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National water policy: a methodology and its application to Israel

U, SHAMIR, J. BEAR
Department of Civil Engineering, Technion - Israel Institute of Technology, Haifa 32000, Israel
N. ARAD
Ministry for Energy and Infrastructure, Jerusalem, Israel
Y. GAL-NOOR
The Hebrew University of Jerusalem, Jerusalem 91904, Israel
N. SELBST
The Water Commission, Ministry of Agriculture, PO Box 7043, Tel Aviv, Israel
Y. VARDI
TAHAL - Water Planning for Israel Ltd, PO Box 11170, Tel Aviv 61111, Israel

ABSTRACT A methodology for formulating and analysing policies of water resource management in the public sector is presented. It has been developed and implemented to analyse alternative water policies for Israel.

Politique nationale pour la gestion des eaux: une méthodologie et son application à Israel

RESUME On présente une méthodologie pour formuler et analyser les politiques de gestion des ressources en eau dans le secteur public. Elle a été raise au point et raise en oeuvre pour analyser différentes politiques de gestion des eaux en Israel.

INTRODUCTION

The authors, who are from universities, agencies, and companies in the public and private sectors, combined to form a team to carry out a study of water policy for Israel. Sponsored in part by the Water Commissioner, the study has been conducted, over a period of four years, at the Neaman Institute, whose objective is to aid decision-making in areas of national importance. The purpose of the study has been to evolve a methodology for policy analysis in the public sector, and to apply it to water policy for Israel.

In this paper we report on the methodology and illustrate some of the applications. Let us begin with some background about Israel's water sector.

Israel's water resources are almost fully developed and utilized. Consumers exert pressure to use more from the existing sources, and to develop marginal and more expensive sources. There is competition between the users in the different sectors and in different parts of the country for the limited resources. As a result there are a number of major issues facing decision-makers in Israel's water sector. Among them:

- Extraction from the major aquifers exceeds in certain places the average annual replenishment, potentially endangering long range supplies.
- Water quality of the sources is endangered by the high level of utilization, as well as by human activities.
- Production and transport of water from the sources to consumers is energy intensive and expensive.
- Development of the few remaining sources is difficult and expensive.
- Reclaimed sewage is the main source for additional supply to agriculture, replacing some of the potable water that has to be diverted to the cities. This may cause health, water quality and environmental problems.
- Competition for the water, between the sectors and regions, necessitates an allocation and pricing policy that may be contentious and difficult to administer.
- Budgets are very limited, and even the needs of maintenance cannot be met without considerable difficulty.
- The legal and institutional structure of the water sector must adapt to changing conditions. It was set up when development of the sources and delivery systems were the main issues, and must now cope with issues resulting from scarcity and competition.

Some aspects of the above issues and problems may be dealt with at the technical level, combining considerations of hydrology, engineering and costing. The broader issues, however, are matters of policy, which entail considerations beyond the mere techno-economic. The study reported herein was aimed at these policy issues.

A policy study must call upon many sciences to form the basis for decision-making: hydrology of surface and ground waters, water quality technology, environmental evaluations, engineering economics, agricultural planning and economics, social, institutional and political sciences. Many people have been involved, in one way or another, in the study - research assistants, experts, interest groups, decision-makers. We conducted much of our work in the public arena, through dissemination of documents, workshops, interviews and group discussions, and enjoyed an open dialogue with the Water Commissioner, who is the foremost decision-maker.

A METHODOLOGY FOR POLICY ANALYSIS

A policy may be defined as a set of "rules of conduct", rules that provide guidelines according to which more specific decisions are to be made. We are concerned here with the policy for managing a scare resource, in the public sector. The methodology which we have evolved for water policy may also be applicable to other similar policy areas.

The analysts' aim is to identify a range of alternative policies, analyse them, and present the results in ways which aid decision-making. In so doing, the analysts should strive to admit the full range of alternatives, without imposing their own bias. They should present the results of the analysis in an objective form, leaving the value judgements to the decision-makers.

This philosophy has led us to adopt a methodology, shown in the flow chart of Fig. l, whose components are:

(1) *Definition of the* *<u>system</u>* *and its division (if necessary) into* *<u>subsystems</u>*. The "system" is defined as that part of the world which is completely or primarily within the responsibility of the particular decision-makers who are being served by the study. Thus, in Israel's water sector, the law and government organization determine quite uniquely which areas of policy are under the jurisdiction of the Water Commissioner, which are outside his control, and in which he has some partial role. A typical question relating to the definition of the water system, in Israel and also elsewhere, regards the responsibility for water quality and setting water quality standards. For potable water, quality standards are set by the health authorities, and so are "outside" the water system. On the other hand, designation of waters of different qualities to various locations and crops is largely decided by the Water Commissioner, and is therefore "inside" the water system.

(2) *Identification of the* *<u>boundaries</u>* *with other systems, and the "<u>boundary conditions</u>" with them.* The boundary conditions are those elements determined by adjacent systems - such as public health,

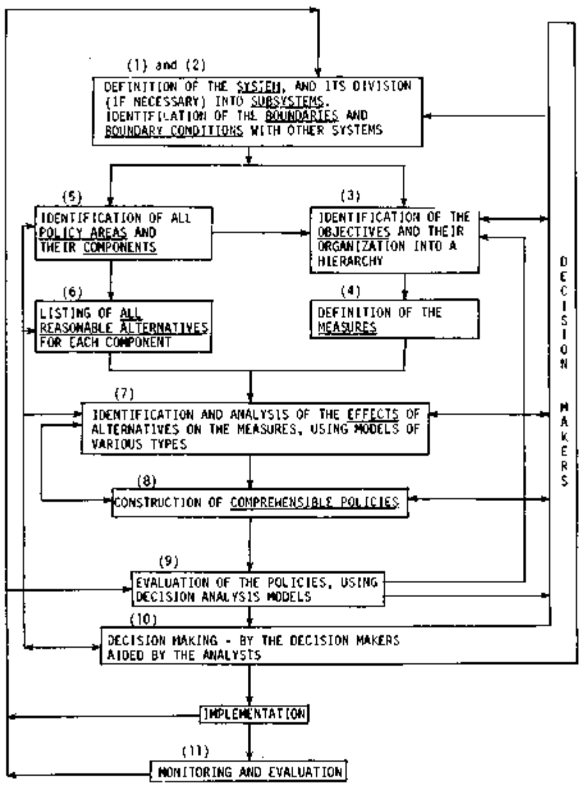

FIG.1 The methodology for policy evaluation and decision-making.

agriculture, urban planning - which the water system has to accept as given, even if it is involved in some way in setting them.

(3) *Identification of the system's objectives, and their organization into a hierarchy.* We use the definition proposed by Keeney & Raiffa (1976): "An objective generally indicates a "direction" in which we should strive to better". (According to their definitions, "goal" is a level of achievement of the objective. We shall not use this term.)

The objectives of the system are to be determined by the decision-makers, since definition of the objectives is a value judgement, which is the prerogative of the decision-makers. The analysts can be of considerable help in the identification process, but they should be careful not to sway it according to their own bias. Advocacy by professionals is not ruled out as a general principle. However, while they act as analysts of policies, professionals should maintain objectivity. This is especially true for a team of analysts, like ours, in which members do not necessarily hold identical views.

Objectives are organized into a hierarchy, from the general at the top to the specific at the bottom. The structure of the hierarchy is revealed as follows. Asking *why* have an objective leads to the objectives above it in the hierarchy; asking *how* to achieve an objective leads to the ones below it, which detail it more specifically.

(4) *Definition of the measures by which the attainment of these objectives is to be evaluated.* "Measures" are what Keeney & Raiffa (1976) have called "attributes". These are quantities which can be computed, or at least defined quite precisely in verbal terms, which indicate to what degree an objective has been achieved.

(5) *Identification of all the policy areas, and for each all of its components.* A "policy area" is made of a group of interrelated "components", each of which is an issue on which a decision is to be made. Examples of an area are: water quality, development of the physical system, water pricing.

(6) *Identification of all "reasonable" alternatives for each component.* "Reasonable" alternatives might be defined as all those which have proponents. The analysts should exercise caution not to eliminate any legitimate alternative from consideration, because if they do, they might affect the outcome decisively, by their own bias.

(7) *Identification and analysis of the effects of each alternative on all of the measures.* Effects are assessed with models - mathematical models as well as "softer" verbal ones, for those areas in which no computation is possible. The models are used to determine the effects on all measures of each possible decision (alternative) for each component. It is often possible to do this analysis only after comprehensive policies for an area or a group of areas (see 8 and 9 below) has been formulated, because of the interactions of decisions on different components.

(8) *Construction of comprehensive policies, for one policy area, for a group of areas, or for all of the areas, by selecting one alternative for each component.* Construction of comprehensive policies must obviously consider consistency in decisions for different components, so that the whole policy has some internal logic. The total number of possible combinations of alternatives for all components is obviously much too large to consider. A reasonable number of alternative policies for examination would be, say, under 10.

(9) *Evaluation of these comprehensive policies according to their effects on the measures, and thus on the objectives.* At this stage decision analysis are used. They aid in selecting that alternative which is "best" with respect to *all* the objectives together. Such a decision is called "the best compromise" rather than "optimal", because "optimal" can be defined uniquely only when there is a single objective. In a later section we shall present the specific multiobjective decision-making method we have used.

(10) *Interaction with the decision-makers, with interest groups, with experts, throughout the above activities, to aid in decision-making.* The whole process described above is conducted with feedback and feed-forward loops in every possible direction. It is not a "linear" process, and is to be conducted continuously, all the while aimed at "producing" decision outcomes.

(11) *Monitoring and evaluation of changing conditions and of the effectiveness of implemented policies must be performed continuously, to report to the decision-makers and to feedback into all phases of the analysis.*

ALTERNATIVE WATER POLICIES FOR ISRAEL

In the limited space allowed here we can only sketch out the application of the methodology of water policy in Israel, with a few examples of some details.

Twelve policy areas have been identified, organized into four sub-systems:

Supply: production and delivery

- Development of the hydraulic transmission and distribution systems;
- level of extraction from the sources and operation of the main reservoirs (Lake Kinneret and the two main aquifers);
- desalination of sea water;
- water quality in the sources and in the central transmission and distribution systems;
- use of water sources and systems common with neighbouring countries;
- operation and maintenance of the hydraulic systems;
- energy management in design and operation.

Demand

- Pricing (primarily for agriculture);
- allocations (primarily for agriculture);
- demand management.

Research , development and demonstration

(a single area).

Legal basis and administrative structure of the water sector

(a single area).

Objectives

Figure 2 shows a hierarchy of objectives for Israel's water sector. As already stated above, this is a version of the objectives which was generated at one point in our study, and may not reflect the present decision-makers' views. It is presented here for purposes of illustration, and should be viewed as a *possible* set of objectives.

At the top are the global national objectives. They are so general as to be universally accepted, but not really operational. It is only at the next level, when objectives are more specific and conflicting, that they also begin to be operational. For example, the statement that it is necessary to supply *all* the water for domestic use, for industries which are not water intensive, and for carrying out national settlement plans, is an operational objective. Other objectives at this same level, for example "To supply water for economic activities" and "To provide water for nature conservation and recreation", are competing, and it is only at the decision-making phase that their relative importance will emerge.

The most important level in the hierarchy is thus the intermediate one. Here opinions vary, interests conflict, and professional controversies abound. Definition of the objectives is difficult, since setting them down, choosing the exact wording, and positioning them in the hierarchy, are the first determinants of the final outcomes.

It is therefore not surprising that the objectives listed in Fig. 2 are the result of many iterations. And even so, they should be viewed merely as a working draft, valid only until the next round of considerations.

Measures

Listed below are only the "global" measures, i.e. those which are relevant to all policy areas and objectives. In certain cases we also need "local" measures, ones which are specific to one particular policy area, which will not be listed here. The measures are:

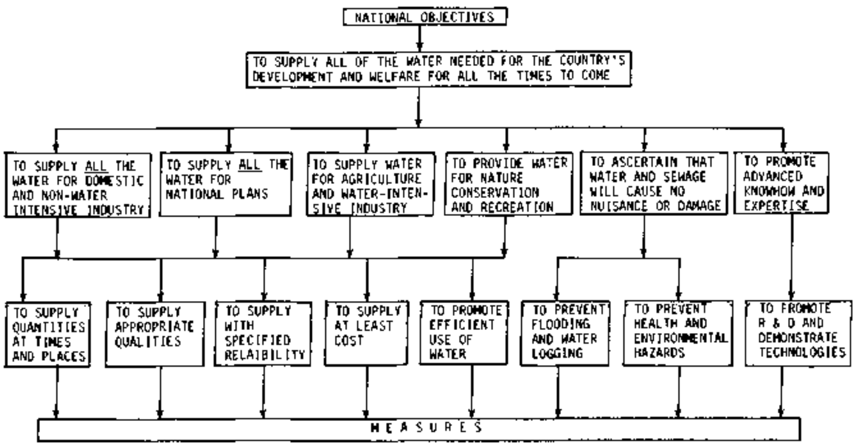

FIG.2 Hierarchy of objectives for Israel's water sector.

(a) Conservation of the sources: the amount of water which will be in the sources in the target year (2000 was selected).

(b) Conservation of the sources: the quality (possibly a vector of several parameters) which will be in the sources in the target year (2000).

(c) Contribution (of the policy) to increasing production of water from all the sources (computed as the total over the planning horizon, to 2000).

(d) Investments over the planning horizon, to the target year (2000).

(e) Cost per unit of water.

(f) Reliability of the supply.

(g) The amount of water actually consumed by the domestic and non water-intensive industry (which can be affected, for example, by pricing and conservation).

(h) Consumption in agriculture and water intensity industry.

(i) Complexity of the control and supervision necessary to execute the policy (a measure of the practicality of the policy).

(j) Professional capability (a measure of the ability to continue operating effectively in the farther future).

(k) Environmental effects: a list of specific parameters, or a combined index.

(l) Public health effects: a list of specific parameters, or a combined index.

(m) Subsidy: the annual expenditure for subsidizing water prices to certain sectors, and the source of the funds.

(n) Equity: a measure of the equity of the policy, between different users and regions.

(o) Energy: total consumption by the water sector, its temporal distribution (daily, annual), effects on capacity expansion of the generation.

(p) Agricultural production and/or exports.

(q) Profitability of agriculture: by crop, region and settlement type.

(r) Distribution of income in agriculture, among regions and settlement types.

This list is quite long, and may even have to be expanded to accommodate more than one value in certain measures (which are really vectors). It turns out, however, that for most of the decision-making situations the number of relevant measures is considerably smaller. We have worked with at most nine measures at once. Even this number might be too large for use in decision-making sessions, and the method of analysis should aid in reducing the number of measures which must be considered at any one time to no more than, say, five or six.

To demonstrate the definition of components and alternatives, consider the area of pricing of water for agriculture. The present policy is based on the following elements:

(a) ceiling prices for water supplied to various consumer sectors;

(b) levies on low-cost water;

(c) Water Prices Adjustment Fund, financed by government subsidy and levies on low-cost water to cover the deficit of high-cost water.

The components of water pricing policy, and their alternatives, are:

COMPONENT 1: Pricing Principle

Alternative 1.1: Ceiling prices on all waters supplied (possibly specific to each sector).

Alternative 1.2: Ceiling prices in specified regions only.

Alternative 1.3: Uniform national prices (specific to each sector).

Alternative 1.4: Prices equal to the cost of supply (with administrative allocations through the licensing system).

Alternative 1.5: Price determined by market forces.

COMPONENT 2: Amortisation as a component in water costs

Alternative 2.1: Will be computed using the present worth of historical investments.

- 2.1.1: On all investments, including those considered to be part of the basic infrastructure.
- 2.1.2: Excluding investments considered to be part of the basic infrastructure.

Alternative 2.2: Will be computed using the historical (nominal) value of the investments.

- 2.2.1 and 2.2.2: same as 2.1.1 and 2.1.2 above.

COMPONENT 3: Interest rate used to compute water costs

Alternative 3.1: The true (social) interest rate will be used.

Alternative 3.2: The interest rate actually paid on water works (which implies a financing subsidy) will be used.

COMPONENT 4: Financing of deficits in sustems where prices do not cover costs

Alternative 4.1: Source of funding - levy on low-cost water and government subsidy.

Alternative 4.2: Source of funding - government subsidy only.

We can now construct several alternative pricing policies, by combining alternatives of the four components. If we assume that alternative 1.5, that of allowing prices for water in agriculture by market forces, is, for the time being at least, unacceptable, we are left with four possible pricing principles. Each of these could be compatible with any of the four alternative methods for calculating amortisation and the two methods of interest calculation. The financing of deficits is relevant only to alternatives 1.1 to 1.3, since the other two do not incur deficits. Four alternative policies are:

PP1: Present policy

1.1: Ceiling price on all waters.
2.1.1: Amortisation computed on historical value of all investments (including infrastructure).
3.2: Actual interest rate used in cost calculation.
4.1: Deficits financed by levies and government subsides.

PP2: Ceiling prices in selected regions

1.2 Ceiling prices in selected regions.
2.1.1: As above.
3.2: As above.
4.1: As above.

PP3: Uniform national prices

1.3: Uniform national prices.
2.1.1: As above.
3.2: As above.
4.1: Deficits financed by government subsidies.

PP4: Prices equal cost of supply

1.4: Prices equal cost of supply.
2.1.2: Amortisation calculated on current value of all investments excluding those considered infrastructure.
3.1: True social interest rate used.
4: Not relevant.

Policy alternatives for the other areas are constructed in a similar fashion, and then combined into comprehensive alternatives for a group of areas. Analysis of the consequences of each alternative ensues. For example, we identified several alternative policies of pricing and allocations - two policy areas closely related - and then analysed the effect they would have on agriculture. To do this we employed a linear programming model of agriculture in Israel, in which regions, settlement types, and crops are modelled. The objective is maximization of agricultural output, and the model predicts the response to allocations and prices of water, which appear in the constraints and objective function of the model. The results of the linear programming runs, each under a different policy of allocations and pricing, is converted into the values of the relevant measures (e.g. water use, agricultural output, export, income distribution, etc.).

Similarly, groundwater models were used to compute the consequences of various development and pumping policies, in terms of the relevant measures. In other areas, for example the institutional structure of the water sector, the consequences of alternative policies are evaluated without use of mathematical models, and the results of the analysis is stated in words.

The decision-making process

Once the analysis of alternative policies has resulted in values of the measures for each, the alternatives and their consequences are used as data in the decision-making process. During this process alternatives are modified and refined, objectives are re-formulated, and measures re-defined - all of this being an essential part of the overall process of aiding the decision-making.

Selecting a preferred alternative is a multiattribute decision. We have chosen Saaty's method (Saaty, 1980). for this purpose. It has three steps:

1. Decision-makers state relative preferences among the attributes (measures, in our case).

2. Analysts evaluate the consequences of the alternatives with respect to each of the measures (as already explained above), and together with the decision-makers assess the performance of the alternatives with respect to each measure separately. (By "performance" we mean not only the outcome in physical, economic, or other terms, but how "well" the alternatives perform with respect to the measure under consideration, an evaluation that has both

objective and subjective elements.)

3. Results of the first two steps are combined to yield the ranking of the alternatives with respect to all measures together.

The comparisons in steps 1 and 2 are performed pair-wise, for all pairs of items (measures in 1, and alternatives in 2). Thus, for N items in the list, N*(N - l)/2 comparisons must be made (e.g. 10 comparisons for five items). The comparisons are made by assigning a value of $A_{i,j}$ when comparing item i to item j, using the following scale:

$A_{i,j}$	*Meaning*
1	i is equal to j
3	i is somewhat superior to j
5	i is superior to j
7	i is much superior to j
9	i dominates j

Intermediate values (2, 4, or even fractional numbers such as 2.5, etc.) can be used to refine the scale, if necessary. Reciprocals (e.g. 1/5) are used when j is superior to i. This scale essentially replaces words, and has been found to be convenient for use by individuals and groups who have had no previous experience with decision models or mathematics. When comparing objectives or measures, "superior" above should be understood as "important". When comparing alternatives it means "better" with respect to the objective or measure being considered.

All pair-wise comparisons are performed, thereby providing more data than would be sufficient to compute the relative weights. This information used is to compute measures of consistency in the comparisons, and these provide a check for errors and point to comparisons which may have to be reconsidered.

The mathematics of computing relative weights of the items of a list is beyond this presentation. Suffice it to say that it is easy to implement on any microcomputer, even on a large programmable calculator. Weights are computed first for the measures, then for the alternatives with respect to each measure separately, and finally these are all combined to yield the relative weights of the alternative with respect to all measures combined. These weights constitute the ranking of the alternatives: the one with the highest weight is best, and so on.

We have found that this decision-making model has a profound impact on the decision-making process. It forces all participants to be specific and precise in their definitions and preferences. Its "language" is concise, yet practical, and makes the discussion more effective than otherwise possible. It is simple, and does not "hide" anything behind a screen of complicated mathematics. It is very easy to explain the final ranking, i.e. the sources of strength and/or weakness of each alternative. It is so easy to re-run, that the whole process can be repeated several times in a single session.

We are fully aware of the theoretical shortcomings of the model, yet believe that it - or a similar type model - is very useful in practice, in situations where the decision-making process involves many actors, experts, interest groups, and officials who are the ultimate decision-makers.

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