]$

interest rate is variable, the duration of the loan is divided into sub-durations where this rate remains constant.

- *Constant principal.* The principal represents the amount reimbursed from the capital, excluding interest. In this case, the part of the debt service representing the principal remains constant over the duration of loan. The formulae used in this case are given in Table 4.
- *Commitment fee.* This represents an amount of money paid by the borrower when he chooses to get the capital in several installments according to an investment schedule. In this case, a commitment fee rate is applied and a part of the annuity corresponding to the commitment fee is calculated by multiplying a commitment fee rate *CFr* by the part of the capital not yet received. The borrower, instead of paying interest on amounts that will not be used immediately, prefers to pay a commitment fee to ensure receiving parts of the capital in the future. The annuity includes interest on the part of the capital already received and a commitment fee on the part of the loan not yet received. After the grace period, the principal reimbursing the amount of loan already received is added to the debt service.

Table 5 gives an example of a reimbursement timetable for a loan of 20 years' duration, a constant interest rate of 5% and a period of grace of 8 years.

Analyzing financial statements

Financial statements are important in conducting financial analysis. These statements need to be formatted so that they are appropriate to the kind of project or business being conducted. *Pro forma* income statements, along with balance sheets and statements of sources and uses of funds, are the most basic elements required by potential lenders, such as banks, investors and vendors using the financial reporting contained therein to determine credit limits.

Ratios and indicators constitute the best way for analyzing financial statements. Such ratios are usually presented in a simplified way in order to make the financial statements easier to understand. More details about financial tools can be found in Brealey & Myers (1988) and Babusiaux (1990).

Evaluation criteria

Various financial criteria are proposed in the financial analysis report to assess water project feasibility and to

Table 5 | Example of reimbursement of loans timetable within EVAPRO.

Sponsor : CFD

Duration (years) : 20

Period of grace (years) : 8

Commitment fee rate (%) : 0.00

Interest rate : 5% constant

Reimbursement with constant annuity

Year	Principal	Interest	Capital left	Debt service
1999	0.00	1,580.00	68,800.00	1,580.00
2000	0.00	3,440.00	68,800.00	3,440.00
2001	0.00	3,440.00	68,800.00	3,440.00
2002	0.00	3,440.00	68,800.00	3,440.00
2003	0.00	3,440.00	68,800.00	3,440.00
2004	0.00	3,440.00	68,800.00	3,440.00
2005	0.00	3,440.00	68,800.00	3,440.00
2006	0.00	3,440.00	68,800.00	3,440.00
2007	4,322.39	3,440.00	64,477.61	7,762.39
2008	4,538.51	3,223.88	59,939.09	7,762.39
2009	4,765.44	2,996.96	55,173.66	7,762.39
2010	5,003.71	2,758.68	50,169.95	7,762.39
2011	5,253.90	2,508.50	44,916.05	7,762.39
2012	5,516.59	2,245.80	39,399.46	7,762.39
2013	5,792.42	1,969.97	33,607.04	7,762.39
2014	6,082.04	1,680.35	27,525.00	7,762.39
2015	6,386.14	1,376.25	21,138.86	7,762.39
2016	6,705.45	1,056.95	14,433.42	7,762.39
2017	7,040.72	721.67	7,392.70	7,762.39
2018	7,392.75	369.64	0.00	7,762.39

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Table 6 | Example of ratios and financial indicators.

Year	Unit economic cost		
2000	7.336		
2008	3.853		
2016	2.707		
2024	2.243		
2032	2.010		
Internal rate of return	10.48%		
Discount rate (%)	**10.00**	**12.00**	**15.00**
Total present cost	139,031.22	123,077.66	107,118.55
Cost per cubic metre	4.23	5.05	6.49
Total investment/m^3	2.73	3.49	4.86
Total expense/m^3	1.50	1.55	1.63
(Resources-expenses)/investment(%)	29.43	21.54	13.97

determine the best variant from several alternative projects on technical and economical grounds and also to evaluate or adjust the tariff policy used or to be used. To this end, EVAPRO offers a number of ratios, including working capital ratio (WCR), operating ratio, unit cost, marginal cost, total investment and total expense per cubic meter along with the total present cost. Other financial criteria include payback period, net present value, internal rate of return and benefit–cost ratio (Brealey & Myers 1988). Table 6 shows some ratios and financial indicators calculated by EVAPRO for a sample project. Three values of discount rate are used in the calculations for sensitivity analysis.

EXAMINATION OF ALTERNATIVES

Planners often find it helpful to look at how their project would fare under different scenarios. They may want, for example, to examine different scenarios of inflation, interest rates, tariff policies or different population or demand forecasts. EVAPRO enables them to look at different combinations of parameters. It is possible to make changes to the data and test different strategies easily and quickly.

A particular scenario for a proposed water supply project is examined. Calculations are made and a financial report is established. Changes can then be made to the initial data, leading to other scenarios. Different scenarios are compared according to the above-mentioned evaluation criteria. Non-competitive approaches are eliminated and the best alternative is then stated for implementation in the investment programme.

The software is intended for use in planning and design but may also be used for a current water supply project in order to control its progress. Thus EVAPRO can be used in two modes:

- Off-line: different project alternatives are evaluated and an option selected minimizing operating costs through optimal hydraulic pumping conditions.

- On-line: the software can be run continuously for a current project, updating when necessary with real-time data when deviations from forecast data are recorded, in financing data, population or demand forecasts for example, thereby giving warnings if deficits occur in supply. The manager should be able to take account of such situations and react to changing circumstances.

HARDWARE AND SOFTWARE REQUIREMENTS

As the use of a PC as the central fileserver is effective and inexpensive, no major hardware investment is necessary. The code implementing the software is written in the object-oriented language Visual C++ (Rumbaugh *et al.* 1991; Microsoft Corporation 1996) in a highly modular format so as to permit easy maintenance and upgrading of modules in the future.

The user interface makes the software usable by operators, not necessarily specialists or engineers, who may not be experts in computers, hydraulics or finance.

CONCLUSIONS

EVAPRO, a computer package, was developed to facilitate feasibility analysis of water supply projects under different operating policies and changes to initial system configuration.

Using demand forecast information and potential water resources, linear programming techniques are applied to find the best daily water sources operation for minimizing the cost of energy and chemicals. The software calculates water production and sales. If demand cannot be satisfied, the value of the deficit is also calculated.

The originality of EVAPRO resides in the fact that it combines supply optimization and financial analysis to assess the feasibility of water supply projects. EVAPRO can also be used to explore the effects of modifications to the project. It helps the planner assess whether the project is worthwhile and enables him to cope with uncertainty by examining the effect on the project of alternative combinations of parameters. It is also possible to measure project adaptability, i.e. the ease with which the system can be changed in response to unexpected developments.

EVAPRO also helps the manager to monitor projects in progress. When an investment decision is made, data and initial forecasts are constantly being modified and some parameters will be different from those projected. In such cases, the manager should be able to make decisions on expansion, contraction or even abandonment of a project. EVAPRO helps managers to take account of such situations when they evaluate a project and to react to changing circumstances.

In its current state, EVAPRO provides the user with a set of evaluation criteria which need to be submitted to expert judgment for decisions on how viable the project may be. A knowledge-based system can be developed using these criteria to produce an efficient decision support tool.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of ONEP (Office National de l'Eau Potable) in Morocco, especially Direction Pole Industriel.

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