# METHODS FOR ANALYZING THE EFFECTS OF APPLICATION OF DECISION SUPPORT SYSTEMS IN R & D DECISIONS

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*Comparative analysis on application of decision support systems in R & D decisions*



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## COLLABORATIVE PAPER SERIES ON COMPARATIVE ANALYSIS ON APPLICATION OF DECISION SUPPORT SYSTEMS IN R & D DECISIONS

This series of papers are a product of collaborative research coordinated through IIASA's Management and Technology Area. The collaborating institutions are Hungarian State Office of Technical Development (personnel: Anna Vari, Janos Vecsenyi, Laszlo David); Decision Analysis Unit, Brunel University, England (Personnel: Patrick Humphreys, Lawrence D. Phillips); All-Union Research Institute of Systems Studies, USSR (Personnel: Oleg. I Larichev).

The papers report case studies prepared by the personnel from the collaborating institutions based on their own, and their colleagues' work in their own institutions. They worked together as a team in developing the methods for the analysis of these case studies which are described in the first paper in the series.

IIASA provided support for this work through its telecenter for communication between the investigations, and provided facilities for short term meetings between the investigations at IIASA for development of case studies and their comparative analysis. Particular MMT staff were Ronald M. Lee, Nora Avedisians, and Miyoko Yamada, who is the editor of this series.

A summary of this comparative analysis, based on the first four case studies in this series was presented at the IFIP/IIASA Conference on *Processes and Tools for Decision Support*, Laxenburg, Austria, July, 1982.

The papers in this series are

1. Humphreys, P.C., A. Vari and J. Vecsenyi: Methods for analyzing the effects of application of Decision Support Systems in R & D decisions (CP-82-69).
2. Vari, A. and L. David: R & D planning involving multicriteria decision analytic methods at the branch level. (CP-82-73).
3. Vecsenyi, J.: Product mix development: strategy making at the enterprise level. (CP-82-74).
4. Larichev, O.I.: A method for evaluating R & D proposals in large research organizations. (CP-82-75).
5. Humphreys, P.C. and L.D. Phillips: Resolution of conflicting objectives in evaluating R & D projects involving collaboration between industry and higher education. (CP-82-xxx, forthcoming).

The paper presented at the IFIP/IIASA conference will be published as Humphreys, P.C., O.I. Larichev, A. Vari, and J. Vecsenyi, Comparative analysis of decision support systems in R & D decisions, in H.G. Sol (ed.), *Processes and Tools for Decision Support*, Amsterdam: North Holland, 1982. Another study in this series was published separately as L.D. Phillips: Requisite decision modeling: a case study. *Journal of the Operations Research Society*, 1982, 33:303-311.

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# METHODS FOR ANALYZING THE EFFECTS OF APPLICATION OF DECISION SUPPORT SYSTEMS IN R & D DECISIONS

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## I. INTRODUCTION

This paper describes the methods for evaluating the effects of the application of decision support systems used in a series of case studies prepared through a collaborative project within IIASA's Management and Technology Area. The case studies describe R & D decision-making activities at various organizational level in United Kingdom, Hungary, and the U.S.S.R. The authors of the case studies are members of the institutions which developed the decision support systems used in the cases analyzed, and were themselves participants in the decision-making process. However, a measure of objectivity has been introduced into the reports through the use of a common analytical framework in their preparation, discussed *in each case* between members of the team from all three countries participating in the project. Here we discuss the nature of this

common analytic framework, and its application to the case studies.

In recent years much effort has been spent developing and applying decision support systems in the field of R & D planning (technology assessment, product mix planning, governmental policy making, etc., c.f., Boichenko et al. 1978, Mansfield 1978, Seo and Sakawa 1979, Souder 1978). While successful implementations have been documented it is more common to find that the role actually for the DSS in the overall decision-making process was much more limited, and quite often at variance with that anticipated by its designers, or by the personnel who introduced the DSS into the decision-making process (von Winterfeldt 1982). Some of these limitations have been due to

(a) the adequacy of the applied tool and methods with respect to the goals of the analysis.

(b) the readiness of the individuals and organizations involved to understand and accept the DSS.

Another difficulty stems from confusion about how exactly DSS should be defined. There is as yet no formal theory of decision support and "Decision Support Systems" (DSS) is partly a rallying cry (Keen and Hackathorn 1979). Here we adopt a very general view of what might constitute a DSS using the provision definition of a set of procedures involving the systematic use of tools, techniques, methods, etc., which support

- the generation of decision alternatives
- the elicitation of models, values, premises, etc.

- the estimation of consequences of possible decisions
- the ranking of the alternatives in order of acceptability

In the case studies reported in this series, some elements of these procedures were computer-based, but the "system" as a whole involved procedures carried out by individuals, in interaction with others within an organizational context.

Most published research has emphasized the methodological problems related to the use of R & D decision aids (e.g., inappropriateness of the models, c.f. Humphreys 1981), and underlined the need for the better understanding of the R & D planning process itself. The R & D planning process varies greatly from organization to organization. In some organizations it is a Black Art unable to be understood by anyone while in others it is itself both a scientific process and a process subject to scientific enquiry. As Ojdana and Weyant (1976) point out:

> It is far more important that organizations have systematic procedures and logical organizational structures to assure that the major R & D planning tasks are effectively accomplished.... Quantitative techniques and computerized models are not likely to improve the effectiveness of a poorly implemented R & D planning process.

Reasons why it is important to make systematic investigation of the effects of application of DSS in this context include:

(a) Decisions concerning the allocation of R & D resources are of great importance in all developed countries, with regard to the relatively high ratio of R & D expenses within GNP.

(b) R & D decisions are usually connected with complex resource allocation problems which require a multiple criteria approach taking into consideration the high degree of uncertainty of successful research and implementation. Because the number of alternatives, the complexity of the problem and the involvement of a number of different interested parties, DSS should play an increasing role in this field. There is a pressing need, which this project is designed to meet, to understand how this role can be optimized.

(c) Cross-national investigation of the use of DSS could explore the general methodological problems and promote joint research and should also be useful in researching situations involving several national perspectives.

(d) Culture-dependent differences in thinking and behavior — explored by cross-cultural studies (e.g., Hofstede 1980) as well as by studies reporting on the pitfalls of transfer of decision analytic tools from one country to the other (Vari and Vecsenyi 1982) — have profound consequences for the development of DSS tools for supporting R & D decision making at the national as well as at the international level.

IIASA has already initiated cross-national studies in other fields like decision making for low probability events (Kunreuther 1982a) and gaming (Stahl et al. 1981). The analysis of DSS use in the field of R & D planning carried out in this project complements these studies.

## II. OBJECTIVES AND SCOPE OF THE RESEARCH

The main objectives of the research reported in this collaborative paper series were:

(a) to develop a methodology for describing the process of DSS implementation and application in R & D planning for evaluating its effectiveness.

(b) to describe typical patterns of DSS usage in R & D planning and to identify the factors which mainly influence its effectiveness under different circumstances.

(c) to define a conceptual basis for proposals for the development and introduction of DSS in different R & D environments.

The starting point of our research was the selection of the cases to be analyzed. From the point of view of comparability it was necessary to develop a taxonomy of R & D planning tasks in terms of:

- institutional background of the decision making (governmental, corporate, etc.);
- level and perspective of the decision (macro or micro level, strategic, tactic or operative);
- type of the problem (e.g., budget allocation, selection among R & D alternatives, etc.).

We decided to analyze cases which had common features on these criteria, limiting our study to cases connected with the planning of ***directed and applied R & D*** in three countries (United Kingdom, Hungary, the USSR) in which the personnel, or their colleagues in the participating

institutions were directly involved at a consultancy level. The nature of the five cases selected for comparison is summarized in Table 1.

The cases include a wide variety of decision aiding tools, although our analysis was restricted to cases which were centered on the application of *methods which support the generation of decision alternatives, the estimation of their consequences and selection of the best alternatives.*

## III. DEVELOPING THE METHODOLOGY FOR THE DESCRIPTION AND EVALUATION OF DSS USAGE IN R & D

R & D planning in real life is a continuous process with sequential variety in the pattern of activities and participants involved. The conceptual framework used here requires that we first divided up the process into interconnected segments which can be separately modeled, together with the specification of linkages between these segments. This involves

*Table 1.* Characteristics of cases selected for comparison.

| Case No. | Type of the problem | Level and perspective | Institutional background | Country |
|---|---|---|---|---|
| 1. | Introduction of a new product | micro level, strategic | company | UK |
| 2. | Product mix development strategy making | micro level, strategic | company | Hungary |
| 3. | Budget allocation between R & D projects | branch level, strategic | state authority | Hungary |
| 4. | Evaluation of R & D proposals | top level, strategic | state authority | USSR |
| 5. | Evaluation of R & D projects | top level, strategic | collaboration between government departments | UK |

identifying a sequence of rounds, and stages within each round in the planning process, as well as specifying the level (or levels) of the decision-making activities within the round.

### A. Rounds and Stages

Our definition of a "round" follows that proposed by Kunreuther (1982b) for the multiattribute, multiparty model of choice developed at IIASA for examining the decision process involved in siting liquid energy gas facilities (Kunreuther et al. 1981). Kunreuther states

> A round is simply a convenient device to illustrate a change in the focus of discussion either because (1) a key decision was taken (or a stalemate reached due to conflicts among parties) or (2) a change occurred in the context of the discussions due to an exogenous event, entrance of a new party or new evidence to the debate ... no matter how a round is initiated it is characterized by a unique problem formulation which is presented in the form of a set of attribute.

Within our models of R & D decision making we identify a set of "stages" within each round. A stage should be clearly located in terms of those stages which precede and follow it, and should have well defined inputs and outputs. The outputs from a stage may serve as inputs to the immediately following stage in the round, or to any defined subsequent stage in the round. The converse holds for inputs to a stage. Inputs and outputs between rounds are generally less well defined as a boundary between rounds generally represents an untheorized discontinuity in the planning process. At the start of a new round outputs from previous rounds tend to be picked up and interpreted as inputs in ways unanticipated during the previous round.

We have sharpened Kunreuther's point (2) in the definition of a round to imply that the exogenous change which marks the end of the round must be such that the anticipated pattern of input-output relations between the stage currently activated in the round and subsequent stages is disrupted or abandoned. Hence there must be a radical re-conceptualization of the stage sequence in the R & D decision process before it can continue, and the effect of doing this is to start a new round.

At each stage the "unique problem formulation" to which the round is addressed will be represented in a different form. Where a DSS is employed will be addressed, in theory at least, to structuring, gaining inputs to and/or manipulating content within the current form of the problem representation. Here it will be important to examine whether the problem representation to which the DSS is addressed is "requisite." Phillips (1982) describes what is ideally involved here:

> To develop a requisite model, it is necessary to involve all those who are in some way responsible for aspects of the decision in the development of the requisite model. The process of building the model is iterative and consultative, and when no new intuitions emerge about the problem, the model is considered to be "requisite." In requisite modeling, it is expected that people will change their view of the problem during the development of the model; that is why the process has to be iterative.

It is necessary to invoke the criterion of "requisiteness," as there is no external criterion against which we can gauge the model. Phillips points out that concerning R & D problem solving there is (without hindsight) no external reality to be modeled: the model is the reality. The ideal described by Phillips is rarely met in practice, but it gives us some clues about questions to ask in examining the degree of "requisiteness" extant in actual applications, viz: Are all those who are in some way

responsible for currently modeled aspects of the decision involved in the development of the model? Are intuitions emerging about the decision in personnel currently involved or responsible for subsequent actions which are not incorporated in the model? Is the modeling process iterative in a way that can encompass changing or different views?

**B. Levels**

R & D policy making usually progresses at several levels. These may be bureaucratically determined, where different strata are charged with policies with different scopes and time horizons (e.g., a department management stratum dealing with the evaluation of the characteristics of a particular product; a general enterprise management stratum dealing with problems of introduction of positively evaluated new products; a corporate or sector management stratum dealing with the future of the enterprise within a wider plan, and so forth). However, while relations may be determined between classes of problem structure which may be "requisite" and the level management stratum considering those problems in an organizational hierarchy (Jaques 1976), these relations do not fully determine the nature of the problem representation which should be supported by a DSS designed for use at any particular level. This will depend also on the nature of the task, the available input and outputs from other rounds and levels in the process, the structure of the organization (Phillips 1980) and the training roles and motivations of the participants. Within any one round of the decision process, "officially" located at the level of a defined stratum we may find participants operating at different levels of problem conceptualization. In these cases some

participants may find the DSS addressing their conceptualization of the problem, but others will not.

### C. Participants in the Round

Within any round, a large number of participants may be involved, acting variously as *decision makers* (defined as those who have the executive power to define the use of outputs from the round); *proposers* (those who have power only to make recommendations on this); *experts* (those whose primary function is to supply inputs to the currently modeled problem structure); *consultants* or decision analysts (those who advise on methods of problem representation) and making process, but who are in a position to facilitate the collaboration of experts, the transmission of the results within and between rounds, and so on). A "communication analysis" of interactions between participants in the round, if conducted using traditional methodology (c.f. Handy 1981:chapter 6) is likely to reveal confused polygons of relationships. However, clarity can be greatly improved by examining the pattern of interactions within each *stage* within the round where only certain channels will be open, and where the roles of participants may be defined in relation to the state of problem representation and DSS in use at that stage. Participants may also serve as links between stages, or rounds, carrying certain information with them, but this is a process which can be studied separately.

**D. Motivation of Participants in the Round**

In the case studies outlined below we will be looking primarily at that round in the R & D planning process where a new form of DSS was introduced for the first time. We shall limit our consideration to cases where the DSS was introduced by one of the participants in the round, with the consent of those other participants with executive powers. We shall see that it is very important to understand the motivation of the participants in the round, as this will affect the results they expect from the DSS, and how they view their significance (Berkeley and Humphreys 1982). Various participants in the round may have very different motivations.

A decision maker may have a very strong motivation to apply decision analytic methods implementing DSS in situations involving many complex R & D proposals. In such cases a decision maker has practically no avenue of influence on decision processes except through the utilization of decision rules superimposed on expert evaluations. DSS helps the decision maker to increase the centralization of decision making in this way. This interest of the decision maker is the basis for successful application of the DSS. It is hazardous to expect success if the decision maker simply seeks a prescription, perhaps not even wishing to participate in criterion weighting procedures (stating, for example, that he is "not interested in the debates amongst the scientists").

A proposer may wish to employ a DSS to get proof of support of experts; while already having some idea of what will make the project acceptable to those who will consider his or her recommendations. Here some of the motivation has to do with the possibilities of manipulation (Humphreys and McFadden 1980), which can lead to particular interest in

a DSS which has simulation capabilities under alternative scenarios. It is often the proposers who introduce consultants, as this might serve their own interest in the subsequent acceptance of their proposals. The consultant's principal motivation, as an outsider, is usually concerned with the acceptance of the procedures he or she introduces, which in the case studies discussed here were linked to the DSS. Other motivations potentially in conflict with this might be for power ("behind the throne"), status ("consorting with the great"), social beliefs (promoting the "decision culture"; improving "organizational democracy") or self image (to be a "helping person").

While the motivation of a participant in the round can be translated into goals which are superordinate to the expected results of the round, the extent to which this will lead to a positive orientation towards DSS usage will depend upon how the effects of DSS are perceived at the outset of the round. Some of the relations involved here are shown in Figure 1.

Perceptions of effects of DSS usage usually change with experience, particularly in cases where individual participants start with potentially conflicting goals, leading to incoherence in their approach to problem generation in the round. Often, DSS have been found to be most effective in aiding the decision making process through the resolution of such incoherence (Jungermann 1980, Humphreys and McFadden 1980) helping people to decide *in general*. In this case, one would expect that the long term effects of successful DSS usage would lead to perceptions more like that shown in Figure 2.

*Perceived effects* *Goals*

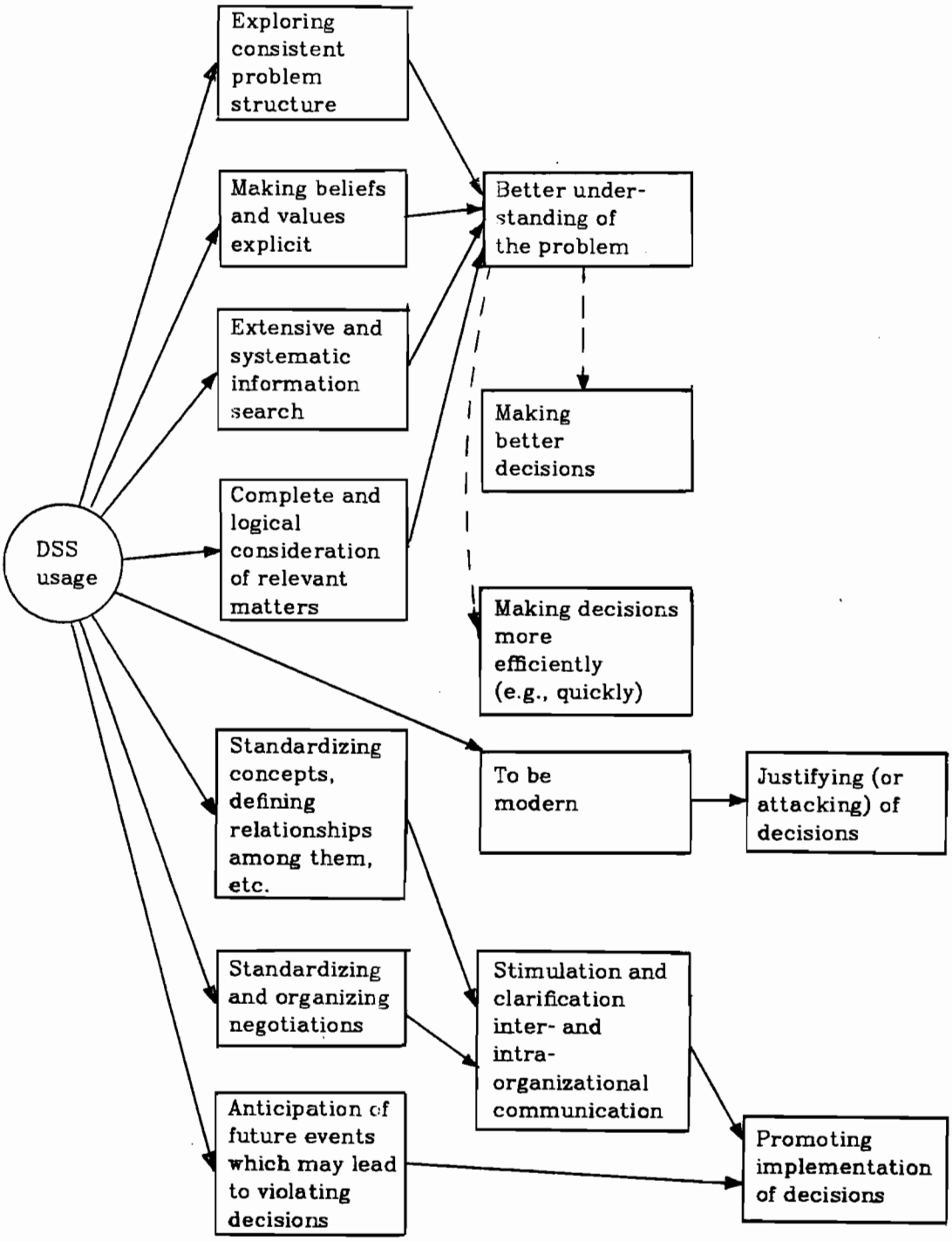


*Figure 1.* Some relations between perceived effects of DSS usage and goals of a participant in a round.

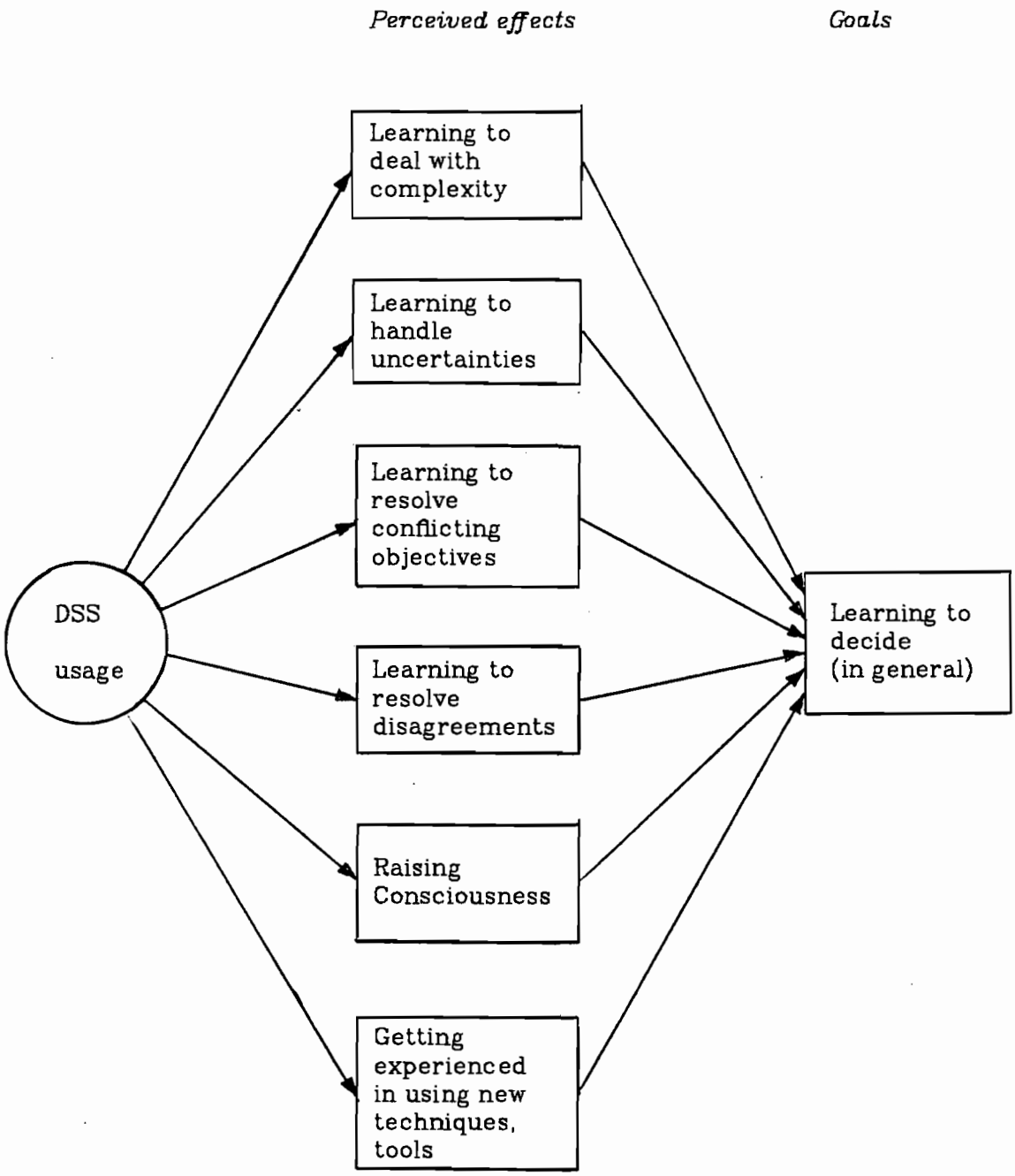


*Figure 2.* Possible long-term effects of DSS-use.

**E. Responsibility**

The relationship between motivation and perceived effects of DSS depends also on the responsibility a participant holds or wishes to assume. A "high level" decision maker with responsibility for implementation of policy may use the report from a decision analysis as justification for the policy. In effect this shifts responsibility in the case of failure onto the report and its creators and where a DSS has been explicitly involved it often ends up collecting a large share of the blame.

Proposers may attempt to structure a problem to fit the preferences that they believe held by those with executive responsibility to whom they report. They may be more sensitive to their own position and career prospects than to an effective outcome, and it is with regard to these prospects that they may examine the "requisiteness" of a problem representation constructed through the use of the DSS.

In view of possibilities like these, we hypothesize that motivation and responsibility will interact in determining DSS acceptability in the way shown in Figure 3.

**F. A Check List for Developing R & D/DSS Case Studies**

The issues raised in the previous section imply that, in comparing R & D/DSS case studies, one should develop a framework whose components are connected with:

(a) the organization and procedure of R & D planning

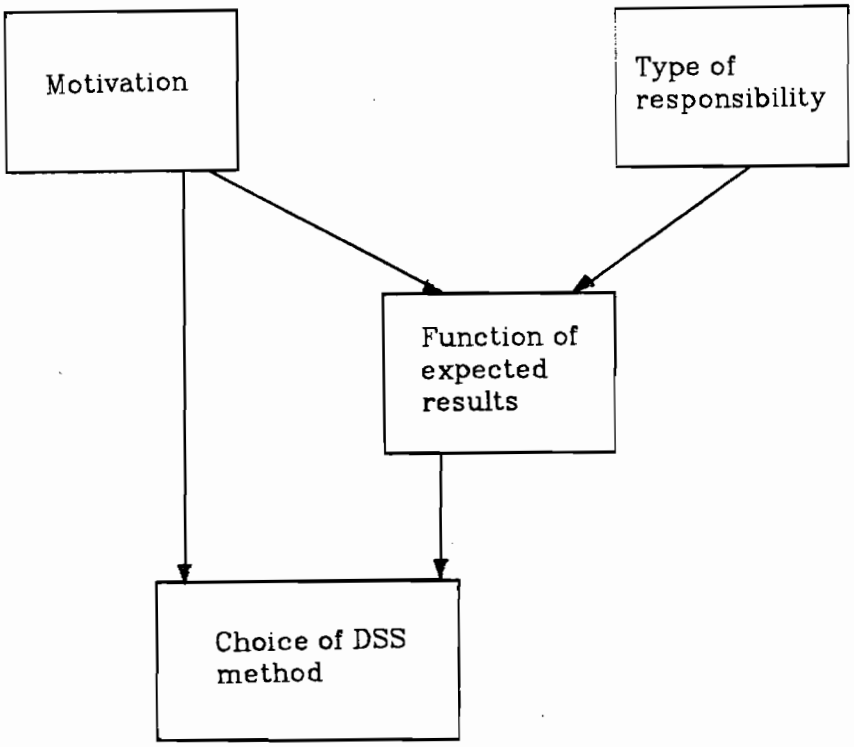


*Figure 3.* Hypothesized effects of motivation and responsibility on choice of DSS.

(b) the goals to be achieved by using DSS within the context of (a) (e.g., better understanding of problems, stimulation and clarification if inter- and intra-organizational communication, persuasion, etc.; (see Figures 1 and 2)

(c) the expected and the actual role of the consultants and of the other participants in stages of the decision process within the round

(d) the expected and real function of inter- and intra-organizational communication within and across stages in the round (e.g., group negotiations)

(e) the requirements for information (e.g., the required number of alternatives, attributes, and scenarios regarded simultaneously), and its mode of availability

(f) the way of handling uncertainties

(g) the way divergent views are reconciled.

From this framework we developed the checklist reproduced in the appendix.

## IV. CONDUCTING THE CASE STUDIES ACROSS COUNTRIES

The checklist was used in the analysis of cases in R & D decision making where the authors and their colleagues acted as consultants (together with researchers acting as assessors). Details of the analyses of the various cases are given in the papers listed in the preface to this report. In the following we introduce the cases by summarizing the decision problems underlying the cases to be investigated.

### A. Introduction of a New Product: Maritime Engines and Motors (MEM)

This study was located at the board level in a single medium-sized British company (MEM) manufacturing outboard engines and small maritime motors (the name of the firm and its product have been changed to maintain confidentiality). A single R & D decision had to be taken between continuing to manufacture an old product that might in the near future be banned by the government for failing to meet exhaust emission standards or introducing an improved product that would beat the ban might lose market share to competing products using micro-chip

technology. The company was unable to move directly to a chip-based product as it did not, as yet, have the required technology and so any product introduced in the next few years would have to rely on improvements in conventional technology.

This problem started off 'ill-structured' (Larichev 1982a); at the outset there was confusion on the decision makers' minds concerning the nature of the problem domain. For example, in anticipation of the possible effects of changed environmental pollution regulations, does one have to consider the possibility of a change of government, in the next ten years, and predict the changed policy that would go with it?

Details of the case study describing the effects of introduction of DSS in this context are published in Phillips (1982); comparisons between the findings from this study and those outlined below are made in Humphreys et al (1982).

**B. Product Mix Development Strategy Making by Chemical Works**

This case is concerned with a Hungarian chemical works whose future was uncertain. The works was producing plastic articles, pesticides, intermediaries used in the pharmaceutical industry and a variety of other organic and non-organic chemicals. Recently its rate of development had decreased, it had economic troubles and the ministry wanted to reduce its autonomy by fusing it with a larger enterprise. In what was seen as a last chance for the chemical works, new top managers were invited to help in solving the company's problems and to formulate a strategy for its development.

At the outset, the problem was defined on the selection of products to be developed, maintained or omitted from the product mix. This selection was based on multiattribute utility assessment of the actual products in the mix. Following the initiative of one of the new managers, the method of decision analysis (and the supporting computer software) was developed by a team of consultants (decision analysts from the Bureau for Systems Analysis of the Hungarian State Office for Technical Development and the Technical University, Budapest).

This, however, was only part of the overall R & D policy making for CW, which was to determine the development and production strategy for the next one to five years. Details of the development of this DSS, and the effects of its use as a *proposal* support system in two rounds of decision making within CW, are given in Vecsenyi (1982).

### C. Budget Allocation Between R & D Projects at the Branch Level

This case was located in a Hungarian state authority which is responsible for a sector of services at the national level. The authority has from time to time faced the problem of budget allocation among R & D projects. Because of the heterogeneity of the R & D activity in the field, the projects, as well as the rounds of the usual decision making processes, were arranged on a three level hierarchy comprising main areas (first level), programs (second level), and tasks (third level). However, each second level program comprised a set of tasks which were not rigidly defined, and each first level area comprised programs which were not rigidly pre-determined, and so decisions arrived at sequentially would not necessarily be consistent. The need for more clearly established and

better organized rounds as well as the need for harmony across the different rounds motivated the decision makers of the authority involved in R & D planning to initiate the development of a suitable procedure formalized as a DSS.

Details of this DSS and experiences with its use in two rounds of R & D decision making are given in Vari and David (1982), together with a discussion of the insights it provided concerning the decision makers' views of R & D planning process.

### D. Top Level Decision Making on R & D Proposals

This case study investigates the appropriate use of DSS at the top level, approaching the problem from the standpoint of a large interdisciplinary research institute in the USSR and from the point of view of the planning office heading a number of research institutes.

In each case the problem concerned the acceptance and rejection of R & D project proposals. Selection was based on a series of evaluations of the proposals submitted by various experts. The decision maker's first task was to make a choice of a set of the best alternatives to be integrated into the R & D plan. His second task was to compare both the accepted and rejected proposals in order to define the merits of the proposal developers. The decisions had to be made as the individual proposals came in. Yet the criteria for choice of projects had to be stable and set *a priori*. Moreover, these criteria, and values on them were all expressed in verbal terms.

Details of the development of a DSS with the capability of structuring these criteria in interaction with the decision maker *a priori* (before the proposals arrived) are given in Larichev (1982). Factors which were crucial to the successful adoption of the DSS in a number of rounds of top level decision making are also identified.

## E. Evaluation of R & D Projects Involving Collaboration Between Higher Education and Industry

This case was located in a British government department where a decision had been taken to develop an award scheme for R & D projects which involved successful participation between industry and higher education. The goal was to encourage, through the publicity which (it was hoped) would be given to the award winning project, active and sustained collaboration between universities, polytechnics and colleges of higher education and industrial companies, with the aim of stimulating improvement in the competitive performance of British industry and commerce. To this end a committee had been set up to develop and structure the criteria to be used in evaluating potential candidates for an award. Candidate projects were expected to be submitted as proposals resulting from publicizing the existence and nature of the award.

The committee comprised senior representatives of higher education institutions, sectors of industry and the two branches of government involved in sponsoring the scheme, the departments of industry and education. At the outset there was little agreement between decision makers on the committee concerning the important criteria, and confusion about their possible interrelations.

Details of the subsequent development of a DSS, structuring the criteria and defining the publicity and evaluation scheme for the award are given in Humphreys and Phillips (1982). This collaborative paper describes the procedures used in interaction with the decision makers to develop the goals to be met by the award, to gain agreement on the requisite structure for the criteria and on the weights to be assigned to individual criteria (and groups of criteria) within the structure. Experiences with the use of the DSS in evaluating the proposals which were subsequently submitted are also reviewed in this paper.

## APPENDIX: INFORMATION REQUIRED IN DEVELOPING CASE STUDIES

1. **Starting point and character of the overall decision problem**

   1.0 How did the problem arise (institutional, organizational and personal backgrounds)

   1.1 What is the character of the problem?

   — requiring single decision? decision will probably be reconsidered in the near future? will be reconsidered within a given period?

   — where is the decision horizon set? long-term, middle-term or operative

   1.2 Does the overall decision problem involve more than one round? if so, where is the round studied located in the overall sequence of rounds?
   At what level is the round located?

   1.4 In what way was each of the following predetermined or constrained for this round?

   (a) structure of the problem (alternatives, criteria, etc.)

   (b) institutions involved

   (c) individuals taking part in the decision making

   (d) methods to be used

   1.5 Who initiated the use of the decision support system(s) employed in this round?
   Who had interactive access to the DSS?
   Who had access to the DSS output?

1.6 What kinds of results were expected from the application of the DSS by each of the parties involved (decision makers, consultants, system implementers)?

(a) personal information resource

(b) information sharing resource

(c) communication of information

(d) simulation of problem representation and content

(e) prescriptions for action

(f) rationalization for action

1.7 What kind of motivational factors can be revealed in the way DSS was used?

(a) by the initiators

(b) by other users in the round

**2. Description of the decision making process**

2.1 What were the stages in the round?
Were they, and their sequencing, habitual or innovative? How do they relate to established practice?
What type of structuring and modeling activities dominated each stage?
How were outputs and inputs linked between stages?

For each stage:

2.2 Who participated?
At what level of modeling did each participant operate?

2.3 What procedures were used?
Which of these involved DSS?
Did the procedures differ from those habitually used by participants in similar cases?

2.4 Process within the stage (use process tracing methodology here)

(a) What opinions (concerning anxieties, uncertainties, criteria, weights, alternatives, evaluations) were revealed by the participants, and in what forms?

(b) How did the opinions alter in the course of the stage; what types of arguments were used?

(c) Were there divergences of views, were they acknowledged at the start, or how did they emerge?
How were they reconciled, accommodated or overcome?

(d) What input was supplied to the procedures, how and by whom?

(e) How were uncertainties and conflicts about information values handled?

(f) Were simulations or sensitivity analyses conducted?
Were these supported by the DSS?
Who directed these analyses?
Who had access to the results?

2.5 What were the characteristic features of the problem structure generated at this stage?

- alternatives?
- criteria, and their nature (qualitative, quantitative)?
- representation of information about alternatives on criteria?
- modeling of uncertainties?
- structural organization (modular, hierarchical, network, dynamic)?
- types of linkage in the structure (act-event, conditioning event-event, decomposition of consequences)?
- method of construction and function of decision rules (select an alternative, divide into groups, etc)?
  Did the function and assumptions of the decision rule match the aims of the decision makers?

2.6 Results of the stage

- was it abandoned (and did this lead to the abandonment of the round, or resequencing of the planned stages?) Or was it successfully concluded?
- what were the outputs of the stage, and where were they taken up?

**3. Method of DSS employed within the round**

3.1 By whom, and on the basis of what criteria, was the method of decision support determined. Were alternative decision support systems considered, and why were they rejected?

3.2 Give a short description of the methods employed within the DSS (models, tools, search procedures, group interaction techniques, etc.)

3.3 What outputs, inputs and interactive procedures were available in the DSS? Which of these were utilized?

3.4 What were the perceived constraints on usage of DSS (availability of input required by the system, users, format and interpretability of output)

3.5 What was the nature of the interface between the DSS and the decision makers? To what extent were decision makers' immediate aims in using the DSS facilitated or frustrated by this interface?

3.6 Features of DSS usage:

- role of decision makers, staff and line personnel, outside consultants experts, etc., in the course of DSS usage?

**4. Questions of adopting the DSS**

4.1 What was the readiness (disposition) of accepting the DSS by the individuals and organizations involved in the round? what kind of resistance was experienced, and in what degree?

4.2 How intense was the participation of the middle- and top level managers in the development, implementation and usage? of the DSS?
What sort of practice and capability did the decision makers acquire in the DSS usage?

4.3 Can data represented in the DSS during this round be updated?

- during this stage of the round?
- during subsequent stages in the round?
- during subsequent rounds of the same decision problem?
- in subsequent applications of the DSS in other problems?

4.4 Will it be possible to use the DSS itself unaltered in subsequent applications. If not, what sort of modifications are necessary, and why?

4.5 Can the DSS be extended to similar problems encountered in the organizations participating in the round?
Under what conditions?
What features of the decision-making process outlined above may help or hinder the institutionalization of the DSS usage
Why?

**5. Results and effects of the decision-making process**

5.1 What were the presuppositions of the decision makers concerning the solution? Do the suggestions given on the basis of the analyses developed during the round differ from these presuppositions? In what ways?

5.2 Did the measures taken consequent on the decision rounds studied differ from the suggestions emanating from these rounds? If so, what were the causes?

5.3 What characteristics of those identified in the previous sections, could you identify as contributing to the success or failure of the DSS within this R&D context?

5.4 How do you evaluate the DSS usage (in terms of the expectations formulated in 1.6, above)? What are the principal positive and negative effects of these? Which factors caused these effects?

5.5 Did the interventions involved in making this study have an effect on

(a) the decision-making process?

(b) DSS usage?

(c) implementation of results.

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