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HOW SYSTEMS ANALYSTS CAN PROVIDE MORE EFFECTIVE ASSISTANCE TO THE POLICY MAKER

Kenneth R. Hammond
J. Kenneth Klitz
Richard L. Cook

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Preface

As stated in its charter, IIASA shall initiate and support research in relation to problems of modern societies arising from scientific and technological development. According to the aspirations of the founders of IIASA and the National Member Organizations (NMO), IIASA is expected to focus on real problems of interest to our NMOs and to be in regular contact with decision and policy makers in order to get a better understanding about the problems faced by them and to try to provide them with guidance or help for decision making.

In an attempt to be better prepared to meet the expectations of its NMOs, IIASA has intensified its interactions with policy or decision makers. This research paper is an attempt to describe and improve the tools for decision making in order to facilitate the interaction between the decision maker and his scientific advisers.

Abstract

Policy makers do not benefit from advances in a) systems analysis or b) judgment and decision theory because neither of these disciplines recognize the incompleteness of its methodology. A complete methodology requires a synthesis of the two. This Research Memorandum explains why such a synthesis is necessary, describes how it can be achieved, and provides a worked-out example of its application to the problem of changing sources of energy production in the US. The example also illustrates that the linkage of systems analysis and judgment theory provides information that neither discipline can provide separately. Finally, the Research Memorandum shows that such information is policy-relevant and that it provides more effective assistance to the policy maker than does either approach used separately.

Acknowledgments

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How Systems Analysts Can Provide More Effective Assistance to the Policy Maker

". . .both organism and environment will have to be seen as systems, each with properties of its own. . . ."
Egon Brunswik
(1900-1955)

The uncertain interdependence of large numbers of difficult-to-measure variables in the socio-physical systems of the world places extraordinary demands on the cognitive capacities of policy makers. Indeed, more and more people are coming to believe that expanding and confusing interdependence within and among such problems as energy development and use, food distribution, and population growth has already put solutions beyond the capacity of human problem-solving abilities. The pressing need for solutions to these and similar problems, and the decreasing optimism regarding the likelihood of finding solutions, is reflected in the virtually continuous series of scientific symposia and intergovernmental meetings directed toward coping with these problems.

Two groups of researchers, whom we shall identify roughly as <u>systems analysts</u> and <u>judgment analysts</u>, have decided that the solutions to these problems are indeed beyond the <u>unaided</u> cognitive capacities of mankind. As a result, they have directed their efforts toward providing <u>decision aids</u> for policy makers [1]. Despite the rapid production of a large scientific literature supporting their contention that scientifically respectable and practically useful decision aids can now be provided for policy makers [2] [3], neither group has been conspicuously successful in convincing policy makers that decision aids are useful. Indeed, success stories of the practical benefits of either research group are so few, and complaints about the failure of both types of models are so common, that a well-known systems analyst (Watt) has written a guest editorial for Simulation plaintively entitled, "Why won't anyone believe us?" [4].

We believe that this situation should be, and can be, remedied. Since both groups of researchers have developed decision aids that policy makers can use now to their considerable advantage, and to the advantage of those who must live with the policies that policy makers produce, they should be used. The purpose of this Research Memorandum, therefore, is, first, to provide a diagnosis of the present situation, that is, to indicate why policy makers have not widely accepted the value of systems analysis or judgment and decision analysis, second, to describe a remedy for this situation, and third, to provide an example of the remedy that is advocated here.

Diagnosis

The main reason for the lack of success of both groups is that the methodology employed by each group is incomplete. Incompleteness is due to:

1. systems analysts devoting themselves to the development of analytical models of external systems, that is, systems that exist outside of persons (for example, energy systems, ecological systems, etc.) while ignoring (or treating amateurishly) internal systems, that is, systems that exist within persons (for example, the cognitive systems of the users of such models) and

2. judgment and decision analysts devoting themselves to developing analytical models of internal (cognitive) systems, while ignoring (or treating amateurishly) the external systems to which such cognitive systems are to be applied.

Unfortunately, the gulf between these two groups of researchers is wide; neither group has acknowledged the potential contribution of the other. Systems analysts who study external systems ignore the potential contribution to policy formation of those who study internal systems. Those who study internal systems ignore the potential contribution of those who study external systems. Indeed, each group is largely ignorant (and when not ignorant, often skeptical) of the work done by the other group. External-systems analysts, for example are usually ignorant of the fact that internal-systems analysts construct and test under controlled conditions quantitative models of judgment and decision processes (an opportunity seldom available to external-systems analysts). Many external-systems analysts will be surprised to learn that the same general approach they use (linking input conditions to output conditions by means of quantitative expressions) is also used by researchers (mainly psychologists) who create and test models of internal cognitive systems.

Even when external-systems analysts do learn (almost invariably by personal contact, not by reading the literature) that scientific work of this kind has been going on for 20 to 30 years, they greet the idea of internal-systems analysis with unhealthy skepticism and adopt a do-it-yourself approach. Consequently, external-systems analysts frequently become amateur psychologists and re-invent explanations of human behavior long ago tested and abandoned as false--hardly a desirable circumstance, for either the scientific or policy making communities. Instances of this sort may be seen in the naive faith exhibited by external-systems analysts when they assume that the policy maker is capable of coping with the information produced by models of external systems. Largely ignorant of all the work that has been done on information processing, external-systems analysts are apt to believe that all that is required in order to persuade the policy maker to use the results of their work is "better communication," meaning more and better graphs and evermore simplified explanations.

The incomplete methodology of internal-systems analysts provides a mirror-image of the incompleteness of the methodology of the external-systems analysts. The internal-systems analysts ordinarily know almost nothing about the techniques employed by external-systems analysts. And when internal-systems analysts do learn (usually from personal contact, not by reading the literature) about the work of their counterparts, they are apt to greet the idea of external-systems analysis with skepticism. Indeed, knowledge of the fact that their (internal) models can be tested empirically under controlled conditions, whereas external models generally cannot, is apt to lead internal-systems analysts to take a holier-than-thou attitude toward the external-systems analyst. On the other hand, since many, if not most, external-systems analysts are trained in mathematics and physical sciences, they are apt to take a holier-than-thou attitude to what they mistakenly consider to be a "soft" approach to an insurmountable problem. "Don't try to quantify the unquantifiable" is the advice an internal-systems analyst often hears from his counterpart.

And just as external-systems analysts become amateur psychologists as a result of ignoring scientific psychology, internal-systems analysts become amateur external-systems analysts. Internal-systems analysts must use representations of the outside world, that is, external systems, in their research, but in order to make their research task more manageable, internal-systems analysts use such oversimplified representations of the outside world, mainly because they ignore the uncertain interdependencies among variables, that the results of their work are often irrelevant to the problem of policy formation.

One of the worst results of the gulf between the two groups of systems analysts is that no formal means have been developed to integrate the information each type of systems analyst provides. Without a formal mechanism for integrating this information, the policy maker must--somehow--integrate that information himself. To do that he must use his cognitive abilities as well as he can to integrate information developed by researchers working independently of one another, and with little regard for the compatibility of the data produced by each group. As will be shown in detail below, achieving such a linkage is difficult enough even when plans for matching the data have been made in advance; attempting to integrate incompatible data by intuitive means after the fact is a hopeless task.

How can this patently undesirable state of affairs be remedied?

Remedy and Example

Both groups of systems analysts should realize that their activities are complementary, and they should develop research teams that build on their complementary efforts. More specifically, a complete methodology should be developed to replace the incomplete methodologies used at present. Our example illustrates both points. We proceed by indicating:

°first, what the task of the internal-systems analyst is,

°second, what the task of the external-systems analyst is,

°third, what the task of the policy consultant is.

The latter role is a new one; the task for the policy consultant is to link, analytically (not intuitively), the information produced by both types of systems analysts, and thus to display the integrated information to the policy maker in a manner that allows him to interact with it in a controlled, explicit manner. Unless this function is deliberately and specifically assigned to someone knowledgeable in both areas of systems analysis, or to a team made up of both types of systems analysts (as in the present study), the policy maker will be left to his own efforts to integrate this information. And because he usually is left to his own resources, it is hardly surprising to find that policy makers do not attempt that which is unfamiliar and difficult, but return to what is familiar and easy, namely, doing what they have always done. In short, it is not a question of policy makers not "believing" systems analysts, as Watt would have it, but a matter of policy makers being incapable of coping with the information provided by systems analysts of either type. Better graphs and simpler illustrations will not help policy makers integrate information.

Linking the information produced by both types of systems analysts is a task that neither group can afford to ignore. For unless the linkage is carried out by scientific/technical means, and in a professionally responsible way, the efforts of the systems analysts and the policy makers will be less than adequate, if not altogether wasted.

In order to make clear the remedy we advocate, we present the logic of the method in the context of an example. Three hypothetical policy makers with different (internal) social value systems were created to use the information provided by a complex (external) model (COAL 1) of the U. S. energy demand system. COAL 1 was constructed by Roger Naill at Dartmouth and is similar in its general form to the Meadows-Forrester type of world model [5]. Hypothetical, rather than real, policy makers were employed in order to simplify the example; COAL 1 was used because it is a highly complex external model, and thus illustrates the point that the method is not restricted to the simpler model used in the first linkage of external and internal models [6].

The tasks of the internal-systems analyst, the external-systems analyst, and the policy consultant are described in relation to the problem of deciding which interventions should be made in the U. S. socio-physical system in order to avoid or reduce aversive conditions regarding sources of energy in the U. S.

The Task for the Internal-Systems Analyst

The primary task for the internal-systems analyst is to discover and to externalize the policy maker's judgment policy with regard to the future conditions he wishes to achieve and the present interventions by which he would like to achieve them. Each of the terms emphasized above is described below.

1. Externalize: This term indicates that the internal-systems analyst attempts to derive an explicit, quantitative description of the policy maker's cognitive system by which he integrates information into

a judgment of preference. Thus, what was formerly an internal (and thus mysterious), implicit, covert cognitive system, becomes an external overt system described in quantitative terms.

2. Policy: This term refers to the parameters of the quantitative expression that describes the policy maker's judgment system. Such parameters include weights, the forms of the functional relations between each policy variable and the policy maker's judgment of preference, as well as the method of aggregating information regarding these variables, and the consistency with which the judgments are made. In the present case, each policy maker's judgment policy will be described by means of an (internal) mathematical model of the form

$$J = w_1x_1 + w_2x_2 + \dots w_nx_n$$

in which the x's refer to the variables in a given policy and the w's refer to the weight or relative importance of each variable. (Note: internal models need not be restricted to the weighted sum expression indicated here; further information regarding such models may be found in [7].)

3. Future conditions: Nearly all models of external systems are time-dependent contingency models. That is, they provide "what if. . ." information regarding the future conditions that will result from various actions that might be taken in the present. It is the internal-systems analyst's task to externalize the policy maker's judgment policy with regard to the future conditions he wishes to achieve. It is essential to note that it is not sufficient merely to know which specific conditions the policy maker wishes to achieve; the policy maker's judgment policy regarding all relevant future conditions must be determined. It is as necessary to have a quantitative model of the policy maker's (internal)

judgment policy regarding future conditions as it is to have a quantitative model of the (external) mechanisms that produce those future conditions. For it is a judgment policy that will evaluate any set of future conditions. Unless that judgment policy is known and described in quantitative form, its parameters and functions will remain elusive; and, therefore, one critical aspect of the policy formation process will remain unknown.

4. Present interventions: Just as it is the internal-systems analyst's task to develop a quantitative model of the policy maker's judgment policy regarding future conditions, it is also the internal-systems analyst's task to develop a quantitative model of the policy maker's judgment policy regarding present interventions--those actions the policy maker might wish to take in order to bring about specific future conditions. And, as in the above case, it is essential to note that it is not sufficient merely to know which specific interventions the policy maker wishes to employ; a quantitative model of the policy maker's judgment policy (as defined above) regarding interventions must be constructed. For without such a model the reasons for the policy maker's preference judgments for any specific set of interventions would remain unknown, and thus a second aspect of the policy formation process would remain unknown.

To summarize: it is the task of the internal-systems analyst to construct a model of the policy maker's judgment processes regarding future conditions and present interventions. The construction of such cognitive models provides general quantitative expressions that permit the internal-systems analyst to predict the preference judgments of a policy maker in response to a number of real or hypothetical future conditions and the interventions that produce them. Moreover, internal models provide systems analysts, policy consultants and policy makers with the opportunity to observe the variables and parameters that control the policy maker's evaluation of any specific set of future conditions or present interventions, and the opportunity to change these if it is desired to do so. (For further information regarding these steps, the reader may consult [8], [9].)

Having indicated the general aims of the internal-systems analyst we turn now to a description of the steps employed to achieve those aims.

Step 1. Discover the General Policy of the Policy Maker Regarding Future Conditions

There are a variety of means by which future conditions may be achieved, and, of course, different policy makers will have different preferences for different means to achieve them. Such differences in preferences are the product of a general policy. But, as is customary in external model building, neither preferences for various means, nor the policy that produces them were explored by Naill in his development of COAL 1. In order to pursue our example here, however, we shall assume that all three of our hypothetical policy makers named the same unidimensional, bi-polar means for producing energy, namely those used in the construction of COAL 1. These include differential dependence on:

1. Conventional oil and gas supplies;
2. Synthetic oil and gas supplies;
3. Importation of oil and gas;
4. Nuclear fueled power;
5. Coal fueled power.

Although we assumed that all three hypothetical policy makers would name the same means for providing energy, we allowed them to differ in the extent to which they prefer to depend upon them. Thus, for example, one policy maker may prefer a future set of conditions in which conventional oil and gas, and coal, provide the major sources of power, whereas a different policy maker may prefer a future in which synthetic oil and gas are combined with nuclear fuel. It is the internal-systems analyst's task to discover not only which specific sources of energy the policy maker prefers to depend upon but the general policy he holds that produces specific preferences. This procedure is described in detail below.

Step 2. Discover the Range of Acceptable Conditions

A second task for the internal-systems analyst is to determine the acceptable range of the means to be employed to bring about desirable future conditions. In the present example, therefore, it is necessary to discover the extent to which dependence on each of the above energy sources would be acceptable to the policy maker. Thus, the policy maker would be required to indicate the acceptable limits (if any) placed on each fraction of energy supplied by each source, say, 20% of energy supplied by conventional oil and gas, 10% by synthetic oil and gas, etc. (The information derived from this step will also be used by the external-systems analyst when constructing the model of the energy system.) For purposes of the present example, no limits were placed on the ranges of any of the above sources of energy by the hypothetical policy makers.

Step 3. Discover the General Policy of the Policy Maker Regarding the Interventions to be Employed

This step requires the internal-systems analyst to determine which interventions the policy maker considers to be socially desirable. The question is: what means should be employed now to bring about desirable future conditions? Naill did not pursue the question of which variety or "mix" of several possible interventions would be chosen by any specific policy maker, nor the question of the nature of the general policy that controlled the choice of that variety of intervention. For the purposes of our example, however, it will be sufficient if we assume that all three policy makers indicate that they wish to make identical policy interventions, namely, those Naill chose to use in COAL 1. These include:

1. Controlling the rate of energy growth;

2. Controlling the time of deregulation of oil and gas prices;

3. Controlling the extent of conservation measures (use of insulation, production of smaller cars, etc.);

4. Controlling the rate of development of nuclear power;

5. Controlling the rate of development of coal resources.

Variations in the level of each of these variables lead to various "packages" of policy interventions.

Step 4. Discover the Range of Acceptability for Each of the Policy Interventions

It is essential that ranges of acceptable policy interventions be specified if a meaningful use of the model is to be achieved. Otherwise the choice of a given level of intervention is arbitrary. (As in the case of establishing ranges on the variables in the subsequent conditions policy, the information derived from this step will also be used by the external-systems analyst when constructing the model of the energy system.) For the purpose of the present example we arbitrarily assigned ranges to each of the following variables: (a) energy growth in 1985, (b) year of deregulation of oil and gas prices, (c) conservation measures, (d) nuclear development, (e) coal development. The specific ranges and descriptions of these interventions are described below (pp. 25-32).

To summarize: the first task for the internal-systems analyst is to assist the policy maker in identifying (a) the general policy controlling the specification of the future conditions the policy maker wishes to achieve, (b) the general policy controlling the specification of the interventions that are intended to produce these conditions, and (c) the range of acceptable variations on the variables within each general policy. Once the variables (and their acceptable ranges) within these policies are established, variations within these ranges will provide a number of specific future conditions as well as a variety of specific interventions. Thus, for example, one variation of future conditions would include (a) large dependence on conventional oil and gas supplies, (b) moderate dependence on imported fuels, (d) low dependence on nuclear fueled power, and (e) low dependence on coal fueled power. Each such variation, of which there will be many, constitutes a Subsequent Conditions Package (SCP). Each SCP thus constitutes a specific set of outcomes or future conditions that fall within the policy maker's policy regarding the future.

The same is true for interventions that are employed to bring about subsequent conditions. Once the variables (and their acceptable ranges) within the intervention policy are established, variations within these ranges will provide a number of specific interventions that can be evaluated by the policy maker. Thus, for example, one policy intervention would include (a) low energy growth in 1985, (b) delay in the deregulation of oil and gas prices, (c) a large effort with regard to conservation, (d) a large effort with regard to nuclear development and (e) a small effort with regard to coal development. As in the case of subsequent conditions, each variation constitutes a Policy Intervention Package (PIP), and each PIP thus constitutes a specific "package" of interventions that fall within the policy maker's general policy concerning "what-to-do-now."

Step 5. Generating a Variety of SCPs and PIPs

In this step a number (N) of SCPs and PIPs are randomly generated in order to provide a sample of outcomes and interventions. (The size of N will be determined by time, resources, and the nature of the problem.) Generating randomly N cases of interventions and outcomes insures that no set of subsequent conditions or policy interventions will be omitted by implicit bias, and provides a base from which inferences may be explicitly and legitimately drawn. (Scenario writing, in which few, usually no more than three, cases are evaluated, fails to meet either criterion.) Cases may be presented on a computer terminal by means of POLICY 3 [8], [9], or by means of a series of charts.

Step 6. The Policy Maker Exercises His Judgment

The policy maker exercises his judgment with regard to each SCP and each PIP in terms of a rating scale (Figures 1 and 2) and thus indicates his preference for each PIP and SCP.

Step 7. The Internal-Systems Analyst Models the Policy Maker's Policy

The policy maker's judgments are now analyzed in terms of a quantitative model. In the present case, a weighted average regression model was used [7]. The policy makers' Subsequent Conditions Policies were quantified in the form indicated below:

CASE 1

Conventional Oil & Gas	29.859
Synthetic Oil & Gas	0.197
Oil & Gas Imports	33.953
Nuclear Power	3.091
Coal Development	25.790

Evaluation? 17

CASE 2

Conventional Oil & Gas	21.958
Synthetic Oil & Gas	0.028
Oil & Gas Imports	41.581
Nuclear Power	2.901
Coal Development	24.380

Evaluation? 13

CASE 3

Conventional Oil & Gas	27.681
Synthetic Oil & Gas	0.025
Oil & Gas Imports	41.582
Nuclear Power	3.652
Coal Development	23.760

Evaluation? 9

Figure 1. Examples of Subsequent Conditions Packages (SCPs) displayed for the policy maker by the POLICY 3 program. Each package is evaluated on a 20-point rating scale.

CASE 1

Energy Growth	2.300
Dereg. Oil & Gas (Year)	1978
Conservation	25
Nuclear Development	8
Coal Development	9

Evaluation? 9

CASE 2

Energy Growth	1.700
Dereg. Oil & Gas (Year)	1982
Conservation	28
Nuclear Development	8
Coal Development	7

Evaluation? 16

CASE 3

Energy Growth	2.300
Dereg. Oil & Gas (Year)	1979
Conservation	18
Nuclear Development	7
Coal Development	2

Evaluation? 7

Figure 2. Examples of Policy Intervention Packages (PIPs) displayed by the POLICY 3 program.

$$J = w_1(x_1) + w_2(x_2),\ldots,w_i(x_i), \text{ or}$$

$J = w_1$(conventional oil and gas) + w_2(synthetic oil and gas) + w_3(oil and gas imports) + w_4(nuclear power) + w_5(coal).

The same step is taken with regard to PIPs. The sample of PIPs is presented to the policy maker, he rates their desirability, and his judgment policy regarding interventions is thus obtained and represented in the form below:

$J = w_1$(energy growth) + w_2(deregulation of oil and gas prices (year)) + w_3(conservation) + w_4(nuclear development) + w_5(coal development).

In both cases, the policy maker's judgment policy is displayed for him immediately, if a computer terminal is used. The policy maker may thus observe (a) the weights that he applies to each single intervention aspect (e.g., the weight given to rate of energy growth, to deregulation of oil and gas, etc.), (b) the function form relating each aspect of intervention to this rating, and (c) the consistency with which he exercised his judgment concerning PIPs and SCPs (see Figures 3 and 4). In addition, the policy maker may change any of these properties of his judgment policy and/or compare them with other policies. (See [10] for an example of the use of the above method in policy making circumstances.)

The intervention policies from two hypothetical policy makers are displayed in Figure 5, together with our estimates of what President Carter's intervention policy was at the time he announced it (based on information printed in the International Herald Tribune, 20 April 1977; the official description of Carter's energy policy, published 29 April 1977, is roughly in accord with the newspaper account [11]). As may be seen in Figure 5, hypothetical J1 emphasizes (given greatest weight to)

```
POLICY 'Evaluation' HAS A PREDICTABILITY OF  0.93

RELATIVE WEIGHT PROFILE

A:Evaluation
0.0------------------0.5------------------1.0      WEIGHT   FUNCT FORM
Energy Growth
AAAAAAAAA                                            0.23     NEGLIN

Dereg. Oil & Gas (Year)
AAA                                                  0.09     NONLIN

Conservation
AAAAAAAAAAAAAAA                                      0.36     POSLIN

Nuclear Development
AAAAAAAAAAAA                                         0.28     NONLIN

Coal Development
A                                                    0.04     POSLIN

0.0------------------0.5------------------1.0
```

Figure 3. A display showing the relative importance of each of the factors in the Policy Intervention Packages to a hypothetical policy maker. The consistency, or predictability, of the policy maker's judgments with respect to the model of the judgments is also shown in the display. (The maximum value is 1.00.)

```
FUNCTION FORM PROFILE
A:Evaluation:MIN =        1.000  MAX =          20.00
  E*A                    *          AAAAAA     *                  A
  v* AA                  *         AA     AA    *                AA
  a*   A                 *        A            *               A
  l*    AA               *       A             *             AA
  u*      A              *      A              *            A
  a*       AA            *     A               *          AA
  t*         A           *    A                *         A
  i*          AA         *   A                 *       AA
  o*            A        *                     *      A
  n*             AA      *  A                  *    AA
   *               A     * A                   *   A
   *                AA   *                     * AA
   *                 A   *A                    *A
    ******************    ******************    ******************
     1.6            3.5 1976.0           1984.0   15.0             32.0
              Energy Growth Dereg. Oil & Gas-Year        Conservation

  E*     AAAAA           *                 A
  v*    A     AA         *               AA
  a*   A        A        *              A
  l*  A          A       *            AA
  u* A                   *           A
  a*A             A      *         AA
  t*               A     *        A
  i*                     *       AA
  o*                A    *      A
  n*                     *    AA
   *                 A   *   A
   *                     * AA
   *                 A   *A
    ******************    ******************
     5.0         10.0      1.0          10.0
    Nuclear Development      Coal Development
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Figure 4. Functional relationships between each factor in the Policy Intervention Packages and the policy maker's judgments.

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POLICY 'J1' HAS A PREDICTABILITY OF  1.00

POLICY 'J2' HAS A PREDICTABILITY OF  1.00

POLICY 'Carter' HAS A PREDICTABILITY OF  1.00


RELATIVE WEIGHT PROFILE

A:J1
B:J2
C:Carter
0.0------------------0.5------------------1.0     WEIGHT   FUNCT FORM
Energy Growth
AAAA                                               0.10      POSLIN
BBB                                                0.10      POSLIN
CCCCCCCC                                           0.20      NEGLIN

Dereg. Oil & Gas (Year)
AAAAAAAAAAAAAAAAA                                  0.40      POSLIN
BBB                                                0.10      POSLIN
CCC                                                0.10      POSLIN

Conservation
AAAAAAAAAAAAAAAAA                                  0.40      POSLIN
BBB                                                0.10      POSLIN
CCCCCCCCCCCCC                                      0.30      POSLIN

Nuclear Development
A                                                  0.05      POSLIN
BBBBBBBBBBBBBBBBBBBBBBBBBB                         0.60      POSLIN
CCC                                                0.10      POSLIN

Coal Development
A                                                  0.05      POSLIN
BBB                                                0.10      POSLIN
CCCCCCCCCCCCC                                      0.30      POSLIN

0.0------------------0.5------------------1.0
```

Figure 5. Descriptions of hypothetical intervention policies for two hypothetical policy makers (J1 & J2) and "President Carter." The specified policies have perfect consistency. Functional relationships were assumed to be linear and are not shown.

deregulation and conservation, J2 emphasizes nuclear power development, whereas "President Carter" emphasizes increasing conservation and coal development while emphasizing decreasing energy growth. (For simplicity of exposition in the present case, all function forms were assumed to be linear over the ranges employed, and the policy makers were assumed to be perfectly consistent. In practice, no difficulties are created when these assumptions are not met.) These policies show in explicit form how the policy maker will evaluate any proposal for intervention that he hopes will achieve those subsequent conditions he considers to be desirable.

The policies that are applied to the evaluation of future conditions are shown in Figure 6. J1 emphasizes coal development, J2 emphasizes conventional oil and gas, while emphasizing negatively oil and gas imports, and nuclear power. "President Carter" emphasizes positively coal development while emphasizing negatively oil and gas imports.

It is important to note that the quantitative description of these judgment policies makes the judgment process explicit and widely understandable; the quantitative character of the externalized judgment policy reduces dependence on the ambiguity of words, and reduces the effect of language differences as well (just as the quantitative character of external models reduces their dependence on the ambiguity of words and language differences).

To summarize: these steps make it possible to show the policy maker the judgment policy he used to evaluate the SCPs and PIPs in terms of (a) the weight applied to various aspects of the SCPs and PIPs, (b) the functional relation between each aspect and his judgment, and (c) the consistency of his judgment. The policy maker may, of course, change

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POLICY 'J1' HAS A PREDICTABILITY OF  1.ØØ

POLICY 'J2' HAS A PREDICTABILITY OF  1.ØØ

POLICY 'Carter' HAS A PREDICTABILITY OF  1.ØØ


RELATIVE WEIGHT PROFILE

A:J1
B:J2
C:Carter
Ø.Ø------------------Ø.5------------------1.Ø     WEIGHT   FUNCT FORM
Conventional Oil & Gas
AA                                                  Ø.Ø7     POSLIN
BBBBBBBBBBBBBBBB                                    Ø.38     POSLIN
CCC                                                 Ø.1Ø     POSLIN

Synthetic Oil & Gas
AA                                                  Ø.Ø7     POSLIN
BB                                                  Ø.Ø6     POSLIN
CCC                                                 Ø.1Ø     POSLIN

Oil & Gas Imports
AAAAA                                               Ø.14     NEGLIN
BBBBBBBBBBBBB                                       Ø.31     NEGLIN
CCCCCCCCCCCCCCCCCCCCCC                              Ø.5Ø     NEGLIN

Nuclear Power
AAAAA                                               Ø.14     POSLIN
BBBBBBBB                                            Ø.19     NEGLIN
CCC                                                 Ø.1Ø     POSLIN

Coal Development
AAAAAAAAAAAAAAAAAAAAAAAAA                           Ø.58     POSLIN
BB                                                  Ø.Ø6     POSLIN
CCCCCCCC                                            Ø.2Ø     POSLIN
Ø.Ø------------------Ø.5------------------1.Ø
```

Figure 6. A display showing the Subsequent Conditions judgment policies of the three policy makers.

these as he sees fit (a step achieved quickly if POLICY 3 is used). The result achieved by this procedure is that an explicit, quantitative model of a policy for evaluating outcomes and interventions is now available for inspection, and for application to specific proposals for interventions and the subsequent outcomes produced by them. We turn now to the modeling of the processes that intervene between policy interventions and subsequent conditions, in other words, to the task of the external-systems analyst.

The Task for the External-Systems Analyst

The external-systems analyst must first develop a model of the external system. The model can then be run in order to determine the subsequent conditions that would result from specific policy interventions.

Step 1. Develop a Model of the External System

The first activity of the external-systems analyst is, therefore, to develop a model of the external system that is under analysis. The appropriate variables must be selected from within the system, and their relations with each other must be defined.

As indicated earlier, a previously developed model, Naill's [5] COAL 1, was selected for purposes of the present demonstration. COAL 1 is a systems dynamic model of energy supply and demand of the United States. Included within the model is an accounting of energy demand growth, resource depletion, price effects, lead times, and financial and environmental constraints on the development of new energy resources. Figure 7 indicates the basic structure of COAL 1. The model describes the U. S. energy

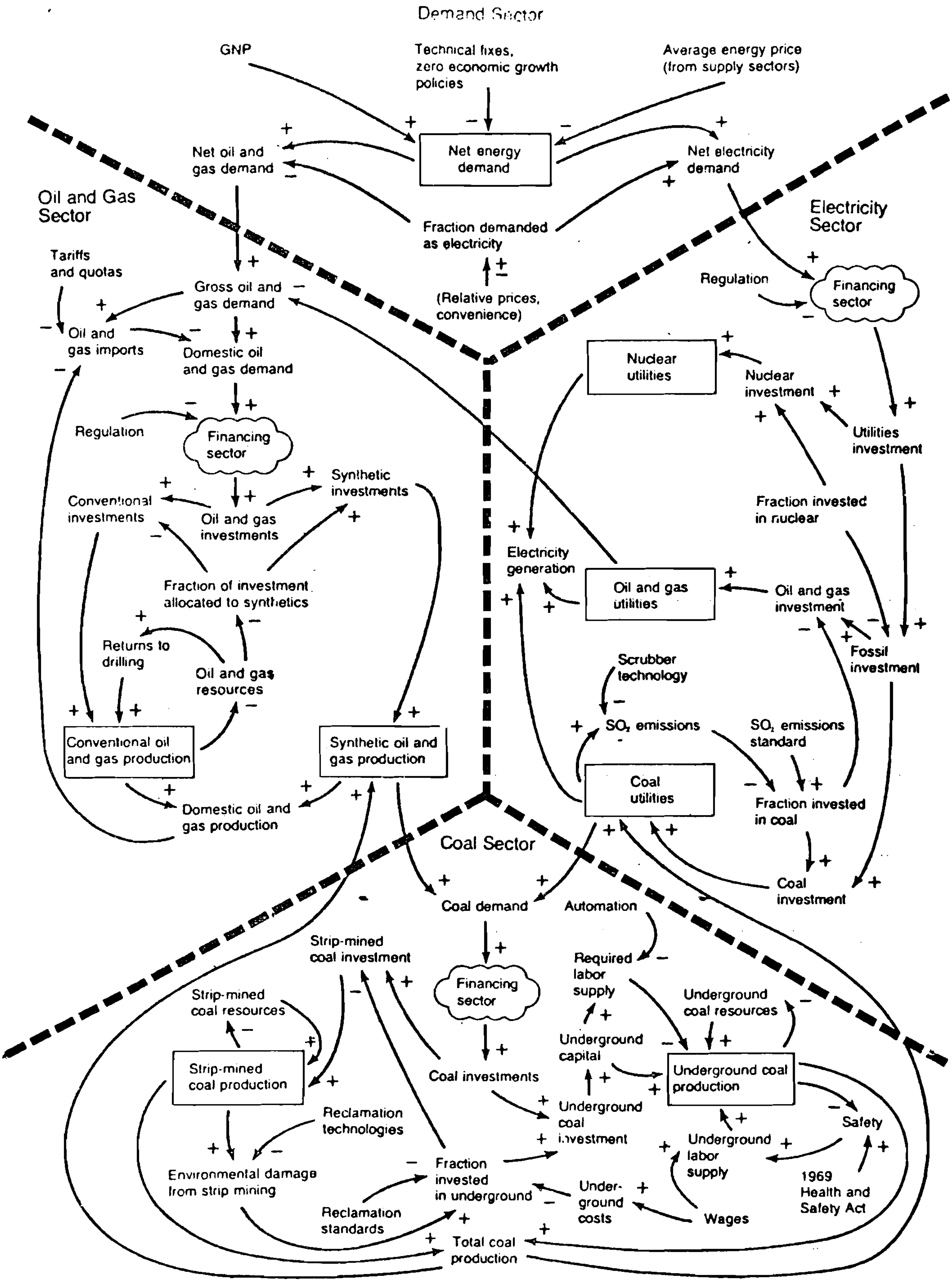


Figure 7. COAL1 MODEL STRUCTURE [5]

system from 1950 till the present time and attempts to predict the future of the system through 2010. It portrays an energy system that was in balance in 1950 and has since deteriorated to the point where in 1976 the U. S. is importing a significant portion of its energy inputs. If no major changes in energy policies take place, the model, when run over a time period of 1977 through 2010, indicates that the U. S. will import more than 50% of its oil by 1990. This situation implies that the U. S. will attempt to move from dependence on scarce oil and gas resources to more abundant energy resources of solar radiation, coal and uranium over the next 35 years. Figure 8 shows the U. S. energy transition problem as projected by COAL 1 if no new U. S. policies are initiated; domestic oil and gas production peaks and declines after 1970, and because of financial and economic constraints and delays, neither coal nor nuclear power grow quickly enough to avoid massive dependence on oil and gas imports during the transition period.

Step 2. Identify Types of Policy Interventions and Specify Their Effects

As a consequence of these conditions, the issue now becomes: what types of policy interventions will affect future reliance upon oil imports by the U. S.? Policy interventions presently being considered and implemented by the U. S. Government, and those indicated by President Carter in his energy policy [11] include (a) conservation measures, (b) reduced growth in energy demand, and (c) an accelerated coal program. Table 1 illustrates additional policy interventions that are available to the U. S. policy maker and accounted for in the COAL 1 model.

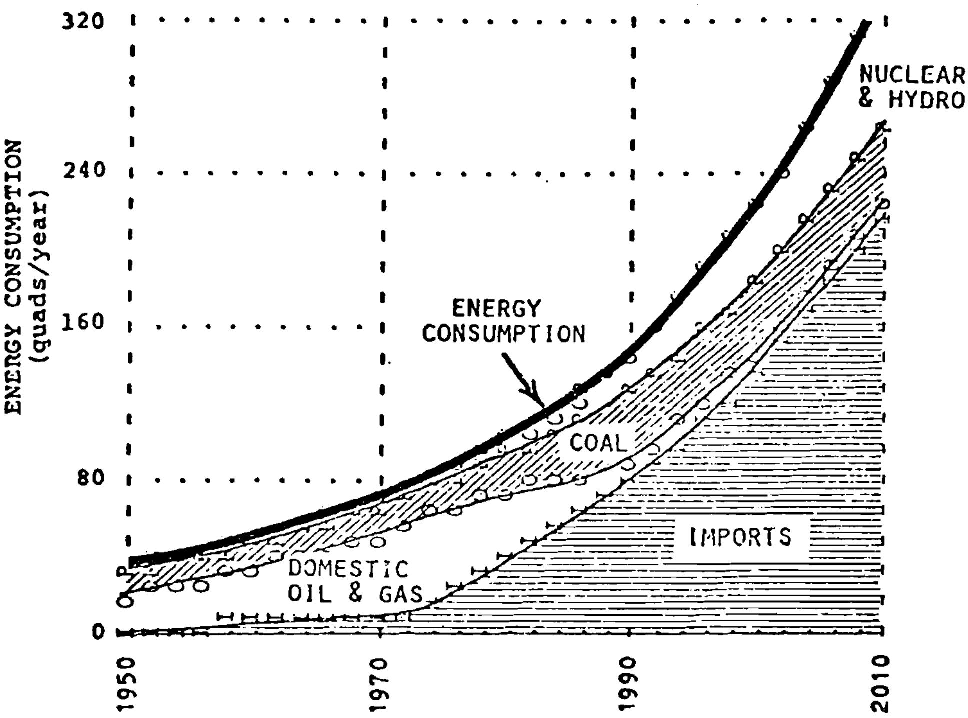


Figure 8. COAL 1 Projections Showing U.S. Energy Transition Problem [5]

Table 1. COAL 1 Policy Options (5)

RESOURCE EXTRACTION REFINING, TRANSPORTATION	SYNTHETIC CONVERSION REFINING, TRANSPORTATION	ELECTRICITY CONVERSION, TRANSPORTATION, DISTRIBUTION	END-USE DEMAND
1. Nuclear fuel subsidies 2. Oil import quotas, embargoes 3. Foreign oil tariffs 4. Enhanced oil or gas recovery 5. Oil or gas price deregulation 6. 1969 Coal Mine Health & Safety Act 7. Ban on surface mining 8. Surface Mining Restrictions a. Steep slope restrictions b. Federal surface coal reclamation standards c. Surface-mined coal tax 9. Coal Investment Incentives a. Loan guarantees b. Coal price support	10. Accelerated R&D in: In-situ oil shale Low-BTU gas High-BTU gas Coal liquefaction 11. Accelerated commercialization incentives (price or loan guarantees) for: Oil from shale Low BTU-gas High-BTU gas Coal liquefaction	12. Utility rate relief 13. Utility load management 14. Reduction of nuclear siting & planning lead time 15. Relaxation of SO_2 standards 16. Accelerated development and implementation of coal combustion technologies: Stack gas crubbers Fluidized bed combustion Solvent-refined coal MHD 17. Nuclear Moratorium	18. Conservation policies ("Technical Fix") 19. Zero Energy Growth 20. Intensive Electrification 21. Accelerated coal use in industry

The following illustrates how one of the policy interventions (conservation) is implemented within COAL 1. Conservation implies such efforts as providing better insulation in homes, use of heat pumps, and smaller cars in order to reduce energy consumption. The Ford Foundation energy study [12] indicated that net energy consumption could be reduced by 28 percent by the year 2000 if maximum conservation measures were to be employed. Assuming that the average energy price increases by a factor of 2.7 by the year 2000 (the minimum price rise generated by COAL 1 to the year 2000), conservation policies imply a price elasticity (e_{tf}) of:

$$e_{tf} = \frac{\ln(.72)}{\ln(2.7)} = -.33$$

If conservation policies ("technical fix") tend to increase the responsiveness of energy demand to price, these policies may be modeled by increasing the slope of DMP2T to correspond to an elasticity of -.33, as shown in Figure 9.

The range of conservation given by Naill lies between the negative slopes of .15 and .33. A negative .15 indicates a "business as usual" environment whereas a negative .33 implies the maximum possible reduction in energy consumption as given in the Ford Foundation energy study. A necessary step in our endeavor was to derive the appropriate formulas to operate between the minimum and maximum values, which had not been previously developed for COAL 1. Such formulas were necessary to allow the policy makers the opportunity to operate within the previously calculated ranges. The following is an illustration of the formula developed for conservation:

$$DMP2T_{ij} = e^{(-A_j \cdot \log Z_i) \cdot \ln 10} \qquad (1)$$

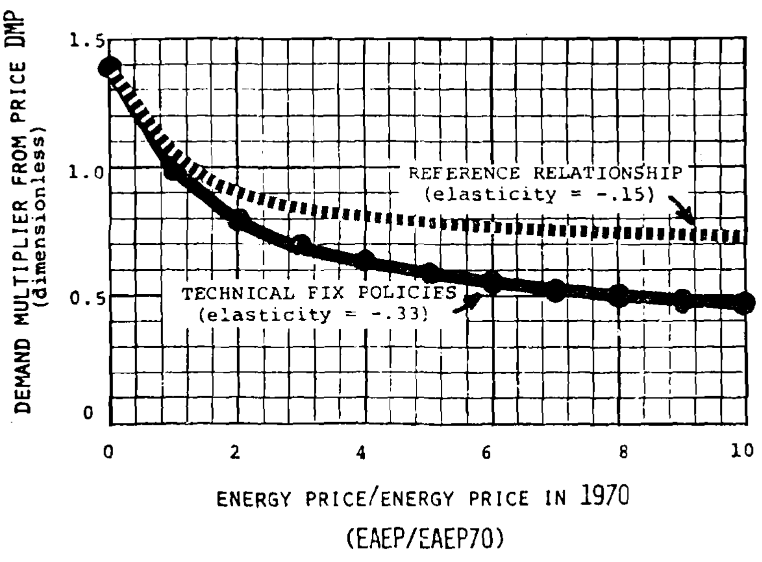


Figure 9. Effects of Ford Foundation Conservation ("Technical Fix") Policies on the Demand Multipliers from Price DMP Relationship (5)

where A_j is a set of slopes representing the elasticity of demand with respect to price;

where Z_i = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 & 10 (Energy price/Energy price in 1970);

for i = 1,2,...,I

where I is 11;

for j = 1,2,...,J

where J is 24

(24 is the number of cases studied).

Similar formulas were developed for several policy interventions available within COAL 1 for purposes of providing a wide range of choices within each intervention. Computer programs were developed for such formulas and were utilized to create much of the required input data necessary for the COAL 1 model runs.

Based upon those factors that are anticipated to be a part of the U. S. energy policy, we selected five policy interventions for the present example; these are presented in Table 2, together with their appropriate ranges.

Policy intervention Number One of Table 2 gives the minimum and maximum range of the expected amount of the annual percent increase in energy demand for the year 1985. Policy intervention Number Two indicates the year when all deregulation of oil and gas would be lifted in the U. S. In an accelerated program, all regulation would be lifted in 1977 or in a "business as usual" environment such regulations would remain in effect until 1985. Intervention Number Three, conservation, has been previously described. Policy intervention Number Four indicates the time required

Table 2: Range of Policy Interventions

	Policy Interventions	Range	
		Minimum	Maximum
1	Energy Growth in 1985	1.5%	3.5%
2	Year of Deregulation of Oil and Gas	1977	1985
3	Conservation of Energy	-.15	-.33
4	Nuclear Development (Years to complete conventional nuclear reactor)	5 years	10 years
5	Coal Development (Scale of 1 to 10 with 1 being business as usual and 10 being maximum acceleration)	1	10

to plan and construct a conventional nuclear reactor. Presently in the U. S. that time is nine years. It is conceivable that by streamlining the planning and construction phase the time requirements could be reduced to five years with the appropriate federal stimulus.

The coal development program, represented by policy intervention Number Five, was dealt with in a separate manner. Within COAL 1 there are six variables that require alteration to effect an accelerated coal program. They include such variables as the fraction of energy demanded for direct coal use in industry, a price support program guaranteeing a minimum rate of return on investment for the coal industry, a guaranteed loan program for the coal industry, etc. A scalar system from one to ten was used to translate the six variables of COAL 1 into an overall choice of emphasis (see Figure 10). A selection of one indicates a non-accelerated coal program, whereas ten indicates a heavy emphasis on an accelerated coal program in the U. S.

A set of 24 Policy Intervention Packages (PIPs) representing a wide range of the conceivable policy interventions for the U. S. system were then developed and applied to COAL 1, as indicated in Table 3. These 24 PIPs were created by selecting random values within the minimum-maximum ranges for each of the five types of policy intervention. The specific values on each intervention were then translated into the input requirements of COAL 1. As mentioned earlier, a series of computer programs were developed for this purpose. Figure 11 demonstrates the translation of the values of the Policy Intervention Package Number Nineteen into the required 63 values necessary for COAL 1 for that particular PIP.

Year	Fractional Range of Energy Demanded as COAL by Industry		Example Input if Scalar Value of 6 selected
	Minimum	Maximum	
1950	.350	.350	.350
1960	.150	.150	.150
1970	.097	.097	.097
1980	.067	.098	.084
1990	.055	.100	.080
2000	.048	.110	.082
2010	.043	.120	.086

Figure 10. Translation of coal program emphasis (1 to 10 scalar system) into one example variable, FEDCT, of the Coal 1 Model.

Table 3. Policy Intervention Packages (PIPs)

Case Number	Energy Growth at 1985	Deregulation of oil/gas controls	Techn. Fix (Conservation)	Nuclear Develop-ment	Coal Develop-ment
1	2.3	1978	.25	8	9
2	1.7	1982	.25	8	7
3	2.3	1979	.18	7	2
4	2.5	1977	.32	7	5
5	2.2	1977	.17	6	2
6	2.4	1984	.20	5	4
7	2.2	1977	.17	7	5
8	1.6	1981	.30	8	6
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
24	2.9	1981	.16	7	10

CASE 19

PIP		VARIABLE			
Energy growth at 1985	2.9%	GNPGRT	3.5	3.5	1.4
Deregt. of oil/gas controls	1977	DEREGT	1977		
Techn. Fix (Conserv.)	-.20 slope	DMP 2T	1.4	1.0	.631
Nuclear Develop. yrs completion	9 yrs	NC 2T	9		
Coal development	10	FEDCT	3.5	0.15	.120
		FIASS 2T	.0	.178	1.000
		SO 2EFT	6.1	6.1	.756
		FFCCRT	.065	.082	.083
		FCRI 2T	.000	.030	.339
		CPRAT 2T	1.267	1.268	2.000

Figure 11. Translation of Policy Intervention Package 19 into Values Necessary for COAL 1.

Step 3. Use the External Model to Determine the Subsequent Conditions Resulting from Each of the Policy Intervention Packages

The final step for the external-systems analyst is to run the computer model of the external system for each of the Policy Intervention Packages (PIPs). The results of step 2 provide descriptions of each policy intervention in terms of the parameters of the model of the system. These values serve as input to the model. In the present exercise, the 24 PIPs were used to generate 24 Subsequent Conditions Packages (SCPs). The subsequent conditions resulting from Case 19 are shown in Table 4.

In summary, the responsibility of the external-systems analyst is to carry out the following steps:

1. Develop a model of the external system; the model quantifies and thus externalizes the relations between policy interventions and subsequent conditions produced by the interventions.

2. Assist in determining what interventions can be employed in changing the system.

3. Assist in providing the appropriate ranges of the selected policy interventions and subsequent conditions.

4. Translate the Policy Intervention Package (PIP) into appropriate input variables necessary for model runs.

5. Translate the output data into appropriate SCPs.

The Policy Consultant's Task

The policy consultant's task has four major components. First, the policy consultant must analytically integrate the information provided by both types of systems analysts, otherwise the policy maker will very

Table 4. Subsequent Conditions that result from applying COAL 1 to Policy Intervention Package 19.*

Time	Gross Energy Consumption	Net Energy Demand	Continental Oil/Gas Prod. Rate	Synthetic Oil/Gas Prod. Rate	Oil/Gas Import	Oil/Gas Electric Generation	Coal Electric Generation	Nuclear Electric Generation	Coal Demand	Average Energy Price
1950.	34.36	29.38	18.320	.000	.851	.281	.545	.000	14.21	.7822
1955.	40.34	34.78	23.546	.000	2.425	.417	.819	.000	13.10	.8271
1960.	47.41	40.95	28.968	.000	5.478	.629	1.268	.000	11.43	.8702
1965.	57.40	48.03	35.645	.000	5.982	.979	1.949	.001	13.70	.9211
1970.	69.19	56.13	43.866	.000	7.013	1.722	2.608	.052	15.56	.9740
1975.	83.37	65.24	42.144	.000	18.945	3.299	3.244	.345	18.22	1.4624
1980.	95.08	71.66	33.906	.000	33.726	4.973	3.631	1.248	20.17	2.5549
1985.	109.23	77.17	34.025	.213	34.167	5.236	5.763	3.046	27.84	3.3499
1990.	126.93	83.11	39.039	3.513	23.258	4.312	9.005	5.367	43.88	4.0771
1995.	156.20	90.06	39.930	17.222	4.963	3.519	13.462	8.348	81.13	4.6394
2000.	188.60	97.76	26.175	36.796	.000	4.447	15.649	11.020	125.93	4.4596
2005.	21[illegible].60	105.15	17.047	51.592	.000	8.256	16.735	14.525	160.39	5.4563
2010.	255.45	110.30	12.750	66.779	.000	12.668	18.763	18.790	179.76	6.3111

*All values of columns 2-10 given in Quads of BTU's and column 11 is in U.S. $ per btu given in values of 10^{-6}.

likely set both types of information aside in favor of the results of older, more familiar, and less effective intuitive procedures. In addition, the integrated information must be displayed in a form that is policy-relevant, otherwise it is not likely to be used, or, if used, likely to be mis-used. Moreover, the policy maker should be able to interact dynamically with the (internal) model of his judgment policies and with the model of the external system in order to pursue "what if. . ." questions. What steps should the policy consultant take to achieve these aims?

Step 1. Establish the Link Between Intervention and Subsequent Conditions Policies

It will be recalled that in Step 4 of the internal-systems analyst's task a sample of SCPs and PIPs was randomly generated in order to provide a set of SCPs and PIPs to be judged by the policy maker. The sample of PIPs also provides a variety of inputs for running the external model a large number of times. In this way a large set of inputs and the outputs associated with them are obtained by virtue of the functional relations within the model. That is, (a) a number (N) of PIPs (each PIP consisting of different discrete values on several dimensions) are applied to the external model, (b) the model is run N times (once for each PIP), thus (c) producing N PIPs (inputs) and associated SCPs (outputs).

The reader will recognize this sort of information as being of the same kind as that usually produced by the external-systems analyst, with the exception that the external model is ordinarily run only a few times, thus allowing the observer to discover the relations between a few specific policy interventions and specific subsequent conditions produced by the model. The information produced by this conventional procedure is limited and incomplete, however, for it does not locate these specific interventions and outcomes in the context of the policy maker's general policy--for the simple reason that the conventional procedure does not include the construction of an internal model of the policy maker's judgment policy.

In the present example, models of three policy maker's judgment policies concerning intervention (see Figure 5 above) and models of their judgment policies for subsequent conditions (see Figure 6 above) were constructed. As a result, it was possible for the policy consultant to apply these judgment policies to the input conditions and output data of several runs of the Naill COAL 1 model.

The Naill model was run 24 times using as inputs the 24 PIPs which represented a wide sample of conceivable U. S. energy policy interventions. Each PIP, with its set of discrete values on each dimension provides the x values in the policy equation.

$$J = w_1x_1 + w_2x_2 + \dots w_nx_n$$

Since the weights (and function forms) for this equation have already been obtained for each policy maker, each set of x values provided by each PIP produces different values of J for each PIP. Calculation of these J's thus produces a prediction of the policy maker's preference judgment. The J values thus make it possible to rank each of the 24 PIPs in terms of the policy maker's preference. The same procedure is carried out for the judgment of SCPs, thus also making it possible to order the SCPs in terms of the policy maker's preference judgments.

The above steps provide the basis of linking the information produced by <u>internal</u> models (i.e., models of judgment policy regarding interventions and subsequent conditions) with <u>external</u> models (in this case, a model of the U. S. energy system).

To summarize: N runs of the external model provide an empirical data base to which internal models of intervention policies and subsequent conditions policies can be applied. When the internal (cognitive) model is of the form $J = w_1x_1 + w_2x_2 + \ldots w_nx_n$ (or similar), the w's are the weights calculated from the policy maker's judgment of N cases and the x's are the numerical values of the inputs (and outputs) of N runs of the external model. Calculation of these Js thus produces a predicted judgment for each of the N runs of the external model; these calculations permit the construction of Forecasting Tables, to be described below. The Forecasting Tables are, therefore, a product of the analytical linkage of value judgments of the policy maker (represented by the internal model) with facts (represented by the external model).

Step 2. Construct Forecasting Tables for Each Policy Maker

The policy consultant constructs a Forecasting Table (see Figure 12) for each policy maker so that he will be able to see the results of the analytical linkage of PIPs and SCPs. In this way, the policy maker will be able to see which PIP leads to which SCP. Forecasting Tables not only enable the policy maker to see the preference rank of any PIP and the preference rank of the SCP it produces, but, in addition, any SCP can be traced back to the preference rank of the PIP that produced it. In short, the Forecasting Tables make it possible for the policy maker not only to work forward from the present to the future but also to work backward from the future to the present.

Consider working forward in Forecasting Table 1 (Figure 12). Observation of Forecasting Table 1 provides the policy maker J1 with two vital

RANK	PIP	J_1	CASE	OUTCOME 1985	J_1	CASE	OUTCOME 2000	J_1
1	16	15.40	19		18.14	9		17.71
2	22	15.76	10		18.11	19		15.19
3	2	13.81	24		13.58	10		14.66
4	21	12.17	9		13.31	24		13.14
5	6	11.95	1		12.73	15		12.64
6	18	11.92	7		12.36	13		12.31
7	20	11.55	15		12.18	22		11.85
8	9	11.45	13		11.64	16		11.71
9	15	11.40	14		11.40	8		11.46
10	4	11.25	18		10.77	18		11.08
11	12	11.15	8		10.67	7		10.85
12	11	10.83	22		10.14	1		10.71
13	17	10.66	5		9.96	14		9.83
14	8	10.11	16		9.61	17		9.10
15	1	9.48	23		9.58	4		9.02
16	13	9.02	4		9.28	12		8.42
17	24	8.90	17		9.05	2		8.17
18	10	8.75	3		8.77	11		7.82
19	3	8.37	6		8.72	5		7.81
20	19	8.13	11		8.45	6		7.70
21	14	5.98	12		8.16	23		7.65
22	7	4.24	21		8.14	3		7.22
23	5	3.73	2		7.86	20		5.71
24	23	2.45	20		5.96	21		4.48

Figure 12. Forecasting Table 1 (J1)

pieces of information; he will learn that his most desirable (rank number 1) intervention (PIP No. 16) results in subsequent conditions (SCP) in 1985 which are far from the conditions he is trying to achieve; indeed, he will see that his most desirable policy intervention (PIP No. 16, rank No. 1) will produce a set of outcomes ranked 14th in the list of 24 in 1985. J1 will also see, however, that the rank of this SCP in 1985 will improve slightly by the year 2000, reaching a rank of 8.

Now consider working backward from the year 2000. J1 can see that in order to achieve the conditions he finds most desirable for the year 2000 (SCP No. 9), he will have to accept a condition ranked 4th for 1985; and in order to achieve both these conditions he will have to intervene with a PIP ranked 8th in desirability in the list of 24.

Consider the situation confronting J2. The information presented in Forecasting Table 2 (Figure 13) tells J2 immediately that if he acts on the basis of his <u>most</u> desirable intervention, the subsequent conditions produced by it would be disastrous. But J2 can also quickly see that he can achieve very desirable outcomes for the years 1985 and 2000 by accepting an intervention policy ranked 6th; not a highly unpalatable set of circumstances.

Now consider "President Carter's" Forecasting Table (Figure 14). The moderate discrepancies indicated there suggest that "Carter" is faced with palatable choices. Note "Carter's" PIP No. 1; it is his 3rd ranking PIP and results in his 2nd ranking SCP for 1985 and his 3rd ranking SCP for the year 2000, a situation any policy maker would find comforting.

In short, the information displayed by the policy consultant in Forecasting Tables of this form is directly, succinctly and graphically

	CASE	POLICY NOW	J_2	CASE	OUTCOME 1985	J_2	CASE	OUTCOME 2000	J_2
1.	21		16.38	19		17.91	23		18.14
2.	22		15.67	23		17.15	7		15.75
3.	9		15.48	4		15.89	17		15.63
4.	13		15.94	10		15.50	20		15.55
5.	19		15.60	11		15.14	3		15.53
6.	23		13.01	1		15.11	12		15.32
7.	2		12.08	7		14.41	4		15.24
8.	.		.	.		.	.		.
9.	.		.	.		.	.		.
10.	.		.	.		.	.		.
11.	.		.	.		.	.		.
12.	.		.	.		.	.		.
13.	.		.	.		.	.		.
14.	.		.	.		.	.		.
15.	.		.	.		.	.		.
16.	.		.	.		.	.		.
17.	.		.	.		.	.		.
18.	.		.	.		.	.		.
19.	.		.	.		.	.		.
20.	6		4.89	16		5.24	24		13.61
21.	5		4.55	21		5.20	18		13.41
22.	17		4.49	17		4.67	10		13.10
23.	20		4.38	15		4.13	15		20.09
24.	14		3.53	6		3.93	21		3.45

Figure 13. Forecasting Table 2 (J2)

	CASE	POLICY (CARTER)	J	CASE	1985 (CARTER)	J	CASE	2000 (CARTER)	J
1.	2		15.32	10		12.32	10		12.08
2.	22		14.63	1		11.99	18		12.08
3.	1		13.43	24		11.92	1		11.88
4.	18		13.20	4		11.66	24		11.45
5.	16		12.85	19		11.60	22		11.39
6.	.		.	.		.	.		.
7.	.		.	.		.	.		.
8.	.		.	.		.	.		.
9.	10		11.00	2		10.76	2		11.11
10.	.		.	.		.	.		.
11.	.		.	.		.	.		.
12.	.		.	.		.	.		.
13.	.		.	.		.	.		.
14.	.		.	.		.	.		.
15.	.		.	.		.	.		.
16.	.		.	.		.	.		.
17.	.		.	.		.	.		.
18.	.		.	.		.	.		.
19.	.		.	.		.	.		.
20.	.		.	.		.	.		.
21.	21		6.76	13		8.44	5		8.38
22.	23		6.53	6		8.05	23		8.17
23.	3		6.51	15		7.15	3		8.15
24.	5		5.52	21		7.05	21		7.01

Figure 14. "President Carter's" Forecasting Table

policy-relevant; it tells the policy maker what he needs to know. This information can be produced only by a) an internal-systems analyst who provides a model of the policy maker's judgment system, b) an external-systems analyst who provides a model of the socio-physical system under study, and c) a policy consultant who links analytically the information provided by both systems analysts.

Forecasting Tables can provide other information of value to the policy makers and the policy consultants, a matter to which we now turn.

Further Information Provided by Forecasting Tables

(Caution: In this section we shall deliberately over-interpret the hypothetical data in the Forecasting Tables for the purpose of explaining the uses to which they may be put.)

Forecasting Tables provide two sorts of further information: a) information within a table regarding one policy maker, and (b) information derived from comparing tables regarding two (or more) policy makers. A table for one policy maker indicates (a) the range of the values of judgment (e.g., from 2.45 to 15.40 in col. 3 in the Forecasting Table for J1) in contrast with a larger or smaller range that might have been obtained, (b) the size of the difference between ranked cases (18.14 - 18.11 in col. 5 in contrast with 17.71 - 15.19 in col. 7), and (c) the degree of correlation between ratings of PIPs and SCPs. Note that a low correlation between ratings of PIPs and SCPs suggests (but does not prove) a lack of "intuitive wisdom" on the part of the policy maker. A low correlation also carries a warning that one or the other model (or both) is apt to be considered wrong, and thus not likely to be trusted by the policy maker. Not shown here are d) the results of an application of a sensitivity analysis (e.g., assuming equal weights on all variables, and/or changing the ranges on certain variables). Sensitivity analyses are of considerable value, for they indicate the extent to which it is important to discriminate between various PIPs and SCPs.

Information that can be gained from comparing data between policy makers includes (a) the degree of conflict between policy makers (e.g., as may be obtained from calculating the correlation between the PIPs and/or SCPs for J1 and J2, thus indicating whether conflict exists between policy makers with regard to means or ends or both; and (b) the absolute degree of desirability of the most desirable cases. Also (c) the effects of a sensitivity analysis between policy makers can be ascertained; what may appear to be a large difference in judgment between policy makers may be highly sensitive to changes in conditions and/or assumptions, and thus be a highly context-dependent difference which can be readily eliminated or reduced.

Although both types of systems analysts will be aware of the uncertainty in both models and will note that such uncertainty is not reflected in the Forecasting Tables, the policy makers will ordinarily not be. Examination of the effects of uncertainty on judgment policies and external simulations can be a sobering experience for policy makers who are prepared to fight to the bitter end for a difference that may turn out to be subject to irreducible uncertainty and thus elusive in fact, however critical it may be in principle. Moreover, examination of the effects of uncertainty can also be a sobering experience for substantive scientists who contribute information and judgments to the development of external models. None of these questions can be addressed unless external and internal models are employed, nor can they be addressed properly unless a complete methodology is employed that links analytically both external and internal models.

Step 3. Displaying Information

The policy consultant cannot simply present the policy maker with Forecasting Tables that indicate the link between present policies and their future consequences (as in the examples presented here), and then simply leave it to the policy maker to "make up his mind" about what he should do. For even though Forecasting Tables provide the policy maker with a form of cognitive assistance he can get from no other source, there is a considerable amount of complex information in such tables and, therefore, they may not be used appropriately or effectively by the policy maker. And because the amount of information is too large to be safely trusted to human information processing, the form in which the information is displayed may itself bias policy choices. Indeed, whenever information is large in amount and/or complex in its meaning, the form of its presentation is apt to have a covert effect on policy choices.

Although the form of the present Forecasting Tables serves the purpose of indicating the links between intervention and subsequent conditions, this display may bias the judgment of the policy maker with regard to ultimate choice of actions for it strongly suggests that a horizontal line, set as high as possible across the columns in the tables (that is, a line that maximized the ranks of PIPs and SCPs across columns) would provide the best policy for both the present and the future. But the selection of a horizontal line would result in a policy of giving equal weight to the present and the future, a fact not likely to be apparent to the policy maker, and a policy that might not represent the policy maker's intentions. Such situations illustrate the need for the policy consultant; it is the policy consultant's responsibility to see to it that the policy maker does not become a victim of the form of the display of information, as well as other psychological factors, when forming policy (see [13], for a further discussion of this point).

Step 4. The Policy Maker's Interaction with Information Provided by Internal and External Models

The policy maker should be able to ask "what if. . ." questions with regard to the information provided by both models. What if the technical data are biased in one direction or another? What if I changed my general policy regarding interventions and give more weight to this intervention and less to that one? These questions can be answered by straightforward quantitative adjustments, and these can be carried out by the policy consultant with instructive results. (See [10] for an example.)

There is a larger "what if. . ." question, however, and that concerns the trade-off between the present and the future. In addition to the above interactions with the models, the policy consultant should provide an opportunity for the policy maker to place different weights on the present and the future. Differential weights on the importance of the present and the future lie at the core of the problem of the use of the earth's resources, including sources of energy. Moreover, placing differential weights on the present and the future is an activity that interacts with democratic control over resources. In the case of energy demand, for example, a president or prime minister might wish to establish or preserve his popularity by implementing the PIP that his present constituents consider most desirable, leaving the undesirable SCPs to be dealt with by his successors. (Such an energy policy has been caricatured by a columnist as "we found our oil, let the kids find theirs!"). On the other hand, a political leader might be so concerned about the welfare of future generations that he would place considerable weight on achieving desirable conditions in the year 2000 at the cost of maintaining his present popularity ("I'd rather be right than be president!") [14].

It will seldom, if ever, be the case that the trade-off between the present and the future can be avoided, since the policy maker's most desirable PIP will seldom, if ever, result in the most desirable SCP. When faced with the situation in which an unpalatable present must be accepted if a palatable future is to be achieved (or vice versa), policy makers will attempt to strike a balance between the desirability of a given intervention and the desirability of a given future. The question then becomes: how much unpalatability is to be accepted <u>now</u>, and how much unpalatability <u>then</u>? How much convenience that could be enjoyed by those living in the present should be sacrificed for the convenience of those who will live in the future?

Societies vary, of course, in the extent to which they make clear their compromises between present and future convenience. But in no society can the link between present policies and subsequent outcomes be traced, because conventional techniques do not provide the information offered by the Forecasting Tables indicated above, nor do they provide safeguards against psychological factors that lead to inappropriate use of large amounts of complex and often uncertain information. As a result, planning often fails because it is largely intuitive. It is the policy consultant's task to remedy this situation. How should he proceed once such Forecasting Tables are made available?

Applying the Techniques of Internal-Systems Analysis to the Trade-Off Between the Present and the Future

Trading off the present for the future is a task that requires judgment; therefore the techniques of internal-systems analysis should be applied to this problem. The simplest way for the policy consultant to proceed is by asking the policy maker to indicate how much weight he would place on the present in relation to the future--when the present is defined in terms of his intervention policy, and the future is defined in terms of his subsequent conditions policy. "Weight" can be expressed by the policy maker by dividing 100 points between the present and the future. This simple step results in expressions of the following kind:

$$J = W_p \text{ (present)} + W_f \text{ (future)}$$

Equal weight would result in J = .5 (present) + .5 (future). When the future is considered to be twice as important as the present, then of course, J = .33 (present) + .66 (future). In short, a weighted sum of the present and the future can be applied to the appropriate columns of the Forecasting Tables indicated above. Various weightings can be used together with a sensitivity analysis in order to discover how large a difference in weights is required to produce a meaningful difference in policy choice.

As an example of the use of such weights, suppose the policy maker places a weight of 0.75 on the present and 0.25 on the future. Now apply those weights to a PIP with a desirability rating of 18 and an associated SCP with a rating of 14. The weighting formula would give us:

$$J = (0.75 \times 18) + (0.25 \times 14) = 17.$$

Judgments such as these, representing the desired compromise policy of the policy maker, can be calculated for each PIP and its associated SCP. If the compromise ratings are then ranked, the combination ranked first constitutes the present Policy Intervention Package and Subsequent Conditions Package that best represent the compromise between the present and the future desired by the policy maker.

Applying weights to the ratings of PIPs and SCPs gives us the best compromise between the policy maker's concern for the present and future for the specific PIP and SCP combinations considered. As indicated above, however, it is essential to know how the policy maker's original policy regarding the present has to be modified in order to accommodate the necessary compromise between present and future as well as knowing how the policy maker's original policy for the future must be modified; it is not sufficient to deal with specific PIPs and SCPs. For unless the policy changes are shown to the policy maker, there is risk that a compromise action will be taken without consideration of its implications for, and changes required in, the original overall policies regarding the present and the future. In short, the policy maker will have lost track of what he is doing. It is the function of the policy consultant to provide the requisite cognitive assistance to prevent that circumstance.

In order to provide this assistance the following procedure can be followed. Recall that each PIP and SCP combination now has a compromise rating associated with it as a result of applying weights to the present and the future. These new ratings are, of course, different from the policy maker's original ratings of PIPs and SCPs because they have been changed to take account of the weighting of the present and the future.

Therefore, the original profiles that were used to evoke the policy maker's original judgments (see Figure 2) now have a new (compromise) judgment associated with them. When these compromise judgments are applied to the original profiles, a new analysis of the parameters (weights, function forms, etc.) of the judgment policy is carried out. These weights and function forms (for both the present and the future) are then shown to the policy maker for his evaluations.

The results of applying this procedure to "President Carter's" policies can be seen in Figures 15 and 16. The compromise ratings used in the judgment analysis were based upon weights of .4 and .6 on the present and the future, respectively. The policy weights shown in Figure 15 should be compared to those shown in Figure 5, which contains "President Carter's" specified policy for the present. This comparison shows that "President Carter" will have to put more emphasis on coal development in the future than his original policy indicated if his desired compromise between present and future is to be achieved. The comparison also shows why "President Carter" cannot implement either his ideal policy for the present nor his ideal policy for the future.

Such information is precisely the information President Carter and other policy makers (as well as their constituents) must have if they are to integrate their social values with scientific information. No procedure, other than that described here will provide that information, and that information is the core of intelligent policy formation in a world of uncertain interdependencies among critical conditions.

```
RELATIVE WEIGHT PROFILE

A:Carter--2ØØØ Compromise
Ø.Ø------------------Ø.5------------------1.Ø      WEIGHT   FUNCT FORM
Energy Growth
AAAAA                                               Ø.13      NEGLIN

Dereg. Oil & Gas (Year)
AAA                                                 Ø.Ø9      NEGLIN

Conservation
AAAAAA                                              Ø.15      POSLIN

Nuclear Development
A                                                   Ø.Ø5      NEGLIN

Coal Development
AAAAAAAAAAAAAAAAAAAAAAAAA                           Ø.58      POSLIN

Ø.Ø------------------Ø.5------------------1.Ø
```

Figure 15. The Intervention Policy "President Carter" should follow if his policy for compromising between present interventions and future conditions (in 2000) is to be achieved.

```
FUNCTION FORM PROFILE
A:Carter--2000 Compromise:MIN =       4.362  MAX =       12.25
  C*A                     *A                     *                  A
  a* AA                   * AA                   *                AA
  r*   A                  *   A                  *               A
  t*    AA                *    AA                *             AA
  e*      A               *      A               *            A
  r*       AA             *       AA             *          AA
  -*         A            *         A            *         A
  -*          AA          *          AA          *       AA
  2*            A         *            A         *      A
  0*             AA       *             AA       *    AA
  0*               A      *               A      *   A
  0*                AA    *                AA    * AA
   *                  A   *                  A   *A
    ******************     ******************     ******************
     1.6           3.5  1976.0         1984.0    15.0          32.0
          Energy Growth  Dereg. Oil & Gas-Year        Conservation

  C*A                     *                  A
  a* AA                   *                AA
  r*   A                  *               A
  t*    AA                *             AA
  e*      A               *            A
  r*       AA             *          AA
  -*         A            *         A
  -*          AA          *       AA
  2*            A         *      A
  0*             AA       *    AA
  0*               A      *   A
  0*                AA    * AA
   *                  A   *A
    ******************     ******************
     5.0          10.0     1.0          10.0
   Nuclear Development       Coal Development
```

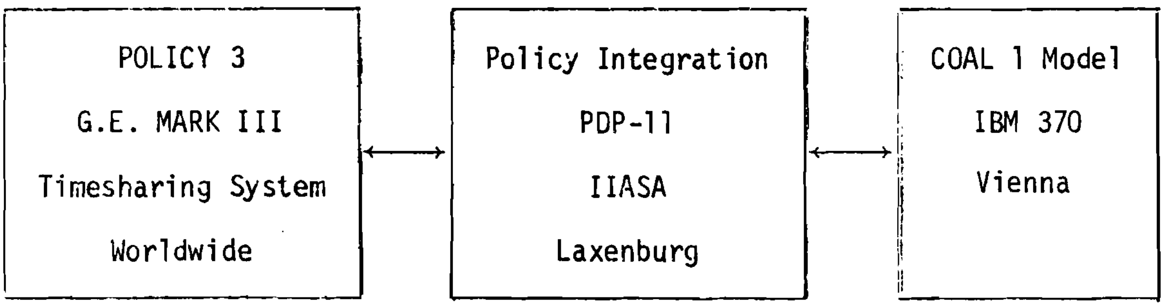
Figure 16. Functional relationships for "President Carter's" policy that would yield a compromise between desirable interventions and desirable subsequent conditions.

Appendix

INTERNATIONAL LINKAGE OF INTERNAL MODELS AND EXTERNAL MODELS VIA COMPUTER INTERCONNECTIONS

In the present example several computers at different locations were interconnected in order to link a model of the judgment process with a model of an environmental process. This procedure, as it stands now, will permit several policy makers in various parts of the world to interact with one another and/or with a computer model and/or data banks stored in various locations.

The interconnections that were used in the present study are broadly depicted below (they are shown in greater detail in Figure 17).



The first set of programs, developed to operate on IIASA's PDP-11, were those necessary to generate the required input for the COAL 1 model. These programs, which were described above, generated a matrix of 50 rows by 63 columns of input values for the COAL 1 model. The COAL 1 model was run on an IBM 370 model 55 computer located in Vienna. The COAL 1 model was operated via a timesharing terminal at IIASA.

The PDP-11 was then programmed to act as a computer terminal to receive the output of COAL 1 from the Vienna computer system. The output

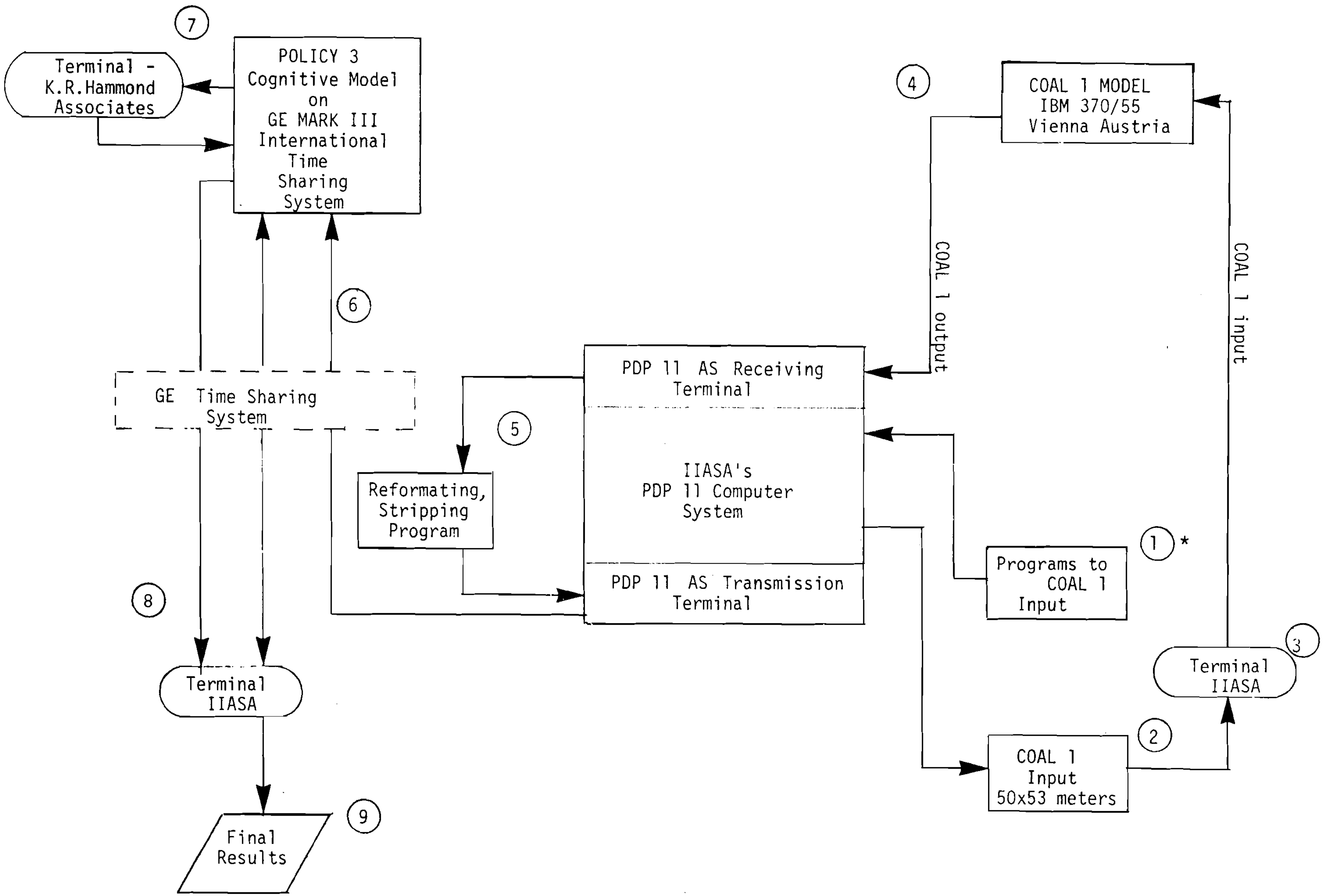


Figure 17. Diagram of International Computer Network System Developed at IIASA

* Note: Sequence of activity is indicated in the various circles

was transferred to the PDP-11 in order to simplify subsequent manipulations of the data and to allow for transfer of the data to other computer systems. A program was developed to select the data required by the judgment model. These data were transferred to the General Electric MARK III® international timesharing computer system, which has computers located in the United States and Europe and access points in some 24 countries. The PDP-11 was again programmed to act as a terminal and the data were transferred via the local MARK III access point in Vienna.

The judgment model, POLICY 3, is available on the MARK III system, and can, therefore, be accessed both from the United States and Austria. The data from COAL 1 were the input to the judgment model. The analyses required for the judgment model were performed in Boulder, Colorado, using POLICY 3 and an interactive statistical package available on the MARK III system. The results of these analyses could then be accessed directly via the terminals available at IIASA.

It should be emphasized that all of the software developed was of a general purpose nature and allows for the ease of automatic transfer of data from one computer system to another. This set of software remains in the possession of IIASA for future activity.

The above described international computer interconnections were developed in the present form for several reasons: First, the interconnections were required in order for us to complete our work. Resources necessary for our work were located at IIASA, Vienna, and in the U.S.A. Consequently, a link between the various resources was required. Second, the various programs developed to provide automatic transfer of data from one system to another were constructed so that they could be used in the future with ease. Third, the interconnections provide an opportunity for IIASA to expand the communication resources of its scientists and their potential interaction with international policy makers. Policy makers need not be located in the U. S. in order to use the above system; they may reside in any of the 24 countries that now use the GE network. It is now possible to link up the IIASA terminals with other networks, or to use a telephone entry and thus link up with Moscow, Warsaw and other countries in the East. Although the COAL 1 model was stored on the IBM Computer in Vienna, we could, of course, have addressed other models on other computers elsewhere.

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