AN INTEGRATED APPROACH FOR IMPROVING DECISION-MAKING PROCESSES

F. Seo

June 1979
WP-79-54

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

Decision-making processes generally have multiple purposes and are made under uncertainty. The objectives are usually noncommensurable and in conflict with one another. The processes are composed of two phases: analytical and judgmental. For treating the analytical phase, mathematical optimization methods such as mathematical programming are efficiently applied. The Nesting method of Lagrangian Multipliers is one device intended to bridge the gap between both phases of decision-making processes. IIASA's System and Decision Science Area has been very involved with multiobjective decision problems. Especially in the Task on Economic Planning and Resource Allocation methodological development for a multicriteria decision-making process has been strongly intended. This study can be seen as one of several introductory and tentative works in this direction. The result will be presented at the International Conference on the Environment: Methods and Strategy for Integrated Development, September 23-29, 1979, Arlon, Belgium.

AN INTEGRATED APPROACH FOR IMPROVING DECISION-MAKING PROCESSES

F. Seo

INTRODUCTION

Decision-making processes are generally multiobjective. Namely, the processes include some complexity; diversification, noncommensurability, conflict, and uncertainty. Due to the diversification of objectives involved in the decision-making processes, the decision-maker is confronted with large-scale decision problems over various fields, such as, social, economic, environmental, and aesthetic. Naturally, the criteria of the decision problems are noncommensurable and usually in conflict with each other. Besides, decisions are usually made with uncertainty. In many cases, the decision-maker cannot wait for obtaining empirical results from mass observation. Thus, he faces a complex decision problem which is called Complex Problematique.

To solve this kind of decision problem, we cannot rely on a conventional monodisciplinary approach. Even though each disciplinary can be tactically connected with another, the monodisciplinary approach lacks comprehensiveness and coherence which are main characteristics of the Complex Problematique. Thus, a more comprehensive and integrated approach--the systems approach--shall be applied.

In this paper a brief introductory description of a sophisticated device for improving decision-making processes is presented, with reference to some examples for application of the methodology.

HIERARCHICAL MODELING OF MULTILEVEL SYSTEMS APPROACH

For modeling the large-scale decision problems in order, a hierarchical modeling of multilevel decision systems shall be formed. Corresponding to an overall decision problem which is partitioned to multilevel systems (Mesarović et al. 1970), an objectives hierarchy is constructed at multiple levels. To solve these decomposed subproblems separately is more computationally efficient than conventional optimization procedures. In this device, the overall decision problems are not necessarily restricted by the size of the problems. The decomposition procedures of mathematical programming have been developed since the Dantzig-Wolfe decomposition algorithm (Dantzig and Wolfe 1960, 1961). Recently, the primal-dual method for nonlinear programming (Lasdon 1968, 1970) has been applied to water quality management by Haimes, Foley and Yu (1972a). Moreover, as pointed out by Haimes (1975), the partitioned subsystem can be individually solved by particular methods in accordance with the nature of the modeling. Thus, the hierarchical systems approach can be used more efficiently for arranging specific characteristics in various aspects of an overall system.

On the other hand, mathematical programming is also considered in a hierarchical structure. Namely, an objective function of mathematical programming represents a "lower-level" objective peculiar to each subsystem. Constraint constants are considered as "upper-level" objectives which are sent from the "upper-level" decision-maker. Decision variables are a normative instrument for achieving these objectives and considered as the lowest-level objectives. Thus, formulations of mathematical programming are considered in the framework of a hierarchical systems structure. In Figure 1, the problem structure is depicted for three level planning--regional, local, and industrial. Here, mathematical programming is formulated as local-level planning. Mathematical programming is solved as a primal-dual problem and dual solution $\underline{\lambda}^1$ as well as primal solution $\underline{x}^1$ are obtained. The framework includes a feedback process. The "upper-level" decision-maker compares the optimal value $\underline{x}^1$ with actual performance $\underline{x}^{1'}$, and can modify his instruction for local-level planning.

Integration of Mathematical Programming and Decision Analysis

The purpose of decision-making processes is to select a set of preferred solutions from among pareto-optimal solutions. This procedure is known as a multiobjective optimization problem. To derive pareto-optimal solutions is an analytical aspect of the decision problem. To select the preferred solution from among the pareto-optimal solutions is a judgmental aspect for the decision problem. Thus, from a methodological point of view, decision problems are composed of two main layers: analytical and judgmental. The analytical aspect of the decision problems has exclusively attached importance in conventional optimization processes. Mathematical programming as well as control theory is a representative technique for the optimization procedure.

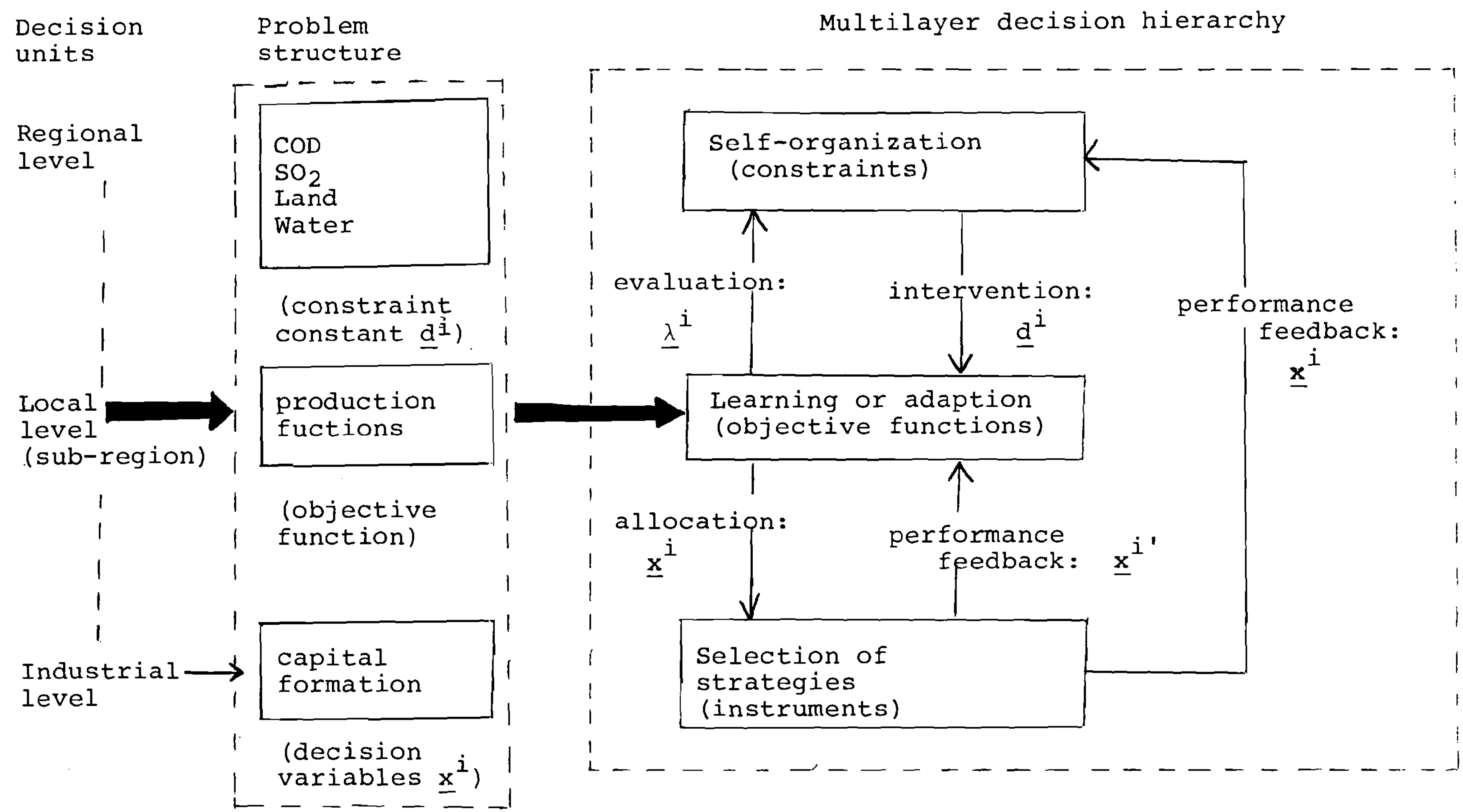

Figure 1. Functional hierachy of local-level planning.

Applications of mathematical programming to environmental management exclusively based on primal problems have shown many good performances since Sobel (1965), Thomann (1965), and Revelle, Loucks and Lynn (1968). Especially multiobjective programming techniques have been developed for environmental management and control, although many developments have been done only in the theoretical aspect (Cochrane and Zeleny eds. 1973), (Zeleny 1974, 1975). Analytical techniques can be exclusively applied to a deterministic phase of the Complex Problematique. However, in mathematical modeling, many ambiguous aspects of actual processes still remain unspecified. Therefore, the discrepancy between model prediction and actual response often misleads the decision-maker. Moreover, entire dependence on rigorous analytical solutions is dangerous because these solutions are generally in conflict with each other and any device for compromising them is not presented by the programming techniques themselves. Constituents may oppose "optimal" policies based on such an analytical solution in their own interest. This shows another discrepancy of formal expectation and social response. Thus, these discrepancies shall be filled by the subjective judgment of the decision-maker or his council board. The judgmental gap composes an indeterministic phase of the Complex Problematique. A device for manipulating this phase is known as decision analysis, which has been developed by Pratt, Raiffa and Schlaifer (1964), Raiffa (1968) and Schlaifer (1969). In these works, utility functions are set up for assessing the degree of satisfaction of performance for attributes quantitatively. In other words, the utility concept is utilized as a score or an index for measuring the worth given to a magnitude of the performance. A procedure for deriving multiattribute utility functions has been established by Keeney and Raiffa (1976). Many examples for application of their methods have been published (Keeney 1975).

The Nested Lagrangian Multiplier Method

A problem we face is how to treat the analytical phase in combination with the judgmental phase of decision problems for solving the Complex Problematique in totality. The Surrogate Worth Trade-Off (SWT) method by Haimes and Hall (1974, 1975) is one device for this approach. An alternative integration method has been presented by Seo (1977) and Seo and Sakawa (1978, 1979). Both methods depend on the derivation of the shadow prices as a base of the systems evaluation. The main objective of our method is to explicitly combine mathematical programming at the first layer with decision analysis at the second layer. A proper procedure of this work is not present in the SWT method. Besides, in our method dual optimal solutions of mathematical programming are directly utilized as inverse images of component utility functions, differing from the SWT method in which the shadow prices are used indirectly for worth assessment.

The outline of our method is as follows.

First, making preference hierarchy. Many objectives which are included in an overall system are decomposed into subsystems, which are subsequently consolidated into a hierarchical system.

Second, constructing mathematical modeling at the first layer. Each subsystem is independent and has its own mathematical formulation. Mathematical programming is solved separately as a single-objective optimization problem.

Third, utilization of dual optimal solutions (i.e. Lagrangian Multiplier) as shadow prices. The shadow prices are regarded as a numerical index which evaluates inversely the degree of performance of the "upper-level" objectives in terms of the "lower-level" objectives. Now consider the following mathematical programming formulation:

maximize

$$f^i(\underline{x}) \quad , \tag{1}$$

subject to

$$h_j^i(\underline{x}^i) \leq d_j^i \quad , \quad j = 1, \ldots, p \quad , \tag{2}$$

$$g_s^i(\underline{x}^i) \leq b_s^i \quad , \quad s = p+1, \ldots, n \quad , \tag{3}$$

where constraint (2) shows a target (soft) constraint imposed by the decision-maker, and constraint (3) a technical (hard) constraint restricted by technological conditions. x^i is a vector of decision variables. Then the Lagrangian function is formulated:

$$L^i(\underline{x}^i, \underline{\lambda}^i, |\underline{d}^i, \underline{b}^i) = f^i(\underline{x}^i) - \sum_{j=1}^{p} \lambda_j^i (h_j^i(\underline{x})^i - d_j^i) - \sum_{s=p+1} \lambda_s^i (g_s^i(\underline{x}^i) - b_s^i) \quad . \tag{4}$$

The inverse of the Lagrangian multiplier in optimal $1/\lambda_j^i$ is an opportunity cost of constraint constants d_j^i traded-off to one additional unit of the objective function f^i because $1/\lambda_j^i = \partial d_j^i / \partial f^i$ in optimal. Thus, the larger λ_j^i is, then the smaller the opportunity cost of d_j^i in terms of one marginal unit of sacrifice of f^i is. In other words, a large value of λ_j^i (shadow price) shows that the degree of satisfaction for present performance level of d_j, the "upper-level" objective, is already high in terms of f^i, the "lower-level" objective.

This interpretation of the shadow prices is almost the same as by Luenberger (1973) and Intrilligator (1971), but is a new version based on the hierarchical structure of mathematical programming.

Fourth, transforming the shadow prices into component utility functions. Based on our interpretation of the shadow prices, we utilize the shadow prices as an inverse image of the utility functions in the lower level. Because numerical values of the shadow prices correspond to a preference ordering of the decision-maker, numerical valuation of utilities is determined by a linear transformation, according to the Von Neumann-Morgenstern theorem (1944)(see next section).

In practice, we choose $0 < \underline{\lambda}_j^i < \lambda_{j\,min}^i$ at $u_j^i(\lambda_j^i) = 0$ and $\overline{\lambda}_j^i > \lambda_{j max}^i > 0$ at $u_j^i(\overline{\lambda}_j^i) = 1$, where $\underline{\lambda}_j^i$ shows a lower bound of λ_j^i and $\overline{\lambda}_j^i$ shows an upper bound of it. Thus, we calculate a linear equation passing through the two points $\overline{\lambda}_j^i$ and $\underline{\lambda}_j^i$ as follows:

$$u_j^i = u_j^i(\lambda_j^i(d_j^i)) \quad ,$$

$$= -a_j^i + b_j^i \lambda_j^i (d_j^i) \quad .$$

The $u_j^i(\lambda_j^i(d_j^i))$ is a component utility function which is related to a target constraint j in subproblem i.

Fifth, deriving multiattribute utility functions. Using the component utility functions, multiattribute utility functions (MUF) are constructed and nested one after another. The procedure for deriving the MUFs is almost similar to the method of multiattribute utility analysis (Keeney and Raiffa 1976), except the evaluation of trade-offs between attributes is based on the normalized utility values. During this process, component utility functions are weighted by the decision-maker and conpromise each other. To include such a coordination procedure in the treatment of various attributes is an eminent characteristic of this method.

Finally, an overall multiattribute utility function is derived for an overall evaluation of the hierarchical system. By this device, a comprehensive project evaluation can be performed and compared for each region and/or each period. The evaluation can be done ex post facto as well as in advance. We call this procedure the Nested Langrangian Multiplier method. The main idea is depicted in Figure 2. Using this procedure, the multicriteria decision problem is reduced to scalar optimization problems in the first step, and then they are coordinated into an overall decision problem in the second step, using the duality of mathematical programming (Figure 3).

$$U = U[\underline{u}^1\{\underline{\lambda}^1(\underline{d}^1)\}, \ldots, \underline{u}^n\{\underline{\lambda}^n(\underline{d}^n)\}]$$

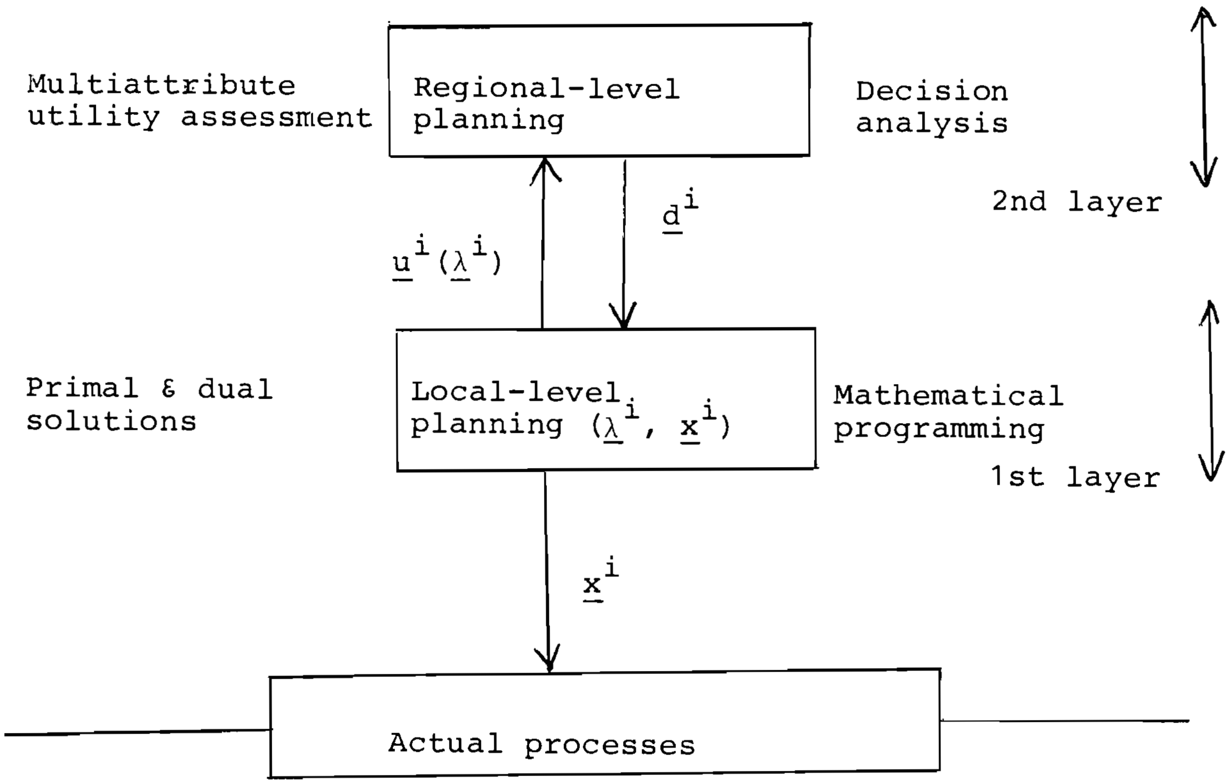

Figure 2. Structure of two layer planning

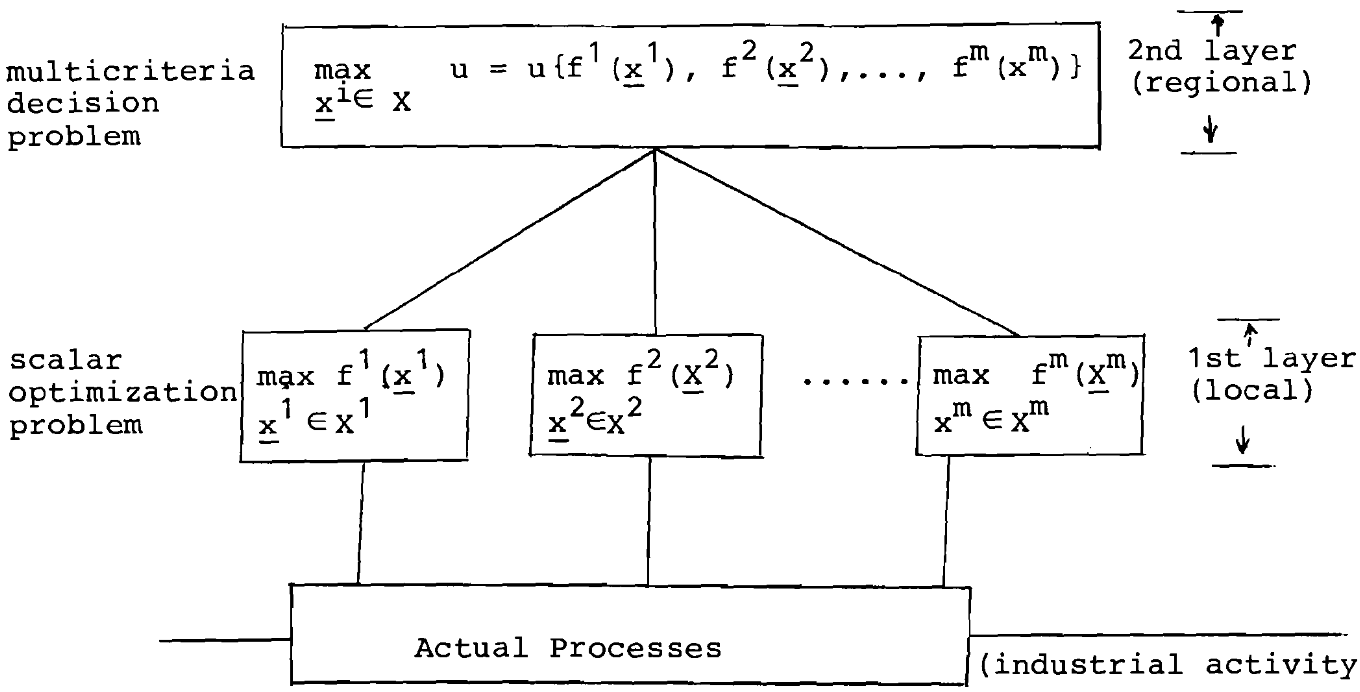

Figure 3. Systems decomposition and coordination in two layers.

Notations in Figures 1, 2, 3, and 5:

$\underline{u}^i$ = a set of multiattribute utility functions for a subproblem i,
$\underline{d}^i$ = a vector of constraint constants for a subproblem i,
$\underline{\lambda}^i$ = an optimal solution set of Lagrangian multipliers for a subproblem i,
$\underline{x}^i$ = an optimal solution set of decision variables for a subproblem i,
u = an overall multiattribute utility function,
$f^i(\underline{x}^i)$ = an objective function for a subsystem i,
X^i = a feasible set for a subsystem i,
$\underline{x}^{i\prime}$ = a vector of actual performance for decision variables.

Concept of the Component Utility Functions

Now a concept of the basic component utility function $u^i_j(\lambda^i_j(\underline{d}^i_j))$ should be explained. First, the Lagrangian Multipliers are defined as an inverse image of the utility functions. In the following, subscripts of notations are omitted because the definitions will be clear.

Define a mapping Ψ such that $\Psi:\Lambda \to T$. Let $\lambda \in \Lambda$, $u \in T$. u is an image of λ by Ψ. A power set $\mathscr{P}(T)$ is a set composed of a total of subsets of the set T. Let a subset of the set T be $\mathcal{U}$. In

$$\mathcal{U} \in \mathscr{P}(T) \quad ,$$

$$\Psi^{-1}(\mathcal{U}) = \{\lambda \mid \lambda \in \Lambda \quad , \quad \Psi(\lambda) \in \mathcal{U}\} \quad ,$$

is an inverse image of $\mathcal{U}$, and $\Psi(\Lambda) = \{\Psi(\lambda) \geq 0 \mid \lambda > 0,\ \lambda \in \Lambda\}$.

Second, along the lines of Von Neumann and Morgenstern's theorem, it can be shown that positive linear transformation of λ to u is admissible.

Define a system of relation $A = \langle \Omega, R \rangle$ and call it to preference relation A. Here Ω is a nonempty set and R is a binary relation defined on elements of Ω.

Definition 1. (preference relation A)

If R is a binary relation on set Ω and if $x, y, z \in \Omega$, then a preference relation A on individual choice satisfies the following axions:

1. Transitivity: if xRy, yRz, then xRz,
2. Weak connectivity: xRy, or yRx,
3. Nonsatiety: if $x > y$ then xpy,
4. Continuity: if xRy and yRz, then there is a real number such that $0 \leq \alpha \leq 1$ and $[\alpha x + (1-\alpha)z]Iy$.

Here R is "prefer to" (p) or "indifferent to" (I).

Definition 2. (Weak ordering)

R on a set Ω is weak ordering if and only if transitivity and connectivity are satisfied. According to the Von Neumann-Morgenstern Theorem, the theorem 1 on the preference relation A is derived (Luce and Suppes 1965).

THEOREM 1. (Von Neumann-Morgenstern)

Under preference relation A, there exists a real-valued function S defined on Ω such that for every y and x in Ω and a paremeter α in [0, 1],

(i) xRy if and only if $S(x) \geq S(y)$

(ii) $S\{\alpha x + (1 - \alpha)y\} = \alpha S(x) + (1 - \alpha)S(y)$

Moreover, if S' is any other function satisfying (i) and (ii), then S' is related to S by a positive linear transformation.

Theoretical background of the NLM method is based on the following proposition.

Proposition

According to the interpretation of Lagrangian multipliers as shadow prices, we replace the Lagrangian multiplier λ with S in theorem 1.

The proposition shows that, because λ is an equivalence (namely, reflexive, symmetric and transitive) set of S based on our interpretation of the Lagrangian multipliers, we can use λ in place of S in theorem 1.

Now these concepts are defined.

Definition 3. (equivalence)

A binary relation R on Ω is an equivalence when it is reflexive, symmetric and transitive.

Definition 4.

1. A binary relation R on set Ω is reflexive is SRS for every $S \in \Omega$.
2. A binary relation R on a set Ω is symmetric if $SR\lambda \rightarrow \lambda RS$ for every $S, \lambda \in \Omega$.

Definition 5. (equivalence classes)

Two elements λ and s of an original set Ω are in an equivalence class when they are equivalent. If a binary relation R is an equivalence, then

$$R(S) = \{\lambda : \lambda \in \Omega \text{ and } \lambda RS\} ,$$

is the equivalence class generated by S.

The equivalence set is a set of the equivalence classes. Based on the interpretation of Lagrangian multipliers as the shadow prices, Theorem 2 and Theorem 3 can be derived. Because in any pair of λ, $S \in \Omega$, $\lambda RS \rightarrow SR\lambda$ can always be assumed.

THEOREM 2.

A set of Lagrangian multiplier λ on a decision problem $D(\underline{\lambda} | \lambda \in \Omega)$ and a set of S defined on Ω in Theorem 1 are in an equivalence class defined on Ω.

THEOREM 3. (Derivation of utility concept)

A Lagrangian multiplier λ can be positive-linearly transformed to a numerical utility u defined on a value between 0 and 1.

The basic idea for deriving the component utility concept is shown Figure 4. For the numerical utility, although differences between the utilities are numerically measurable, the position of origin and the unit of a numerical scale for the utilities can be arbitrarily decided. This type of scale is called an interval scale.

$$\begin{tikzcd}[column sep=huge, row sep=large] S \arrow[r, "\left(\text{LINEAR TRANSFORMATION}\right)"] \arrow[d, equal, "\left(\text{EQUIVALENCE CLASS}\right)"'] & S' \arrow[d, equal, "\left(\text{EQUIVALENCE CLASS}\right)"] \\ \lambda \arrow[r, "\left(\text{LINEAR TRANSFORMATION}\right)"'] & U \end{tikzcd}$$

Figure 4. Derivation of a component utility function U.

Applications

As demonstrations of this method, there are some examples of a case study. A residential problem which maximized nonlinear satisfaction functions of wage earners subject to equity and minimum wage restrictions has been examined in the industrialized Osaka area (Seo 1977). For the same area an industrial reallocation problem subject to environmental (COD, SO_2) as well as resource restrictions (land, water) have been examined (Seo and Sakawa 1979). The problem also has upper and lower bound constraints of decision variables for avoiding radical structural changes. The problem is to maximize local industrial outputs, which are described by Cobb-Douglas type production functions, subject to these constraints.

This problem has been revised for the dynamic model including technological changes (Seo et al. 1978). The revised problem includes 200 decision variables and 25 constraints except upper and lower bound conditions for the decision variables.

These problems have been formulated for four subregions--Osaka, Yao, Daito and Higashi--Osaka cities with their particular parameters. Thus, regional as well as functional decomposition has been performed.

According to the duality of mathematical programming, the optimal resource reallocation (capital formation) problem has been simultaneously solved with evaluation of the environmental management program. With the Nested Lagrangian Multiplier method, the numerical values of the multiattribute utility functions have been calculated in a commensurate term and have been utilized to find trouble spots for carrying out the environmental management policy, which has been imposed by the "upper-level" decision-maker.

Interactive Computer Utilization

For structuring the framework of this method with computer utilization, an interactive or conversational monitor system (CMS) will be recommended. The outline is depicted in Figure 5. Primal and dual solutions of nonlinear programming are separately saved, and then restored an utilized for calculating and assessing the multiattribute utility functions. In a feedback process for parameter-setting, sensitivity analysis can be executed. Technical input factors can also be controlled by scientific policy of the decision-maker in political processes.

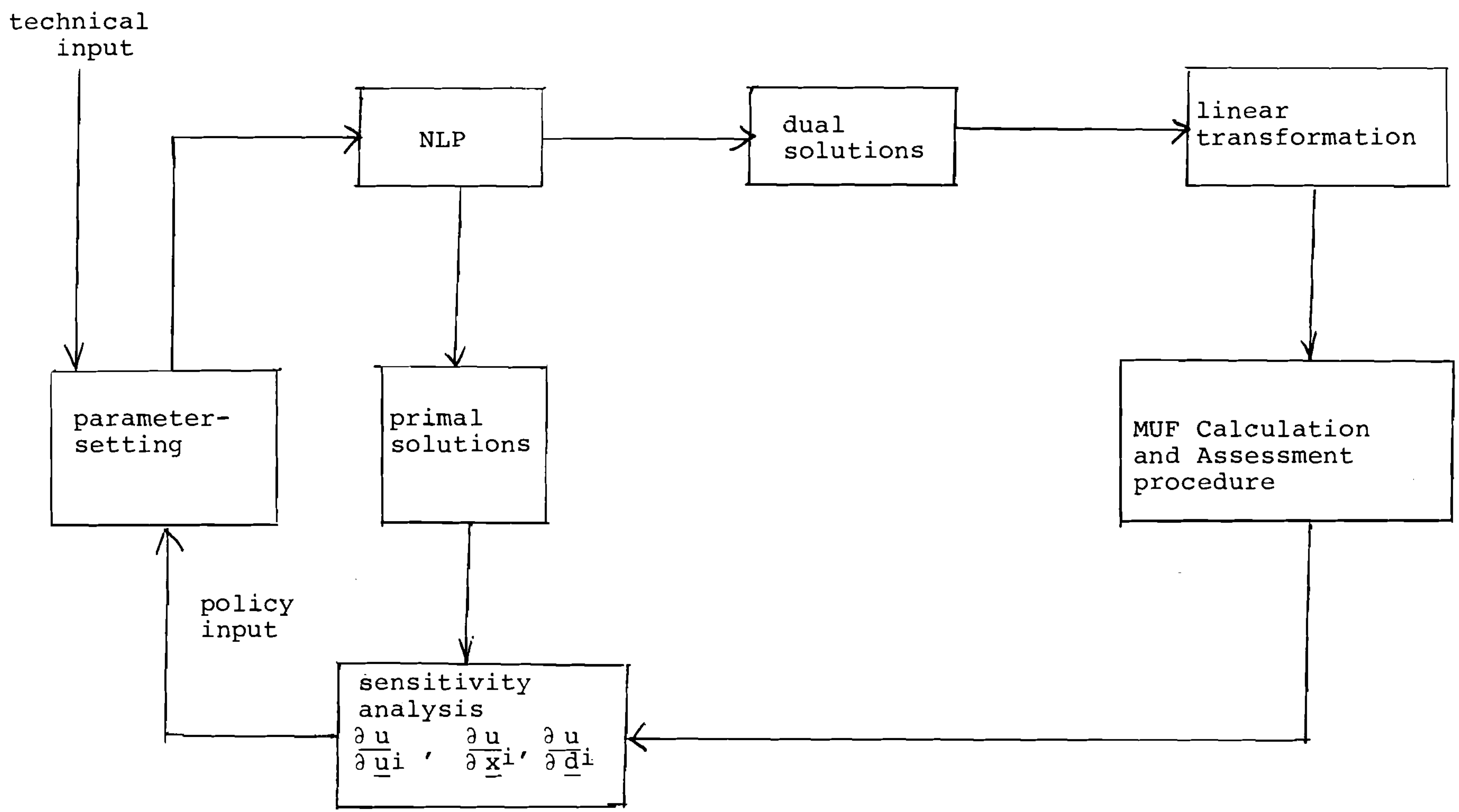

Figure 5. Computational structure fo the Nested Lagrangian method.

Concluding Remarks

The Nested Lagrangian Multiplier method is only one approach which intends to consolidate the analytical and the subjective phase of decision-making processes. The method also includes devices for evaluating noncommensurable attributes in a commensurate term and for compromising each evaluation which is often in conflict with another. Because the numerical values of the shadow prices correspond to preference ordering of the decision-maker, the values are used as inverse images of component utility functions. Multiattribute utility analysis depends on preferential as well as utility independence assumption (Keeney 1974). The system decomposition procedure in our method will contribute to avoiding this difficulty because the value of the Lagrangian Multiplier exclusively depends on each constraint of the independently constructed subproblem.

However, to solve mathematical programming is a rather formidable task. More efficient algorithms for obtaining dual solutions of nonlinear mathematical programming shall be expected. Interactive computer algorithms for calculating and assessing the multiattribute utility functions are also under development. The MUFCAP by Sicherman (1975) as well as MANECON by Schlaifer (1971) present an excellent basis. Graphical representations and a successive revision technique of trade-offs of the decision-maker are cornerstones which are also left in the hands of successors.

REFERENCES

Bell, D.E., R.L. Keeney and H. Raiffa (1979) Conflicting Objectives in Decisions. Laxenburg Austria: International Institute for Applied Systems Analysis.

Cochrane, J.L. and M. Zeleny eds. (1973) Multiple Criteria Decision-Making. South Carolina: University Press.

Coombs, C. H., R.M. Dames and A. Tversky (1970) Mathematical Psychology. New Jersey: Prentice-Hall.

Dantzig, G.B. and P. Wolfe (1960) Decomposition principle for linear programs. Operations Research 8(1).

Dantzig, G.B. and P. Wolfe (1961) The decomposition algorithm for linear programs. Economitrica 9(4).

Fishburn, P.C. (1970) Utility Theory for Decision Making. New York: John Wiley & Sons.

Haimes, Y.Y., J. Foley and W. Yu (1972) Computational results for water pollution taxation using multilevel approach. Water Resources Bulletin 8(4).

Haimes, Y.Y., M.A. Kaplan and M.A. Hauser (1972) A multilevel approach to determining optimal taxation for the abatement of water pollution. Water Resources Research 8(4).

Haimes, Y.Y. (1975) Hierarchical modeling of regional total water resources systems. Automatica 11.

Haimes, Y.Y. and W.A. Hall (1974) Multiobjectives in water resources systems analysis: the Surrogate Worth Trade-Off method. Water Resources Research 10 (4).

Haimes, Y.Y., W.A. Hall and H.T. Freedman (1975) Multiobjective Optimization in Water Resources Systems. Amsterdam: Elsevier.

Hass, J.E. (1970) Optimal taxing for the abatement of water pollution. Water Resources Research 6 (2).

Intrilligator, M.D. (1971) Mathematical Optimization and Economic Theory. New Jersey: Prentice-Hall.

Keeney, R. (1974) Multiplicative utility functions. Operations Research 22.

Keeney, R. (1975) Multiattribute Utility Analysis: A Brief Summary. RM-75-043. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Keeney, R.L. and H. Raiffa (1976) Decisions with Multiple Objectives: Preferences and Value Trade-Offs. New York: John Wiley & Sons.

Lasdon, L.S. (1968) Duality and decomposition in mathematical programming. IEEE Trans. Systems Science and Cybernetics 4(2).

Lasdon, L.S. (1970) Optimization Theory for Large Systems. New York: Macmillan.

Luce, R.D. and P. Suppes (1965) Preference, Utility and Subjective Probability in Luce, R.D., R.R. Bush and E. Galanter, eds. Handbook of Mathematical Psychology II. New York: John Wiley & Sons.

Luenberger, D.G. (1973) Introduction to Linear and Nonlinear Programming. Reading, Massachusetts: Addision-Wesley.

Mesarović, M.D., D. Macko and Y. Takahara (1970) Theory of Hierarchical Multilevel Systems. New York: Academic Press.

Pratt, J.W., H. Raiffa and R. Schlaifer (1964) The foundation of decision under uncertainty: an elementary exposition. Journal of American Statistical Association 59.

Raiffa, H. (1968) Decision Analysis. Reading, Massachusetts: Addison-Wesley.

Revelle, C.S., D.P. Louks and W.R. Lynn (1968) Linear programming applied to water quality management. Water Resources Research 4 (1).

Schlaifer, R. (1969) Analysis of Decisions Under Uncertainty. New York: McGraw-Hill.

Schlaifer, R. (1971) Computer Programs for Elementary Decision Analysis. Boston: Harvard University Press.

Seo, F. (1977) Evaluation and control of regional environmental systems in the Yodo River Basin: Socio-economic Aspects. Proceedings of IFAC Symposium on Environmental Systems Planning, Design and Control. Oxford: Pergamon Press.

Seo, F., M. Sakawa and T. Sasakura (1978) Environmental Systems Evaluation in the Industrialized Greater Osaka Area: Dynamic Application of Nested Lagrangian Multiplier Method. Proceedings of the International Conference on Cybernetics and Society, IEEE-SMC, Tokyo, Japan.

Seo, F. and M. Sakawa (1979) An evaluation method for environmental-systems planning: an alternative utility approach. Environmental and Planning A, 11(2).

Sicherman, A. (1975) An interactive computer program for assessing and using multiattribute utility funcitons. Technical Report 111, Operations Research Center, Massachusetts Institute of Technology.

Sobel, M.J. (1965) Quality improvement programming problem. Water Resources Research 1(3).

Thomann, R.V. (1965) Recent results from a mathematical model of water pollution control in the Delaware Estuary. Water Resources Research 1(3).

Von Neumann, J.V. and O. Morgenstern (1944) Theory of Games and Economic Behavior. New York: John Wiley & Sons.

Zeleny, M. (1974) Linear Multiobjective Programming. Berlin: Springer-Verlag.

Zeleny, M., ed. (1975) Multiple Criteria Decision-Making. Berlin: Springer-Verlag.