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ABSTRACT

This paper presents an R & D planning system (RDPS) that consists of (1) a multistage model for formulating projects and (2) a "reward" model for selecting projects. The system is based on a combination of decisionmaking and operations research approaches. Using the system concept, the R & D process is defined in three interrelated terms -- mission, goals, and objectives -- that serve as the radix for generating projects in multistages. The project selection model is used to select projects that maximize expected total "reward" within budgetary limitations. The proposed RDPS can be used to concentrate and coordinate research and development activities. (Author)

DEVELOPMENT TRAINING RESEARCH

THE DEVELOPMENT OF A RESEARCH AND DEVELOPMENT PLANNING SYSTEM IN EDUCATION

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CENTER FOR OCCUPATIONAL EDUCATION

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PREFACE

The concept of research and development is a relatively recent addition to the field of education. Not too many years ago, most educational research was carried out by individual researchers from different fields of study, either working alone or in small teams. These men identified problems, found a source of funding, and then attempted to solve the problems they had identified. Over the years a great deal of research has been very successfully carried out in this manner. However, with the growing recognition of the magnitude of the problems facing those in education today, the need for purposeful direction in research has become apparent. The funds available for research are not sufficient to support all the work that needs to be done. Thus, some system must be developed that will lead to an efficient and effective use of available resources.

In subsuming a part of the educational research enterprise, research and development centers were a response to the problem of the lack of integration and direction in educational research. However, they have proven to be only a partial answer. They have moved toward the narrowing of research directions into manageable channels, but as yet they have not been as successful in providing an integrative and additive affect for the research which has been produced. Recognizing this problem Dr. Vivekananthan has developed a planning system for educational research and development which may help to overcome some of the present problems in research and development, and help the centers achieve their full potential.

The Center would like to extend its appreciation to Dr. Vivekananthan for developing the system, to Dr. Donald Drewes of North Carolina State University who provided consultation in the development of the planning

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John K. Coster
Director

SUMMARY

This paper presents a R & D planning system (RDPS) that consists of (1) a multistage model for formulating projects, and (2) a "reward" model for selecting projects. The system is based upon a combination of decision-making and operations research approaches. Using the system concept, performance of the R & D process is defined in terms of three interrelated terms: mission, goals, and objectives. These serve as the radix for generating projects in multistages. The project selection model is used to select projects that maximize expected total "reward" within budgetary limitations. The proposed RDPS can be used to concentrate and coordinate research and development activities.

INTRODUCTION

Chase (1970) has indicated that the educational R & D organizations have set themselves "to provide educational agencies with carefully designed and tested products, processes, and systems appropriate to their goals and functions." A unified, integrated planning system can help the R & D organization to achieve this goal. The present paper is addressed to the development of such an overall planning system suited to educational R & D organizations, based on a mission-oriented approach. It should be emphasized that this is only one of many possible planning systems. (For a different approach, see Vivekananthan, 1971.)

As generally used, the term "planning" refers to the development of a detailed method, formulated beforehand, for doing or making something. Planning thus implies a coordinated activity with a concentrated purpose. Planning also serves as a vehicle for controlling and directing activities.

For our purpose, the planning system is defined as a comprehensive operating scheme to cover R & D activities. The R & D planning system consists of (1) a procedure to systematize the formulation of projects, and (2) a project selection model to optimize the expected returns of R & D efforts within resource constraints.

Basis for Formulation of Projects

The machinery for generation of educational R & D projects to be carried out by a center must be based on what the center is expected to perform. For this purpose the systems approach is very useful.

The systems approach helps to view the research and development process as an entity and not simply as a combination of some research and some developmental activities. Research and development is thus considered as a set of interrelated processes for dealing with problems. Coordinated efforts are required in solving the problems. The R & D process being defined as a system has a clear-cut mission. Incorporation of this fundamental assumption is necessary for the development of the planning system.

System performance has meaning in the context of three mutually dependent terms: mission, goals, and objectives. Mission is the ultimate aim of the system, that is, what will have been accomplished at the end of the terminal phase. The system implements this ultimate purpose through a series of preliminary activities performed through time and phases. As such, the mission is achieved through desired outcomes over time and phases. Desired outcomes are the goals of the system. Those functions which assign utility (value) to outcomes are termed criterion measures. Each goal is assumed to have measurable units. Objectives are defined as desired states of criterion measures of performance. They are precise and specific measures of goals. In other words objectives are the desired outputs from the system needed to accomplish the goals. The system outputs react with environmental states to produce desired outcomes. The objectives indicate the system performance in measurable units and, as such, they reveal how well the system is progressing towards attaining the goals.

The three concepts--mission, goal, and objective--as they are defined, form the base from which projects can be formulated in multistages. At each stage a mission-profile is drawn that illustrates the major sequential activities, the profile is used to segment the mission. The segments are classifications of activities in the profile which are arbitrarily selected on the basis of both homogeneity of operations or coherence within the segment, and easily recognized start and stop points. Once a mission is stated clearly, the feasibility of segmenting the mission can be explored.

After segmenting a mission into goals and the goals into objectives at the first stage, one goal area serves as a mission for the second stage. The mission profile of the second stage aids in deriving the goals and objectives of that stage, and ideally the goals of the second stage are the objectives which pertained to the goals of the first stage. The multi-stage transitional process is depicted in Figure 1, and illustrated with an example in Figure 2. Stage 1 in Figure 2 may be viewed as a breakdown at the center level. The center mission is broken down into programs and subprograms. Stage 2 can be considered as a breakdown of the programs. At stage 2, programs are broken down to subprograms, and subprograms to sub-subprograms. At stage 3, the subprograms are broken down to sub-subprograms, and sub-subprograms to sub-sub-subprograms. The process is continued until a convenient stage is reached to formulate projects.

Stage 1	Stage 2	Stage 3	
Mission	Mission	Mission	. . . .
Goals	Goals	Goals	. . . .
Objectives	Objectives	Objectives	. . . .

Figure 1 "Multi-stage" Transitional Process

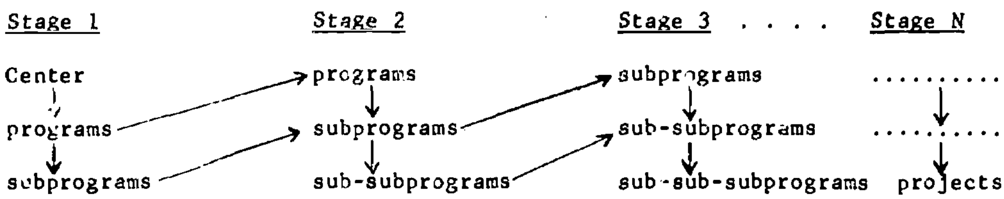

Figure 2 An Example of the Multi-stage Transitional Process

One goal area of the second stage forms a mission to the third stage, one goal area of the third stage forms a mission for the fourth stage, and so on. The transitional process can be stopped at the most convenient stage. Following this procedure, ten objectives are arrived at in Figure 3.

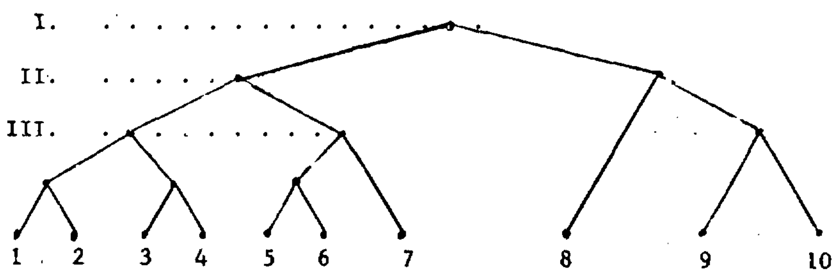

Figure 3 A Process of Deriving 10 Projects

Each of the objectives of the last stage forms a problem area for investigation and as such, an objective dictates formulation of a project. A project, in this sense, incorporates one of the objectives as its main theme of research. A project is thus aimed to deal with an objective.

Who Formulates Projects?

The first problem to arise in the implementation of the planning system is who is going to segment the mission. One of the most interesting solutions to this problem comes from Bloom (1968): "This writer (Bloom) suspects that a theory must be formulated by one person, preferably the leader of an R & D center, and then altered as the result of heated debate by a group."

An alternative method is the use of the Delphi technique (Helmer, 1966). The Delphi procedure is a method for systematically soliciting, collating and developing a consenses of expert opinion. The Delphi method replaces direct confrontation between members of a decision-making panel with a series of questionnaires that feed back information collected from the members. The questionnaires cover the members' statements and the reason for their statements. The information is kept anonymous and redistributed to the members who may then revise their statements in the light of the statements of others. The process is continued until a satisfactory consensus is obtained. The Delphi method requires a decision-making panel.

The decision-making panel can segment the mission to goals, and goals to objectives. The panel can use the following guidelines in stopping the multi-transitional process.

When to Stop the Multi-Transitional Process?

The multi-transitional process can be terminated at a convenient stage. The information requirements of the system determine the convenience. Meehan's (1968) notion of scope, precision, power, and reliability can be used to determine the information requirements in a statement of objectives.

The scope of a statement of objectives indicates the range of information that the project will yield at the project's completion. If the scope is too wide, it loosens the precision of information in that it may be vague and ambiguous. Too broad a scope may trap many areas without a well-defined purpose of research. On the other hand, too narrow a scope produces outcomes which are minute and applicable to a very limited area, giving collected information that is very detailed but restrictive. The scope of the statement of objectives ought to be between the two extremes.

The precision of a statement of objectives refers to the exactness with which the projected outcomes are related to real outcomes. It refers to specificity and accuracy of information. The multi-transitional process is stopped as the objectives achieve the required precision level. Too precise information would reduce the scope; a broad scope would reduce the precision level. Decision makers have to decide on the trade-off between scope and precision level.

Power bears upon the notion of relevance of the project outcomes to the goals. As such, power deals with how much control the objectives would provide in integrating the information gleaned from the projects with the goals. A weak statement of objectives may do no more than suggest the relevance of the outcome of the project to the overall mission without stipulating the nature of the outcome, while a strong statement of the objectives would readily show the relevancy stipulated in precisely measured terms. Powerful objectives would help to integrate project outcomes into attaining the overall mission of the Center.

Reliability has to do with repeatability in arriving at the objectives. Reliability, thus, deals with the question of "Would the same set of objectives be generated if the transitional process is repeated again?" The discrepancy between segmentations is revealed only by observation and intuitive judgment. Usually, reliability can be increased by decreasing the precision of the statement of objectives. Reliability will be lower as the multi-transitional stages increase. In other words, a larger number of stages would decrease reliability and a smaller number of stages would increase reliability.

The multi-transitional process is stopped when the objectives have sufficient scope, the needed precision level, enough power to integrate, and when the transitional process has adequate reliability. The number of objectives there are at the last stage of the transitional process would govern as many projects. After objectives are formed, project statements are written by interested investigators.

The investigators choose objectives relevant to their interests from the generated pool of objectives and write project statements incorporating the objectives of their choice.

The investigator details in the project statement the methodology to be followed in attaining the stated objective. The methodology includes design of the investigation, statistical techniques, data collection method, and similar information. The investigator also indicates the amount of time required to complete the project. He presents a schedule of activities. Estimated expenditures are also listed in the project statement. Expenditure or data collection, field trips, data analysis (cost for computer use), and other expenses are estimated by the investigator. Each project statement will include a budget to carry out the project.

The multi-transitional process provides a rationale and justification for project formulations. Actually projects are formulated by the investigators. The multi-transitional process simply supplies objectives that investigators use in formulating projects. In order to attain the stated mission, the projects have to be executed. Some projects may have more utility than others, which leads to project selection process.

Project Selection Model

Since the resources available may not be sufficient to support all projects which are formulated by the investigators, a systematic procedure is required to select projects that can be accommodated within available resources.

With the notion that a systematic project selection procedure helps to visualize the expected payoff for the resources expended, the development of a project selection model should incorporate three basic variables: (1) utility of a project, (2) uncertainty, and (3) constraints. Utility refers to a project's contribution to accomplishment of the mission of the center. The utility is realized when a project is successfully completed. However, there is uncertainty involved in project completion. In the case of R & D Centers, the uncertainty refers to the probability of successful completion of a project.

Assuming that there are not enough resources to carry out all the projects, there is a constraint that is levied on the selection process. The constraint refers to the condition that the total required resources are within the total available resources.

A project is carried out because it would yield a certain amount of "return" at its termination. The return from a project is assumed equal to the utility of the project. However, the utility cannot be realized fully unless the project is completed successfully. Because of the uncertainty associated with successful completion, one can only estimate the "expected return" rather than the actual return from a project at its termination. The expected return (R) is, following probability theory, a function of utility and probability of successful completion. In mathematical notation the function can be described as follows:

$$R_i = U_i \cdot P_i,$$

where

R_i = expected return from the i^{th} project,

U_i = utility value of the i^{th} project, and

P_i = probability of successful completion of the i^{th} project.

It is assumed the U_i and P_i are fixed for a given period of time. In other words, during the decision-making period the values of utility and probability do not change.

The actual decision-making problem is to select a set of projects from the total projects generated such that the cumulative expected returns from the selected projects is maximum. In other words, we have to select a combination of projects whose expected returns (R_i)* when added would give a higher total of expected returns than any other combination of projects. This maximization problem can be formulated as:

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*The expected return (R_i) looks similar to Ward Edwards' notion of subjective expected utility (SEU). However there are differences between R_i and SEU. In SEU, the sum of probability values across all outcomes is equal to one. In the project selection model, for each project the probability ranges from 0 to 1. The SEU model allows selection of only one action from a list of possible actions. The project selection model does not place a restriction on the number of projects which may be selected. There is also no resource constraint in the selection process of the SEU model. The project model takes into account the given resource constraint.

Maximize

$$A = \sum_{i=1}^{N} R_i \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where

R_i = expected return from the i^{th} project,

A = anticipated reward (cumulative expected return), and

N = number of selected projects.

It can be seen that in order to maximize the anticipated reward, A, all generated projects have to be selected. That is, the highest anticipated reward can be obtained when all generated projects are carried out. However we know that all projects cannot be carried out because there are not enough resources to carry out all the generated projects. Actually, it is given that there is a limited resource available sufficient to accommodate only a subset of generated projects. The selection criteria should satisfy the resource constraint.

It costs a certain amount of resources to carry out a project. As stated earlier, the available resources limit the selection to a subset of projects. The resource constraint is such that the would-be alloted resources to the selected projects should not exceed the available resource. Letting C_i stand for a project's cost and T for total available resources, the constraint can be stated as follows:

$$\sum_{i=1}^{N} C_i \leq T, \quad \ldots\ldots\ldots\ldots\ldots (2)$$

where,

C_i = required resource for the i^{th} project,

T = total available resources, and

N = number of selected projects.

Combining equations (1) and (2) the project selection problem can be formulated as follows:

Maximize

$$A = \sum_{i=1}^{N} R_i \qquad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

such that

$$\sum_{i=1}^{N} C_i \leq T.$$

The problem is to find a value for N and to identify the projects, i. This is, the project selection problem is to find the subset of projects to be selected and also the content of the subset. The problem can be solved by an iterative process or more precisely by the dynamic programming technique (Beckman, 1968). Forming the project selection problem as a knapsack problem in dynamic programming (Beckman, 1968), the dynamic programming method would give the number of projects the subset contains and the content of the set of the selected projects. The method would also indicate the anticipated reward for the total required resources. The variables that are used in the project selection model require numerical values. Procedures to estimate variable values are suggested in the following section.

Estimation of Variable Values

The project selection procedure requires that values be stated for project utility, probability of successful project completion, project cost, and total resources available. A project's utility represents the contribution that a project would make toward achieving the overall mission. The project utility value depends, therefore, on how crucial the project contribution is and how close it comes to achieving the mission. The project whose contribution is both significant in terms of achieving the mission and also close to achieving it would have a high utility value. Closeness is defined in terms of number of stages required in attaining the overall mission. For example, a project covering an objective of the first stage in the multi-transitional process is closer to the mission than a project covering an objective of one of the later stages.

In order to estimate the utility value, a procedure similar to computing a probability estimate following the Markov Chain process (Kemeny and Snell, 1960) can be adopted. For example, at each segment stage an arbitrary value of 1 can be distributed to goal areas, indicating priority levels. Allocation of priority can be based on some predetermined level of importance. Another arbitrary value of 1 can be distributed to the objectives in a goal area. Such a procedure is illustrated in Figure 4.

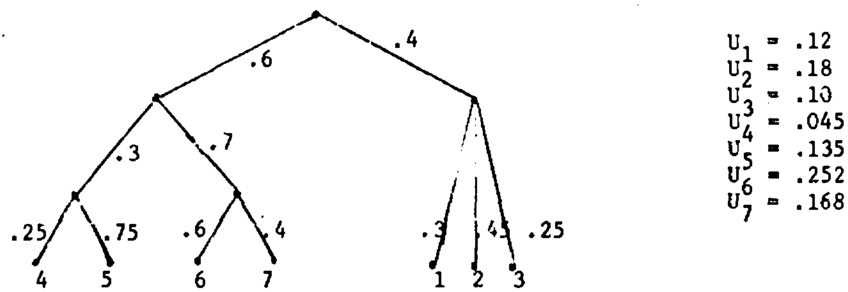

Figure 4. Markov Chain Procedure to Compute Utility Scores

A project utility value can be obtained by multiplying the numerical values following along from the top of the Markov chain tree to the appropriate objective. For example, the utility of the project dealing with objective 1 in Figure 4 is $U_1 = (.4) \cdot (.3) = .12$. The project utility of objective 5 is $U_5 = (.6) \cdot (.3) \cdot (.75) = .135$. Allocation of priority values can be done by one man or by a panel of experts. When a panel of judges is used, the Delphi technique can prove very valuable.

The project statements supplied by the investigators can be used in ascertaining the probability of successful project completion. The probability is conceived in terms of the amount of risk involved in attaining the stated objective in the project statement. Amount of risk is assumed to be a function of proposed methodology in the project statement, investigator's ability and competency, and estimated time required for project completion. If the project statement offers ill-conceived methodology and inadequate techniques of investigation, at the completion of the project it will fail to achieve the stated objective in the project statement. Sound methodology is useless unless the investigator possesses the abilities to put the method in operation. Thus, not only sound methodology but also the ability and skill of the investigator seems to add to the quality of the project statement. A certain amount of time is required to complete a job. The time element refers to the months or years required to complete a project successfully. If the time to complete a project is not properly estimated the probability time would be low. The time element is very important, particularly in adopting the PERT or CPM techniques.

An instrument can be prepared covering all relevant technical aspects of a project statement to ascertain the probability of completion. The instrument can follow the rating scale format. A method of arriving at a numerical value for this probability needs investigation.

Another variable that requires estimation is the project cost. The project statement indicates the amount of money that would be required to carry out the project. Other expenses such as salary for the investigator and overhead expenses can be added to the estimated project cost, thus giving a gross estimation of project cost. The gross estimated cost (C_1) can be used in the project selection procedure.

The total resources available (T), is assumed as given for the decision-maker. The resource here means dollar amount. From normal accounting procedures and knowledge of available funds it is assumed that the user can calculate available dollar amounts for R & D purposes.

A fundamental assumption in the Research & Development Planning System (RDPS) is that all objectives which are developed using the multi-transitional process should be satisfied, i.e., projects covering all objectives should be completed to achieve the overall mission. However, it may be true that all projects cannot be carried out at one time because of a resource constraint. After the projects initially selected are completed, the project selection model may then be applied to the remaining projects. When doing this, the utility values are recomputed with completed projects being assigned utility values of zero. This assumes, of course, that other resources have become available.

Implications of the RDPS

The project generation procedure can show programmatic thrust. After the projects are completed, the results can readily be integrated and easily assimilated. By following the RDPS the centers can rationalize and justify the projects that the centers undertake. The RDPS also helps to evaluate the centers' progress, show the direction in which a center is moving, and in concentrating the R & D activities.

The project selection model can serve as a tool in decision-making The educational centers are mostly supported by the USOE. The number of projects that a center can undertake depends on the size of the grant by the USOE. Whenever the decision-maker suspects that the size of the grant may change, he has to make decisions on what projects to undertake and what not to undertake. The project selection model can ease some of his worries. The decision-maker can manipulate the model by changing the total money level, T. He can evaluate the project potentials at different levels. Accordingly, he can select projects within the available money. It should be remembered that the project selection model does not replace the decision-maker. The model simply serves as a guideline in making decisions. The project selection model by no means determines the final decision.

Conclusions

The planning system that is proposed in this study appears to have intuitive validity. Implementation of the system proposed in this paper would help to alleviate the present diffuse project selection situation by leading the educational R & D centers to more rigorous project selection and concentrated and coordinated research and development activities.

The intentions of the educational R & D centers, according to Boyan and Mason (1968), require the management ability and the organizational desire to marshall extraordinary human and financial resources into well-designed sets of continuous and cumulative programmatic activities. The planning system developed in this study would seem to support these intentions.

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