16th WEDC Conference
Infrastructure for low-income communities
Hyderabad, India 1990

Appraisal and evaluation: A new approach

George Akosa, Peter Barker and Richard Franceys

The ex post monitoring of the performance of investment projects in developing countries is critical to evaluation of future programmes. This paper proposes that the performance of a group of projects in a programme area may be compared using objective measures of their ability to deliver outputs relative to their usage of inputs. To this end non parametric productive efficiency measures are calculated for a variety of alternative water supply and sanitation projects in Ghana. The aim is to rank the projects in terms of their productive or technological efficiency, so that conclusions about their relative efficiency in performance can be reached. As Cost-Benefit Analysis is a useful tool in the ex ante appraisal of projects so the technique used here, Data Envelope Analysis (D.E.A.) is a valuable aid to the ex post evaluation of projects in operation.

Data Envelope Analysis (D.E.A.) and Productive Efficiency

D.E.A. measures the technical efficiency of firms, processes or projects. Each project can be represented by a point on an isoquant diagram. An isoquant shows all the technically efficient combinations of inputs (X_1 and X_2) which will yield a particular output level. Efficiency between inputs and output is represented by an isoquant and the problem is to identify the efficient isoquant. In figure 1 TT is the efficient isoquant in the sense that no firms produce a unit of output using fewer inputs than firms located on the isoquant. All points to the right of the isoquant represent projects which require more of at least one input to produce a unit of output.

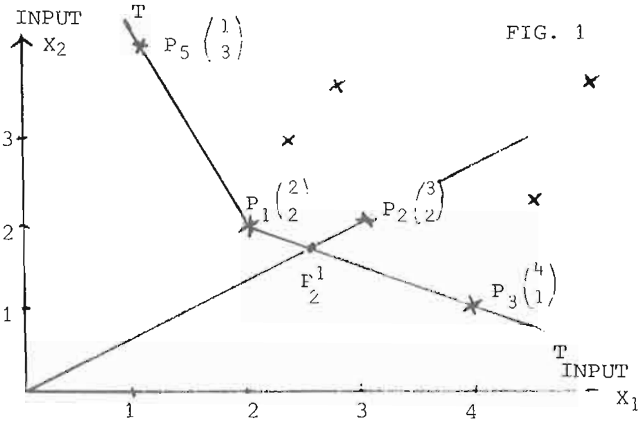

FIG. 1

P_2 has observed input requirements of 3 of X_1 and 2 of X_2 to produce one unit of output. P_2^1 uses the same ratio of inputs but is on the unit isoquant. This means P_2^1 would produce one unit of output producing less of each input. The ratio $OP_2^1/OP_2 < 1$ is a measure of the efficiency of the project P_2. The efficient processes P_5, P_1 and P_3 would score unity as they are efficient, located on the isoquant.

D.E.A. is employed to calculate the efficiency scores of projects which use several inputs and produce several outputs. Efficiency is defined as the ratio of the weighted sums of the outputs to the weighted sums of the inputs. For a project identified by the subscript 0, the efficiency score h_o is:

$$(1) \quad h_o = \sum_{r=1}^{s} U_r Y_{ro} \Big/ \sum_{i=1}^{m} V_i X_{io}$$

where,
- Y_{ro} = is the amount of the r^{th} output from project 0
- U_r = the weight given to the r^{th} output
- X_{io} = the amount of the i^{th} input used by project 0
- V_i = the weight given to the i^{th} input
- s = the number of outputs
- m = the number of inputs

The object is to find the set of non-negative output and input weights (U_r, V_i) which maximise h. Choice of the weights is limited by the constraint that when they are applied to each process the corresponding ratios cannot exceed unity. Thus (1) is maximised subject to:

$$\frac{\sum_{r=1}^{r=s} U_r Y_{ro}}{\sum_{i=1}^{i=m} V_i X_{io}} \leq 1 \qquad o = 1 \ldots n$$

$$U_r, V_i > 0$$

Software suitable for personal microcomputer use is available which will solve h for each project.

Description of Inputs and Outputs

Application of the D.E.A. technique requires identification of output attributes associated with each project or process. The ultimate goal of improved water supply and sanitation provision in developing countries is the capturing of health benefits, the freeing of time for productive and leisure uses and generally reducing the drudgery and toil of water collection which figures so prominently especially in the life of women.

Three desirable output attributes were considered in this study, reliability of service, utilization of service and convenience to the consumer.

Reliability Output Factor This is measured as the fraction of time that the facility is operational R.O.F. = 1 - System Down Time.

Utilization Output Factor For water projects this was taken to be the fraction of daily water use from the improved source. For Accra water utilization was measured by population coverage. For sanitation the fraction of compartments available for use was taken for the VIPs. In the case of Accra Sewerage the fraction of time the system was fully operational was recorded.

Convenience Output Factor This was determined by population density. Densities were associated with different standards of service.

Production of clean water without high levels of consumption will not capture health benefits. Direct measurement of health benefits and their monetary evaluation have proved extremely difficult in practice so this study postulated that a supply service characterised by reliability, high utilization and convenience to comsumers would encourage consumption and consequently capture health benefits. The problem is to determine the technologies that most effectively deliver the output attributes.

Experience indicates that the success or failure of water and sanitation projects is determined by an amalgam of technical, financial, economic, social, institutional and environmental factors.

Neglect of one or more inputs at either the appraisal or evaluation stages may commend inappropriate and inefficient technology. The D.E.A. technique requires identification of relevant inputs and the selection of indicators which best capture the significance of each identified input. In this study the following inputs were selected as appropriate.

Technical input It was decided that the best single factor reflecting the technical complexity and dependency of the project on the scarce input foreign exchange was the foreign exchange component expressed as a ratio of the total capital cost. Important determinants of this input score are the technological sophistication and the method of financing the project.

Financial input This factor attempts to measure the cost recovery aspect of the projects. Cost recovery is defined here as the ratio of the actual annual revenue collection to the annual full cost of delivery of the service. Full cost is calculated as the annualised cost of capital and operation and maintenance expenditures at the 15% discount rate over a 20 year project life. The financial input factor is measured by the deficit on full cost. For projects on which the served community bears all cost, the financial input is zero. Where the community contributes nothing the input fact is unity.

Economic input Calculation of this factor required the separation of foreign exchange and local components of capital and the apportionment of labour input into skilled and unskilled. By this means and with the use of appropriate shadow prices the variability of quality of inputs is taken into account. To arrive at the economic resource cost the scarce inputs are multiplied by the appropriate shadow price conversion factors. Again, the annual economic cost per person per annum was determined for each project.

Institutional input The great diversity of the type and sophistication of the project technologies made for considerable differences in the institutional support demands of the technologies. The institutional input was measured by the amount of skilled manpower employed full-time to operate and maintain the water supply or sanitation project. The number so obtained was increased proportionately to provide the equivalent number of skilled personnel for an assumed population of one million.

Social input Considerable evidence exists which suggests that a precondition of project success in the developing world is a substantial degree of community participation. The social factor aimed to measure such factors as the degree of community involvement in requesting the service, the level of service desired, commitment to continuance of use and ability and willingness to pay contributions to cost recovery. Together these factors represent the issues central to effective community participation. In this study community participation was split into elements of involvement. Elements recording negligible community involvement were scored one and high involvement zero. Summing element scores for each individual project yielded low scores for high community involvement and high scores for poor involvement.

Environmental input This factor measured the cost of elimination or reducing to acceptable levels any environmental problems associated with individual technologies. For the water supply projects the environmental problem considered was sullage disposal. The cost per person of effective disposal is the environmental input factor for water projects. For sanitation projects the environmental problem was associated with sludge disposal in the case of the K-VIPs and with final disposal of sewage in the case of the Central Accra Sewerage project.

Table 2 (appended) records the input and output factors calcualted as described above.

The D.E.A. Results and Interpretation

The computer solutions provided the following efficiency scores for the six water and four sanitation projects.

Table 1

Project	Efficiency Score
Accra + Tema Water	1.000
Borehole Water	.903
Package Plant Water	.978
2500 Drilled Wells	.530
3000 Drilled Wells	.223
Hand Dug Wells	1.000

Project	Efficiency Score
Central Accra Sewerage	.019
Urban K-VIP Latrines	.111
Rural K-VIP Latrines	.064
Traditional Pit Latrines	1.000

Of the water supply projects the most efficient are at the extremes of water supply technology. The technical sophistication of the Accra-Tema system absorbs large amounts of foreign exchange, skilled labour and institutional support. At present sullage disposal is inadequate and providing a satisfactory solution would impose a considerable environmental input cost. Some 60% of the total capital cost of this project was in foreign exchange. This is attributable to the mode of financing, by supplier's credits, and the complexity of the technology. Large urban water supply in Ghana necessarily requires a surface water source. Phase 1 of this project involved Volta River water 54 km to the west of Tema. The project required large capacity pumps, large diameter steel pipes plus other imported inputs. Moreover, the initial quality of raw water extracted meant that a full conventional treatment plant with consequent high foreign exchange requirements had to be provided.

However, the very high degree of reliability (97%) and utilization (80%) accorded the project top efficiency rating. The high level of utilization is attributable to the concentration of stand-pipes and the lack of alternatives, most traditional sources now being polluted or unavailable.

In technical contrast hand dug wells were equally efficient. This technology required modest levels of foreign exchange and no skilled labour. The foreign cost component of the well was only 25% but 90% of the handpump. The project had a high degree of community participation. More than 90% of all operation and maintenance plans were met on this project. In addition the project had no adverse environmental impact. Hand dug wells scored particularly on reliability (98% availability). Examination of the records showed that only 25 days of pump downtime occurred in 3 years. Even then water was available to the community by the simple expedient of a hatch, rope and bucket.

The 2500 Drilled Wells and 3000 Wells programmes fared less well, with efficiency ratings of .530 and .223 respectively. Both of these projects had considerable foreign exchange requirements and both used relatively little of abundant unskilled labour. In both projects the degrees of community participation were modest. The 3000 Wells project scored only .4 on reliability. By December 1988 only 40% were operating, moreover water quality problems have caused widespread rejection of well water and accounts for the low utilization score. Cost recovery has been poor as consumers have refused to pay for a low quality service from a scheme that was basically imposed upon them.

The weakness of the 2500 Wells programme has (5.0). The sparsity of the northern population means that in the rainy season traditional sources are nearer than the wells and people's perceptions of the health benefits are not strong enough to overcome the inconvenience of more distant location.

Of the sanitation systems the Accra Sewerage project is by far the most technically sophisticated but has a poor efficiency score (.019). Though the project scores well on reliability (.90) and convenience (200) the poor connection record means utilization is low (.20). For this sewered solution consumers were expected to provide their own internal plumbing and to pay the substantial connection cost. For the poor this has proved too much of a financial burden. Furthermore, the perception of benefits of improved sanitation is minimal among the affected population. Improvement of the connection rate would improve the poor utilization rate and a more adequate revenue collection system would improve the financial recovery which currently is only 12%. As a sanitation solution for a developing country the sewered system represents a high cost, inefficient solution.

The urban Kumasi type VIP is a community based system, it embodies relatively simple technology and is a non-sewered solution. Correctly operated and maintained such systems are capable of capturing the health benefits of much more technically complex solutions.

The efficiency rating of this project has been reduced by the modest utilization score (30%) which is mainly due to lack of capacity at peak times and the deterrent of recently introduced charges. Public health education would encourage higher usage if sufficient capacity could be installed.

The traditional pit latrine's technical simplicity allows it to be wholly provided by the served community and operated without external assistance. Together with use of local materials and labour this technology represents the most efficient sanitation system especially for populations who put little weight on aesthetics or privacy.

Table 2

	INPUT FACTORS						OUTPUT FACTORS		
PROJECT	Technical	Financial	Economic	Institu-tional	Social	Environ-mental	Relia-bility	Utiliz-ation	Convenience
Accra-Tema Water	0.60	0.73	2.43	479	6	2.0	0.97	0.80	150
Borehole Water	0.65	0.95	2.20	450	6	0	0.78	0.50	80
Package Plant Water	0.60	0.97	4.56	1000	7	0	0.33	0.40	80
2500 Drilled Wells	0.72	0.95	1.97	72	5	0	0.85	0.40	5
3000 Drilled Wells	0.84	0.99	4.42	66	6	0	0.40	0.30	70
Hand Dug Well	0.44	0.54	0.93	0	0	0	0.98	0.90	60
Central Accra Sewerage	0.46	0.38	77.60	1150	8	3.3	0.90	0.20	200
Urban K-VIP Lat.	0.50	0.31	6.77	0	2	1.0	0.90	0.30	100
Rural K-VIP Lat.	0.50	0.22	8.15	0	3	1.0	0.90	0.10	70
Traditional Pit Latrine	0	0	0.45	0	0	0	0.90	0.44	60