Innovations in Management of Research and Development

Diane Chrzanowski Roberts, Office of the Secretary of Transportation, U.S. Department of Transportation
Martin M. Stein, Socio-Economic Group, Maryland Department of Transportation

Effective management of research and development requires effective analysis and evaluation of its programs and projects. At the project level, for example, it is not enough that an effort meet the requirements set forth in the project's work statement; it must also advance or implement an organization's policy. Implementing policy and changing it when necessary is what an effective organization is all about, and its program structure should reflect this. This paper demonstrates an approach to evaluating research and development activities that attempts to achieve this ideal.

A synthesis of management science techniques, including Ackoff's theory of human communication (1, 2, 3) as adapted by Martin (4), and Forrester's theory of systems dynamics (5, 6, 7), was developed to evaluate the significance of projects and programs and their potential contributions, as well as subjective performance factors that may influence the outcome of each individual project or program. A Policy Interaction Potential (PIP) Index was devised to evaluate both the projects and the program containing them in terms of three functions—information, instruction, and policy. These functions were assigned weights that assist in decision making. The informational components carry the least significance and the policy components the most. A simple equation was devised to produce numbers that provide management with information concerning the extent to which its research and development effort is supportive of its policies.

A lot of money is spent on research and development (8)—in 1975 about $34.3 billion (2.3 percent of our gross national product). A more detailed picture of the national research and development effort in 1975 shows that, in terms of funding sources, the federal government provided 53 percent ($18.2 billion), while industry contributed 44 percent ($15 billion). Industry performed 70 percent of the work ($23.9 billion) and the federal government 15 percent ($5.2 billion). For state research and development expenditures, the latest figures available are for 1973, when $340.3 million was spent, more than 63 percent by the federal government.

About 20 percent of our gross national product consists either directly or indirectly of transportation of one kind or another. The U.S. Department of Transportation (DOT) share of this for research and development in fiscal year 1976 is more than $416 million. The total DOT figure represents about a 6 percent increase over that for fiscal year 1975 (9).

The PIP Index was applied to programs and projects at three different levels—international, federal, and state. On the international level, DOT's International Cooperation Program (ICP) was used, at the federal level we used DOT's Federal Highway Administration (FHWA) Federally Coordinated Program of Research and Development in Highway Transportation (FCP), and at the state level we use the Maryland Department of Transportation's Annual Work Program (AWP) under the Systems Planning and Development Division.

DOT has cooperative arrangements with more than 25 countries and international organizations. This gives the department access to foreign research and development activities, and the results of these activities are applied to the solution of U.S. transportation problems. Cooperation takes the forms of information and personnel exchanges, complementary research, and task and cost sharing.

FHWA's FCP sets up research and development activity centered on the most critical problems in seven major categories (10). In this paper, we will analyze category 3—Environmental Considerations in Highway Design, Location, Construction, and Operation. The FCP also coordinates the work of state agencies, private industry, research organizations, universities, and federal agencies.

The Maryland Department of Transportation's AWP is funded by federal, state, and local revenues. In fiscal year 1976, $225 000 was expended for research and development. These studies support a multimodal transportation planning and programming process (11).

EVOLUTION OF THE PIP INDEX

Research and development planning and control techniques

Publication of this paper sponsored by Committee on Management Review.

Figure 1. Project PIP Index for DOT's International Cooperation Program in Poland.

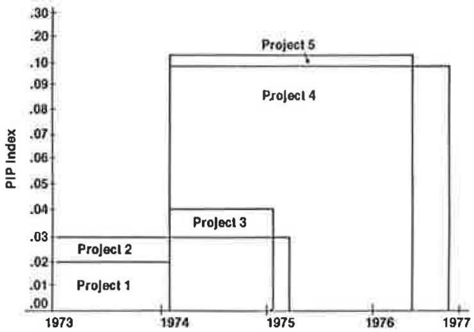
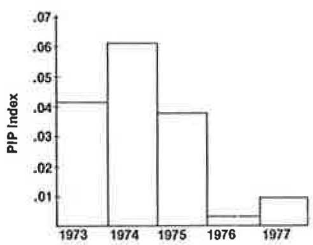


Figure 2. Project PIP Index for FHWA's Project 3B.



were used as a basis for setting up the PIP Index. Our major focus, however, was on Forrester's industrial/ systems dynamics, since it has direct input into the PIP Index.

Systems dynamics was developed by J. W. Forrester (5, 6, 7) as a model of organization. Edward Roberts (12, 13) adapted this concept for a dynamic planning and control system for research and development. Roberts was critical of other planning and control techniques because he felt they lacked the basic element of a control system—the human variable, the scientist or researcher. It is the individual who evaluates the progress of a research and development activity; if the individual is not motivated, he or she will be nonproductive and completion time will be affected. Roberts, however, neglected to provide adequate measurement criteria for individual behavior.

This omission was remedied by Ackoff (1, 2, 3), who proposed a theory of human communication by defining "purposeful state," which is based on an individual's perception of his alternative courses of action, probabilities of outcomes, and alterations in the initial conception of a purposeful state. Martin (4) adapted Ackoff's theory and proposed three levels of communication. He called the first level, which refers to information, "inbits"—a message that provides knowledge of new courses of action. He called the second level, which refers to instruction, "hubits"—a message that changes an individual's evaluation of the outcome of alternative courses of action. The third level, which refers to motivation or policy, he called "mobits"—a message that changes an individual's value of the worth of the outcomes of certain actions. This represents a hierarchy from inbits at the most elementary level to mobits at the most sophisticated level. This classification was applied to research and development programs and projects.

The PIP Index is divided into Project PIP and Program PIP. These indices involve a functional relationship and are calculated as follows:

$$\text{Program PIP} = f_I(0.01) + f_H(0.10) + f_M(1.00) \quad (1)$$

$$\text{Project PIP} = [DT_I(0.01) + DT_H(0.10) + DT_M(1.00)]/PC \quad (2)$$

The Program PIP Index is a function of the total number of inbits, hubits, and mobits, multiplied by their respective weights—inbits = 0.01, hubits = 0.10, and mobits = 1.00. The Project PIP Index is a function of the project task costs multiplied by the respective weights in relation to the resources of the whole project.

IMPLEMENTATION OF THE PIP INDEX

The PIP indices were applied to DOT's ICP, FHWA's FCP, and the Maryland Department of Transportation's AWP. The Program PIP Index evaluation of DOT's ICP indicates the relative importance of programs in various countries. Four example countries are shown below in terms of the three functions.

Country	Inbits	Hubits	Mobits	Total
Iran	–	–	3.00	3.00
Israel	0.04	0.10	1.00	1.14
Poland	0.04	0.10	–	0.14
U.S.S.R.	0.06	0.10	1.00	1.16

The program in Iran is the most sensitive to policy (index score = 3.00), followed by the Soviet Union, Israel, and Poland.

Figure 1 shows the Project PIP Index scored cumulatively in Poland. Since project intensity is expected to increase in a cumulative fashion, Figure 1 contains the cumulative values of individual project scores. While the Program PIP Index for Poland was an unimpressive 0.14, there was an encouraging increase as projects were added. Project 1 began with an index of 0.02 in 1973, and, by the beginning of project 5 in 1974, the index had increased to 0.14. This tends to support our expectations that projects will become more sensitive to policy over time.

Application of the Project PIP Index to FHWA's Project 3B (see Figure 2) shows a peak value of 0.06 in 1974; from then on the project had diminishing policy utility. In fact, FHWA has decided to phase out this project. In an improvement over the earlier analysis of Polish projects, better data on task costs permitted the development of an annual indicator for a specific project rather than a cumulative evaluation of projects within a country.

Applying the Program PIP Index to Maryland's AWP shows a Program PIP of 1.46, which indicates heavy emphasis on informational (0.06) and instructional (0.40) components.

Project Number	Inbits	Hubits	Mobits	Total
6000	0.01	–	–	0.01
6001	0.01	0.10	–	0.11
6003	0.01	–	–	0.01
6004	–	0.10	1.00	1.10
All projects	0.06	0.40	1.00	1.46

This indicates that Maryland's Department of Transportation should try to incorporate more policy components in order to implement policy.

CONCLUSION

Two questions may arise: How difficult is PIP to apply? What benefits does PIP bring?

The application of PIP is easy. As illustrated here, it is a procedure that can be applied to existing as well as proposed projects and programs.

Among its benefits, PIP can give management a good idea of the policy value of its programs and projects just by the use of some numbers. For example, when management sees a high mobit count for a project, it can be certain that many policy-sensitive components are involved. When it is used as an ongoing check, PIP can indicate changes and types of changes involved in terms of informational, instructional, and policy components. PIP is versatile. It can be applied to a program, to a project, or to tasks within a project. It can provide management with an overall program assessment as well as detailed project evaluation. PIP is inexpensive. Its application can be routinely set up and become part of a manager's job. A special form could be developed that required program and project information in each of the three areas, with quarterly monitoring to see whether any change has occurred. Moreover, since management is primarily interested in implementing policy, analysis of elements in projects and programs is essential and PIP can do this.

The PIP concept, of course, needs further exploration. It is offered here in a preliminary way as an easy, inexpensive, time-saving tool to help management obtain the best results from its research and development effort. Figures for inefficient research and development in terms of lack of applicability of results are not available, since no one readily admits that his research and development effort is not as productive as desired. There are, however, numerous completed studies that are reviewed and placed on shelves, never to be implemented. Moreover, although these transportation research and development programs may be atypical, they are sufficiently diversified so that successful application of the PIP indices in evaluating them is evidence of the potential application for evaluating other programs and projects.

REFERENCES

1. R. L. Ackoff. Progress in Operations Research. Wiley, New York, 1961.
2. R. L. Ackoff, S. K. Gupta, and J. S. Minas. Scientific Methodology. Wiley, New York, 1962.
3. R. L. Ackoff and P. Rivett. A Manager's Guide to Operations Research. Wiley, New York, 1966.
4. W. M. Martin, Jr. Chapter 3. In Operations Research and Development (B. V. Dean and R. H. Culhan, eds.), Wiley, New York, 1963.
5. J. W. Forrester. Industrial Dynamics—A Reply to Ansoff and Slevin. Management Science, Vol. 14, No. 9, May 1968, pp. 37-60.
6. J. W. Forrester. Urban Dynamics. MIT Press, Cambridge, Mass., 1969.
7. J. W. Forrester. World Dynamics. Wright-Allen, Cambridge, Mass., 1971.
8. National Patterns of Research and Development Resources: Funds and Manpower in the United States—1953-1975. National Science Foundation, Washington, D.C., NSF 75-307, April 1975.
9. Research and Development by R&D Management Objectives: FY 1976 Program Analysis. U.S. Department of Transportation, Transportation Research Activity Information Service Report B 76, May 30, 1975.
10. Research and Development Program: Fiscal 1974. Federal Highway Administration, U.S. Department of Transportation, 1975.
11. Annual Work Program, Fiscal 1976. Division of Systems Planning and Development, Maryland Department of Transportation, 1975.
12. E. B. Roberts. The Dynamics of Research and Development. Harper and Row, New York, 1964.
13. E. B. Roberts. Industrial Dynamics and the Design of Management Control Systems. In Management Controls (C. Bonini and others, eds.), McGraw-Hill, New York, 1964, pp. 77-85.