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The purpose of this investigation is to explore research management problems pertaining to types of research where direct outputs are in terms of intangible ideas or the kind of knowledge which takes years to be proven applicable or economically fruitful.

The study was based on the analysis of the more cogent facets of research input-outputs concerning non-profit research organizations represented as open systems. The main inputs are information, manpower, and capital, and the outputs are in terms of direct and indirect contributions to different segments of society.

The investigation led to the following conclusions:

a. The prototype classification (basic research, applied research, and development) is of no value at investigators level, but may be of value for external budgeting.

b. Research management could increase the extent of its influence and control over both internal and external budgeting by increasing its knowledge of relationships between expenditures.

c. Qualitative attributes of researchers should not influence the allocation of research funds.

d. Discussion on the quality of types of research and comparative value of research proposals along with other discussed materials in this study, led to a new perspective on the "old concept of R&D evaluation". A ten-step procedure regarding the evaluation of research proposals and allocation of resources in non-profit research institutes was proposed.

PERSPECTIVES: ACADEMIC RESEARCH MANAGEMENT

by

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I would like to thank those people affiliated with Oregon State University whose names have appeared throughout this thesis for taking the time to discuss various aspects of the research with me.

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CHAPTER I

INTRODUCTION

Numerous attempts have been made to define management. Some professionals have used their intuition and have treated management from an artistic perspective, while others have used judgment and have tried to analyze (the management process) with scientific tools. Some of the claimed outcomes are contentment, frustration, and surrender.

Plato tells us in "The Republic" that, the state or condition which enables a "thing" to perform its proper function well is called the "virtue" of that thing. Unfortunately, this "thing" namely management is not like a knife whose sharpness is considered to be its only virtue. Management is a variety of things with a variety of virtues. When the subject is narrowed down to the point where the concept of management is applied to a specific area or discipline, the complexity will decrease and a chance for better and more meaningful definition will increase.

Management of Research and Development (R&D) in a university is characterized by an interlocking interaction among the donor, the grantee, and the research institution. The role of the research manager is to attempt to seek and align the relevant ideals and interests of his subordinates in such a way as to smooth the way for achieving the research objectives. Any research project at a university is thus under two main constraints. One is an internally motivated pressure which is generated by project management (namely principal investigator(s)), and the other is an externally motivated pressure which is generated by the administration (i.e., program administration, research committee, university administration, etc.). The extent to which these pressures can influence the success of research varies from project to project, program to program, and among types of research.

The feeling has been expressed by many sources that "basic research"[1/] should be as free from administrative details as possible (Jackson and Spurlock, 1966, p. 232). This is due primarily to the desirability of lessening outside interference with the researchers' free frame of thought, and secondarily to the fact that there is no set time for completion of any specific objectives or discoveries. The question of time and productivity is not the primary consideration, but rather the future use and applicability of its output.[2/] Since the motives for funding such projects center around the investigator's qualifications and the content of his research proposal, any administrative efforts should be directed toward facilitating and accommodating the research environment for better utilization of researchers' creative abilities.

In applied research, the objectives are stated in more detail, and the time for their completion is determined to some degree of certainty. In most cases when there is competition among similar projects,

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[1/] The classification of research into basic, applied, and development is discussed in Chapter II.

[2/] According to the National Science Foundation, "We have no way of telling where or how new observations or discoveries will be made,... Moreover, we cannot be certain that a given study will have practical value or, if it has, in what field". NSF 57-35, p. 13.

there exists a presupposed master plan for the proposed research projects. This suggests that the investigator has a clear knowledge of what is going to be performed along with knowledge of requirements for completion of each phase of the research. In this case, administrative control is accomplished, for example, through submission of a progress report, or through supervision by a selected committee.

Development work, as performed by universities as part of their research program, usually takes the form of advanced applied research or exploratory economic development. Again,administrative control increases as the knowledge about time of completion and specificity of expected results increase.

Research management is basically concerned with three types of decision making: 1) Obtaining and utilizing the research funds and other resources, 2) the qualifications of the researchers themselves, and 3) the quality of research proposals and output. Each of these aspects is treated in the following chapters. The structure of this study is shown as an open system in Figure 1-1.

The Research Evaluation Problem

The area of research management has been criticized for the lack of internal initiative towards creating and/or applying new tools" (Moore, 1973). This is especially alarming in view of the continuing growth of research activities. In the last decade, the rate of growth in R&D manpower in the United States has been faster than that of the population as a whole (Hiller, 1971); on the other hand, research organizations are proposing more problems for investigation than available

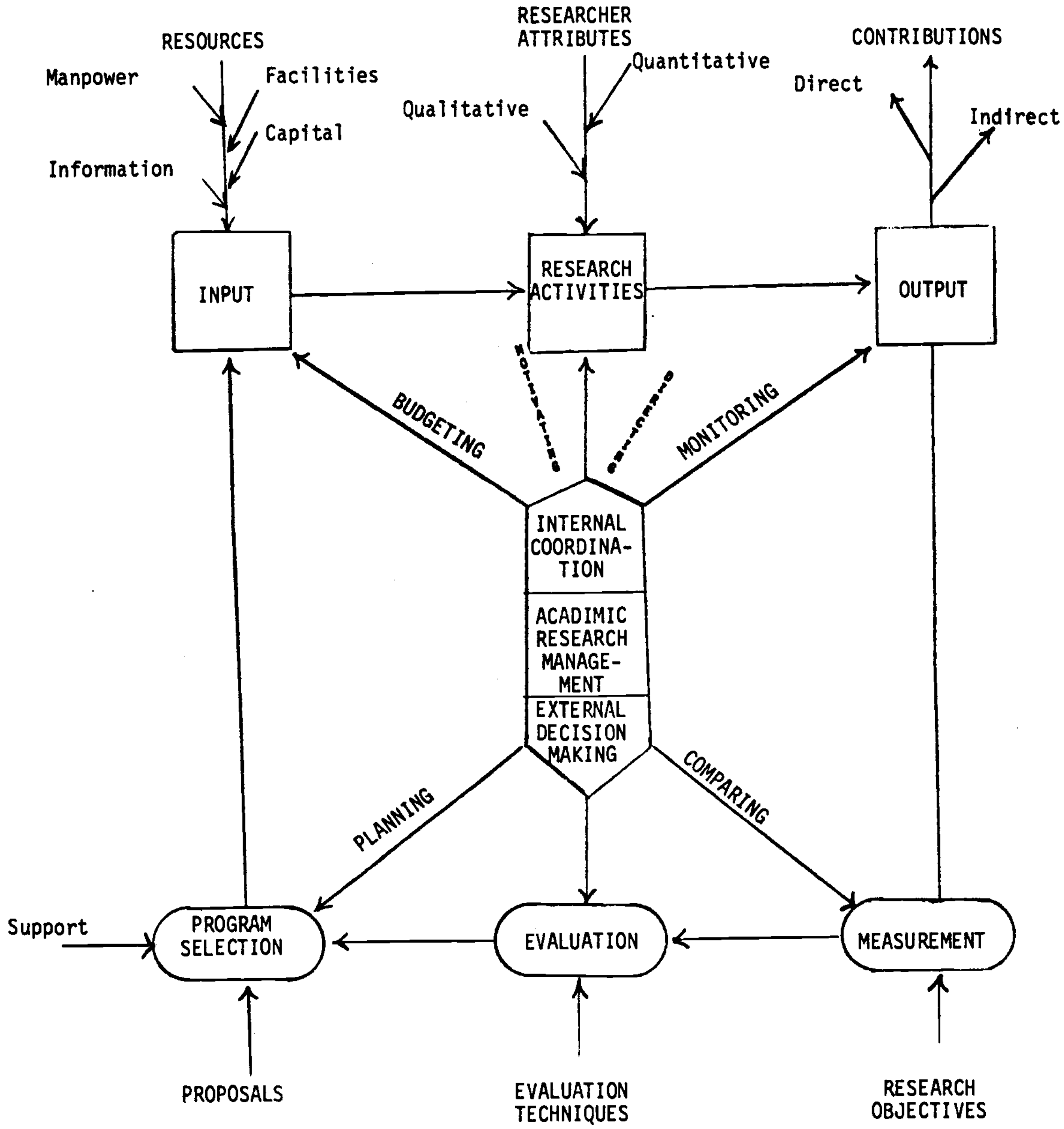

Figure 1-1. Academic research management realm of decision making.

resources can support.

Several models for the evaluation of research and development programs have been constructed by various researchers to assist management. The Linear Production Model, Project Model, and Organic Model, for instance have been discussed by Bryan (1973). Baker-Pound (1964), and Cetron et al. (1967) have reviewed the nature of different modeling approaches: such as linear programming, dynamic programming, and economic analysis. Models for Evaluating Engineers and Scientists for a Research and Development Activity (Martin-Pachares, 1957), and Researchers Performance Measurement Models by Edwards and McCarrey (1973) have been proposed.

In most cases, the discussion tends to be more academic and theoretical than practical, with little or no evidence of the model's comparative effectiveness in simulating actual R&D outputs. It seems that most of the efforts have been focused on the input-output type of models, analogous to those used to forecast production. These techniques are designed for projects which have a definite presupposed structure which assumes that researchers and management are certain of the research outcomes. The area of applicability of such models, if any, falls between highly applied research and advanced development.

This thesis is primarily concerned with the type of research performed by non-profit or academic organizations. It is intended to provide management of non-profit research institutions with new perspectives on old concepts for improving his subjective evaluative judgments. This will be accomplished through analyses of the more cogent facets of the research management problem:

- Explanation of various interpretations of the concept of research, and exposition and comparison of alternative research classifications (Chap. II);
- Discussion of sources of research funds and their utilization (Chap. III);
- Discussion of various aspects of research input and output; with emphasis on the inputs of the researcher himself (Chap. IV);
- Exposition and analysis of the present techniques and tools for measurement and evaluation of research and development activities (Chap. V);
- Introduction of new methodological tools for procuring appropriate information which is useful for the appraisal of R&D projects in non-profit research institutions; construction of a model based upon the above information, for evaluation and control of research program (Chap. VI).

Despite the fact this thesis is not a field study, some of its contents is based on discussions with researchers engaged in different areas of research activities.[3/]

[3/]The following people, all of whom are affiliated with Oregon State University, have intellectually contributed to this investigation: Dr. David Bella, Civil Engineering; Mr. Anthony Birch, Director of Budget and Personnel Services; Dr. David Birkes, Statistics; Dr. Douglas Egan, Business Administration; Dr. Clifford Gray, Business Administration; Dr. Michael Inoue, Industrial and General Engineering; Dr. John Kinney, Mechanical Engineering; Dr. Stephen Love, Industrial and General Engineering; Dr. John Nath, Director of Fluids Dynamics Laboratory; Dr. James Riggs, Head of Industrial and General Engineering; Dr. Larry Schecter, Chairman of Physics; Dr. Dale Simmons, Psychology; Dr. Larry Slotta, Director of Ocean Engineering; Dr. Justus Seely, Statistics; Dr. John Smith, Mathematics; Dr. Andrew Vogt, Visiting Professor, Mathematics; Dr. Charles Warren, Head of Fisheries and Wildlife and Dr. Gregory Wood, Director of Agricultural Experiment Station. Should any of the content strike a discord and the shortcomings are my responsibility, and does not in any way represent opinions of others.

CHAPTER II

RESEARCH AND RESEARCH CLASSIFICATION

The answer to the question "what is research" may be observed from two perspectives. A denotative approach is that the word "research" is derived from the French word "recherche". The "cherche" means "to look for, to hunt" which is equivalent to "to search", and the prefix "re" meaning "do it over" gives the added emphasis of diligence. When we collect terms, research suggests a search conducted very carefully and very diligently.[1/]

A connotative approach can itself be viewed in two ways. One is the consideration of descriptive characteristics for research: who the researchers are and what they have done or are doing. The second is the consideration of a prescription for research: what researchers ought to do. The latter is a philosophical approach regarding the appraisal of values and will remain a perennial debate among the public, researchers, and politicians. The former has served as a foundation for the research empire upon which our present knowledge about research has been built up. Consequently, our formalized understanding of research is rooted in the accumulation of bits and pieces of information and their interpretations through the contribution of past and present scientists, engineers, and other authorities in the field of research.

[1/]Private conversation with Dr. James W. Groshong, OSU English Department.

Kidd (1959) distinguishes between two contradictory definitions: One is that research is defined in terms of "investigator's motives and interest and the conditions under which they work", and the other is in terms of "the work itself".[2/]

Due to the current broad spectrum of research it is no longer possible to delineate and demarcate its boundaries. A universal or an imutable definition is not only irrational, but impossible.

An equally frustrating task in the turmoil of definitional difficulties is the proper classification of research projects and distinctions among these breakdowns. Generally speaking, Research and Development[3/] is regarded as the increase of knowledge and its application. This includes production, dissemination, and improvement. In 1953, a nation-wide survey through questionnaires and interviews regarding the status of R&D effort in both non-profit institutes and commercial laboratories was made by the National Science Foundation. One of the outcomes of that survey revealed that there was a misconception of the meaning of basic research among the interviewees.

[2/]The difficulties involved in the distinction and definition of research is discussed in many sources. A few examples of some of the refinements are provided by: Furnas (1948, p. 2-10), Jackson and Spurlock (1966, p. 1-14), Korol (1965, p. VII-XVI), Machlup (1962, p. 145-150), Wolfle (1959, p. 253-257).

[3/]Since it is the results of research that are developed and not the research, Machlup(1962) criticizes the term R&D as being a "poor one". He notes that it is the successful outputs of research which eventually lead to development.

> Respondents varied in their comments on the distinction between basic and applied research, commonly interpreting these terms as synonymous with purposive or less purposive, sponsored or unsponsored, or general as contrasted with useful research (NSF 56-15, p. 3).

The need for uniformity of classification of research is of utmost importance. Classifications serve as a device for communication both nationally and internationally.[4/] Another use of such classifications becomes apparent at the time of Governmental budget distribution.

One of the most widely used and commonly accepted classifications of research and development is a division into basic research, applied research, and development.

General definitions of research do not exactly describe basic research. If basic research is defined in terms of basic researchers' work then as Markham (1965) has pointed out, it is extremely difficult to differentiate between research scientists employed in industry and their counterparts in university or government research laboratories. Basic research is the discovery of fundamental laws and phenomena of nature (whether physical or organic), and the examination of ideas. The importance of basic research in the world goes back more than two centuries, when the basic sciences demonstrated their usefulness in European governments. The goal of research was "to implement the

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[4/]Discussion presented by Korol (1965) discloses the fact, that "there is no single Russian term equivalent to Research and Development or its adjectival form R&D", this in turn, will raise the "counterpart" problem regarding the presentation of scientific materials in their publications. Terms such as "scientific research work and perfection of production,... Scientific research and project-design activities,... Research work and scientific-technical studies,... Scientific research and experimental design" are literally translated Russian phrases for Research and Development.

traditional purposes of state policy" (Schmookler, 1965), which were considered to be health, welfare, and military strength. According to Schmookler (1965), the same goals formed the basis for financing basic research in the United States of America. Schmookler also discusses and emphasizes the utilitarian aspect of research as a vital stimulating factor for motivation and eventual involvement of scientists and engineers in research activities. It was this utility concept which led to the belief in the practical usefulness of basic research and consequent support from the public and the government. The facts that have been discovered out of basic research have been used in the processes of creating new devices and methods.

Applied research is "problem-oriented research" Creutz (1971), and is the search for application of basic research products or the use of basic research products directed toward invention of new devices or methods for ameliorating existing problems. The motive for performing basic research is the investigator's curiosity, while the motivation for applied research is search for solving a specific problem through applications of those discovered facts (NSF 60-10, p. 5).

Development is the improvement of those inventions and methods which results in better products or processes. In a military context, Klein Burton has explained Development as [Tybout (ed.), 1965]:

> The identification, modification, and combination of feasible components and devices to provide a distinctly new application practical in terms of performance, reliability, and cost.

Development has also been divided into subclassifications such as development of new products, development of new processes, development of manufacturing methods, economical exploratory development, etc.

A project is classified as Basic, Applied, or Development at the time when its objectives are set out and not at the time of its completion. As Machlup(1962) has pointed out in one example: to determine whether a statistician should properly enter some dollar figures under a basic section or an applied section, he has to wait for the outcome of the research to decide which one of the two should be more appropriate. Another example given by Wolfle reinforces this point:

> A commercial chemist may seek means of improving the drying qualities of a paint, and in the course of his work discovers something fundamental about molecular layers. Was he engaged in basic or applied research? (Wolfle (ed.), 1959, p. 256).

For ease of communication throughout this thesis, definitions adopted by the National Science Foundation will be used:[5/]

<u>Basic Research</u>: research projects which represent original investigation for the advancement of scientific knowledge and which do not have specific commercial objectives, although they may be in field of present or potential interest of the reporting company.

<u>Applied Research</u>: research projects which represent investigation directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes.

<u>Development</u>: technical activities concerned with non-routine problems which are encountered in translating research findings or other general scientific knowledge into products or processes (NSF 63-7, p. 109).

[5/]Reasons for selection of these definitions by the National Science Foundation, are a) That more efforts have been made by NSF through interviews and questionnaires for collection and adaption of definitions; b) because of their commonality of understood purposes among a majority of scientists and engineers and other people engaged in R&D activities; c) because government's funds allocations and budget follow this pattern.

Due to immediate needs and other practical interests, and as a result of adaptations to unique operating conditions, new classifications of research are introduced frequently. Some of the terminology which has contributed to the formation of an overcrowded lexicon is presented in Table 2-1.

Input and Output of a Research Project

Major inputs to any research projects consist of capital, manpower, and information. The primary outputs of research activity can be discovery, inventions, and innovations which may in turn result in profits and improvements. (To get a better picture of this input and output concept, refer again to Figure 1-1.) Any research project will eventually contribute to the training of the personnel being involved in that research activity, however, this will not be regarded as an output because the goals of research usually do not include personnel training.

Table 2-2 is designed to help the reader clearly distinguish between the constituent input-outputs of Basic, Applied, and Development along with a better understanding of each classified group's concept. This is intended to remove some of the ambiguities present in previously stated definitions.

One can classify a given research project based on an analysis of the project's inputs and outputs (provided that he already has determined the proper concept of research according to the given definitions). This might be accomplished by simply listing the expected inputs and outputs; prior to the start of research tasks, and comparing

	BASIC	APPLIED	DEVELOPMENT
Defensive Development 1/			GGR...61 p.24
Defensive Fundamental Research		GGR...61 p.24	
Offensive Research 2/	QJB59	QJB59 p.44	QJB59 p.52 GGR...61 p.24
Defensive Research 2/		QJB59 p.44,131	QJB59 pp.51-52
Offensive Development			GGR...61 p.24
Protective Research		SPC68 p.17 3/	
Innovative Research		SPC68 p.17	SPC68 p.17
General Research	SPC68 p.17	SPC68 p.17	
Broad-based Fundamental Research		GGR...61 p.24	
Research	SB65	SB65 p.321	SB.65 YMC.65ed
Exploratory Development		SB.65 p.321	SB.65 p.321
Pure Research	MT63 p.4		
Design Engineering			MT63 p.4
Pilot Production			MT63 p.4
Functional Research			SPC68 p.17
Necessity Research			SPC68 p.16
Venture Research		SPC68 p.16	
Market Research		BLW65 p.104	BLW65 p.104
Market Development			FCC48 p.54
Production Research			FCC48 p.10
Fundamental Research	FCC48 p.6	FCC48 p.6	
Exploratory Research	FCC48 p.3		
Programmatic Research		SPC68 p.16	SPC68 p.16
Nonprogrammatic Research	SPC68 p.16		
Preoroduct-Oriented Research	SPC68 p.16	SPC68 p.16	
Product-Oriented Research		SPC68 p.16	SPC68 p.16

1/ The sources of the terminologies in the leftmost column are indicated by three initials of the author and year of publication in proper boxes. Each box when it is marked shows the compatability of that terminology with that of the previous classification according to their definition Dots between initials and year indicates the number of co-authors.

2/ Some of these terminologies represent a new classification such as Defensive and Offensive research, while others are somehow synonyms for Basic, Applied, and Development such as Pure or Fundamental which now is referred to as Basic research.

3/ Phrases marked by SPC68 pp.16-7 are quoted from other authors who had used those terms for the first time.

Table 2-1 Comparison of Terminologies used to classify research.

	BASIC	APPLIED	DEVELOPMENT
INPUT	Scientific manpower and curiosity Capital, Fundamental scientific knowledge, Facilities, Time	Scientific manpower, Information Methodology, Capital, Set time	Scientific manpower, Pilot plant Methodology, Facilities, Capital Limited time
ACTIVITY CONCEPT	Fundamental research: Fundamental laws and phenomena of nature (Furnas, 1948) Compilation and interpretation of information on their operation (Furnas, 1948) Increase of knowledge, no commercial objectives (NSF-1960) Basic knowledge (Bush, 1945) General knowledge (Machlup, 1962) Understanding nature by its laws 1/ (NSF-1960) Pure research: Search for facts and knowledge without reference to their application (Howard, 1955) Exploratory research: Try and see without preconceived objectives (Furnas, 1948)	Planned program toward a definite practical objective (Furnas, 1948) Better products and their improvments (Machlup, 1962) Applied knowledge (Machlup, 1962) Practical application of knowledge 2/ (NSF-1960) Search for a new knowledge applicacable to a specific problem 3/ And/or application of all existing Application of all existing knowledge to the practical solution of the problem (Howard (1955)	Extension of findings and theories of a scientific or technical nature into practical application for experimental or demonstrative purposes (Howard, 1955) Application of technology to the improvement, testing, and material or devices resulting from applied research (Furnas, 1948) Non-routine problems in translating research findings or other general scientific knowledge into products or processes (NSF-1963) Coordination of ideas, resources, and people to achieve profitable
OUTPUT	Discovery, Methodology, Hypotheses and theories, Scientific problems and new hunches	Invention, Innovation, Profit Methodology, Improvement	Improvement, Innovation, Profit

1/ NSF report of 1970 has cited "Basic research as that type of research which is directed toward increase of knowledge in science."

2/ NSF report of 1970 has substituted "science" for "knowledge"

3/ This type of activity is considered to be basic research in profit oriented research industries.

Table 2-2. Input-output and activity concept associated with the prototype classification.

with the corresponding entries in Table 2-2 to determine whether the project most closely matches the prototype for basic research, applied research or development.

Machlup (1962) has also related inputs and outputs of research and development activities to their proper classification. By rearranging his suggested information, a Venn Diagram is constructed (Figure 2-1) to show those inputs and outputs which are common to one or more classes. This may serve as yet another tool for distinguishing among the three mentioned types of activities. It will also be helpful as a means of communication for our future discussion.

<u>Input</u>

Tangible:	A.	non-scientists
	BAD.	Scientists, technical aides, clerical aides, laboratories materials
	D.	Pilot plants
	AD.	Engineers
Intangible:	B.	Scientific problems and hunches
	D.	Raw inventions and improvements
	BAD.	Scientific knowledge
	AD.	Technology, practical problems and ideas
Measurable:	D.	Investment
	BAD.	Men, man-hours, payrolls

<u>Output</u>

Intangible:	B.	New scientific knowledge; hypotheses and theories
	A.	Inventions, minor improvements
	D.	Developed inventions
	BAD.	New scientific problems and hunches, new practical problems and ideas
Measurable:	BAD.	Publication

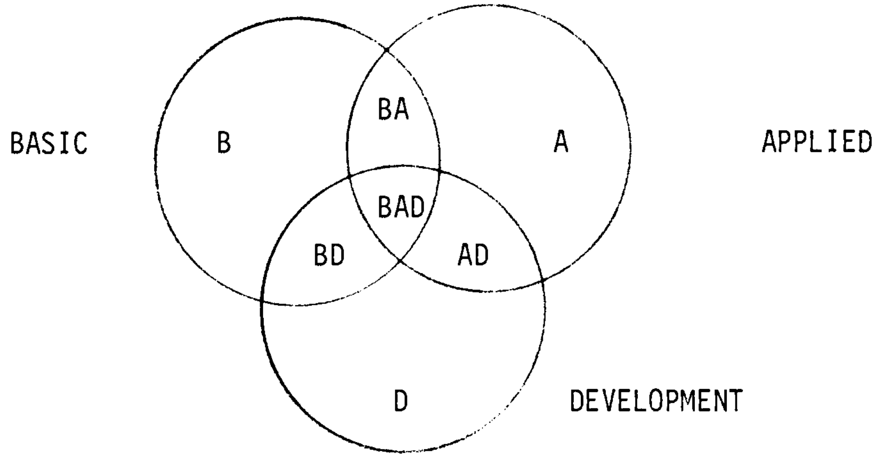


Figure Legend: "B" stands for basic research, "A" for applied research, and "D" for development. Note that each section of the Venn Diagram indicates only the commonality of inputs and outputs, and does not represent what they may have shared with other sections. "BA", for example, represents what is in common between applied and basic research but "BAD' might represent some of the commonality of basic research and applied research along with that of development.

Figure 2-1. Input-output commonality among basic research, applied research, and development.

CHAPTER III

RESEARCH BUDGETING

Before discussing internal and external budgeting, let us briefly examine the background of the support of research in the United States.

Development and promotion of research in the United States stemmed partially from the impacts of the two World Wars which resulted in the creation of foundations and support of laboratories, electronics, communications, and nuclear power (Stever). The funding of the land-grant colleges and establishment of universities such as John Hopkins University is considered to have played an important role in research activities. Also, the ultimate success of research which has proved to be a constituent factor in the political stabilization and attainment of power among competing countries has helped the support and expansion of such activities to a great extent.

A report by the National Science Foundation on organization and growth of research in non-profit institutes and commercial laboratories indicates that approximately 75 percent of the laboratories were established after 1940. Ten percent of 156 commercial laboratories interviewed in 1953 had 51 to 100 employees, and only seven percent had more (NSF 56-15). In 1961, 7.9 million employees out of the total R&D employment of 11.3 million were retained by R&D companies with fewer than 1000 employees. The total number of research laboratories increased from 290 to 5420 between 1920 and 1960 (Woytinsky, 1967). Expansion was mainly accounted for by Federal Government support for the purposes of military development (Bass, 1965).

The rate of increase in R&D support has been remarkably high. A report by the NSF points out that the United States has registered an increase of 150 percent in total R&D expenditures between 1963 and 1973. The increase in basic research support is registered at 100 percent between 1963 and 1973 (NSF 73-303). The percent distribution of U.S. scientists engaged in each of four research categories for four different institutional types of activities and aggregated over all institutions is shown in Figure 3-1. (The figure does not include engineers. According to the National Science Foundation, the percent distribution has changed only slightly since 1960.)

Universities and colleges are accounted to be doing 3/5 of total basic research in the nation. By way of contrast, the distribution of research expenditures by industrial firms (in 1973) is 78 percent, 19 percent, and three percent for development, applied research, and basic research respectively.

Projections by the National Science Foundation indicate that the number of scientists and engineers in R&D activities will be around 650,000 for a $35 billion research budget in 1980, if the same rate of increase holds. Another projection by Bureau of Labor Statistics claims the total amount of R&D expenditures will reach between $32.4 and $40.5 billion by 1980. (This is based on the ratio of R&D/GNP which is expected to be between 2.0 and 2.5 percent with a GNP expectation of $1.62 trillion in 1980.)

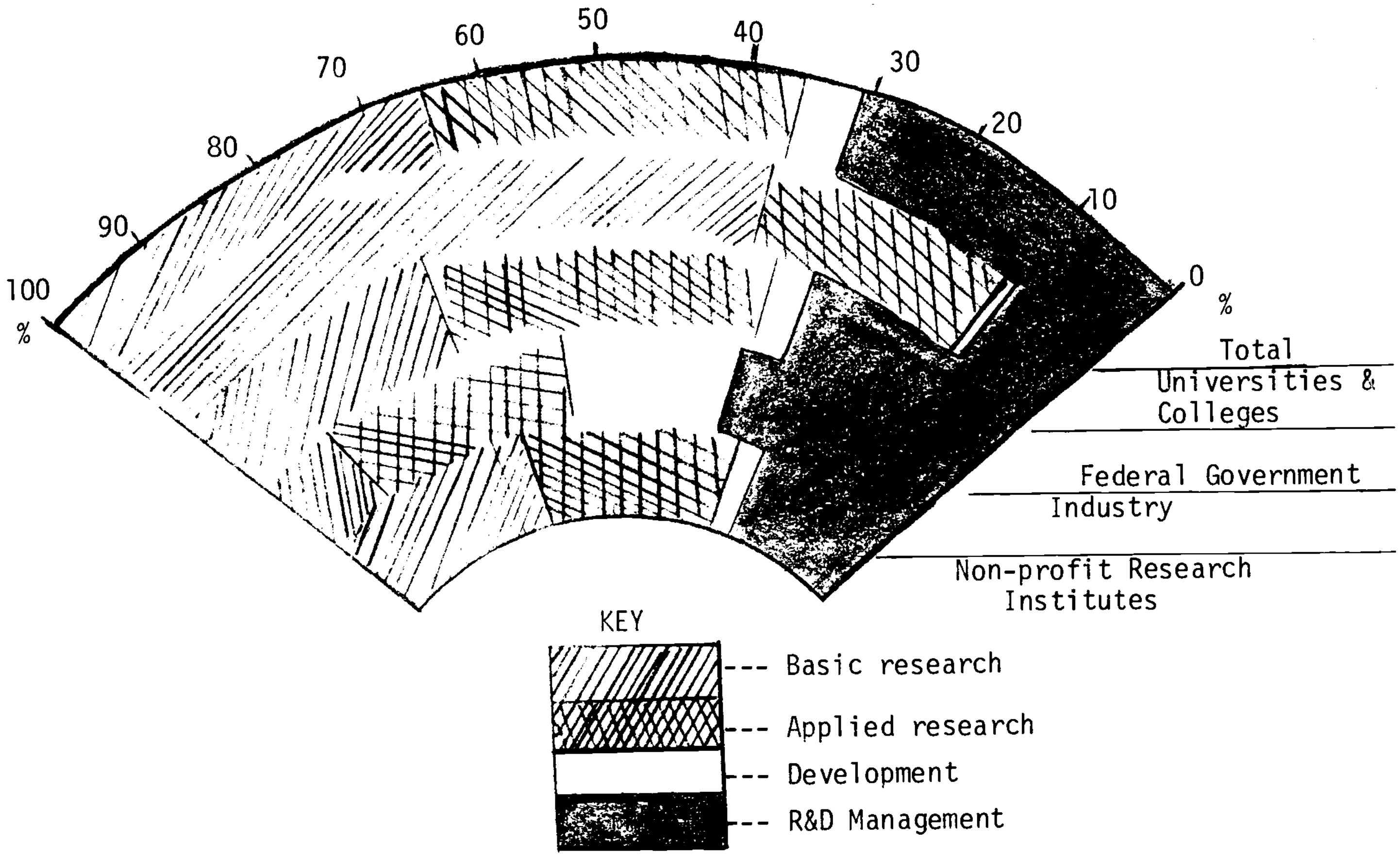


Figure 3-1. Distribution of United States scientists engaged in basic research, applied research, development, and management of R&D in 1970.1/

1/ Sources: NSF. National patterns of R&D resources: funds and manpower in the United States 1953-1973. February 1973. 36 p. NSF 73-303.

Digest of Educational Statistics, 1971 edition (US/DHEW,DHEW Publication no. OE 72-45)

Budgeting

For purposes of obtaining and distributing research money, research management ought to know whence the funds come and whither they are utilized. The first process we call external budgeting. Information accumulated in this chapter is designed to provide management with a broad spectrum on sources of funds and distribution of funds by research classification and by research institutional type. The second process is called internal budgeting. The included information is intended to familiarize management with internal distribution and timing of funds throughout research projects.

External Budgeting

The sources of research money can be observed in Figure 3-2. The sources of funds are typically distributed to four primary types of institutions which will herein be called sectors: government, industry, university (universities and colleges), and other non-profit research institutes. For instance, money contributed by private foundations may go to university and industry funds, individuals may contribute to universities, or state dollars may be used by universities and/or industries. The outcome of these transactions is that each sector will have a certain amount of money for research and development activities. Of course it is not always the case that the amount spent by a sector reflects research performance. Although the industry sector, say, has raised a certain amount of money for R&D expenditures this does not necessarily indicate that the same amount is being performed by the industries. For example, Table 3-1 shows that in 1953 the percentage

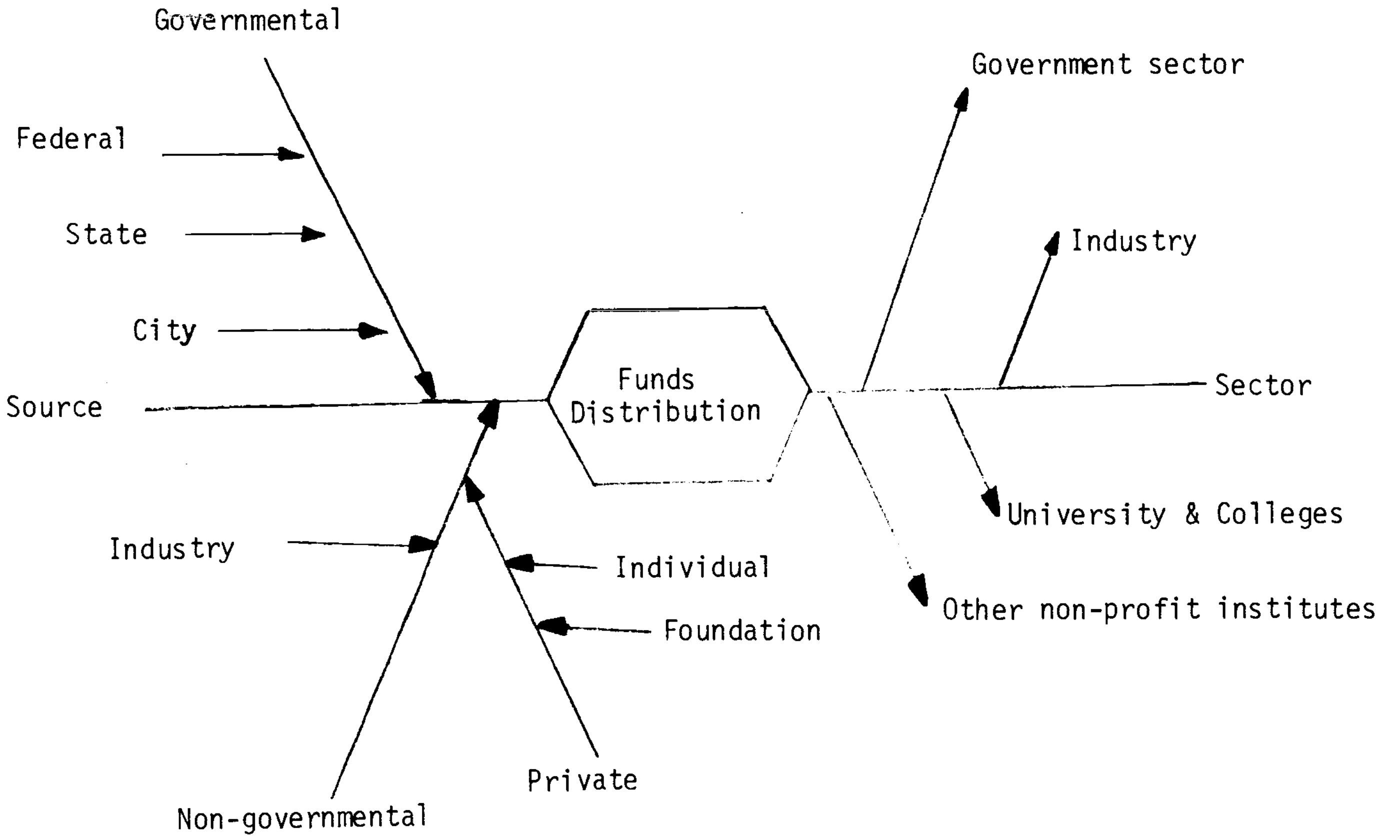


Figure 3-2. Source and users of research funds.

Sectors (Sources)	1953	1963	1970	1973	Total Thru 63	Total Thru 73	
Government	47.9	59.7	62.6	58.	53.1	59.7	BASIC
Industries	30.3	18.9	13.6	14.4	24.5	17.	
Universities	14.9	15.6	19.	22.6	15.9	18.	
Other	6.9	5.8	5.8	5.	6.5	5.3	
Government	58.5	56.8	54.4	53.1	55.5	55.2	APPLIED
Industries	34.5	38.3	40.1	41.	39.4	39.4	
Universities	5.5	3.3	3.4	3.8	3.7	3.6	
Other	1.5	1.6	2.1	2.1	1.4	1.8	
Government	51.7	68.3	54.4	51.9	65.4	60.8	DEVELOPMENT
Industries	48.1	31.4	45.1	47.6	34.3	38.8	
Universities	.1	.1	.1	.1	.1	.1	
Other	.1	.2	.4	.4	.2	.3	
Government	53.	64.5	55.6	53.1	61.8	59.4	TOTAL
Industries	43.	31.4	39.3	41.2	34.5	36.1	
Universities	2.9	2.8	3.6	4.3	2.6	3.2	
Other	1.1	1.3	1.5	1.4	1.1	1.3	

Table 3-1. Percent by sector of funds spent for three classes of research and development for selected years.

Source: US Department of Commerce. Abstract of the United States, 93rd Annual Edition.

National Patterns of R&D Resources: Funds and Manpower in the United States 1953-1973. 36 p. NSF 73-303.

Digest of Educational Statistics, 1971 edition (US/DHEW, DHEW Publication no. OE 72-45 of basic research expenditures by sectors was 47.9 by federal government, 30.3 by industry, 14.9 by universities and colleges, and 6.9 by other non-profit research organizations. However, the amount of basic research performed by sector was 42 percent by universities and colleges (a few percent of this was spent by Associated Federally Funded Research and Development Centers), 31 percent by industry, 21 percent by the federal government, and six percent by other non-profit research institutes (U.S. abstract, 1971). The principal sources of university funds are shown in Table 3-2. The table also exhibits the yearly changes, and the yearly average rate of increase as a percentage of 1961 expenditures. The total increase between 1961 and 1971 was over 203 percent, with percentage increase of 240 in the federal government, 174 in universities and colleges, and 134 in other sectors.

Another feature of expenditures of funds versus research performance may be observed in Figure 3-3. It shows that universities and colleges are the main performers of basic research while most of the funds come from the government sector. Comparing the basic research figures with the total expenditures of R&D in universities and colleges reveals that most of the research being performed at these institutions is basic research.

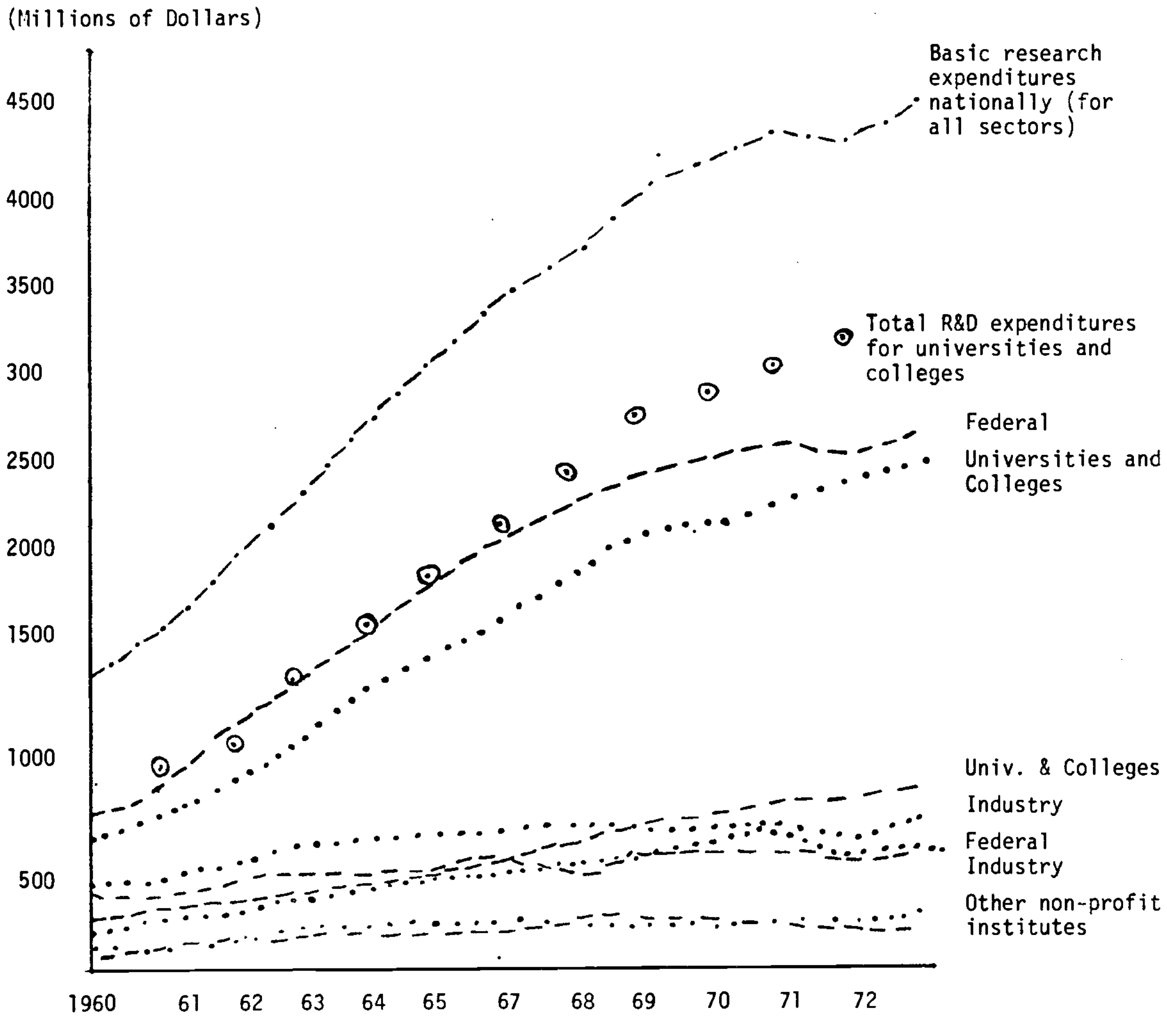
A critical area of consideration for universities and colleges is to draw funds from the government, industry, and private foundations. In other words the university is considered to be the cradle of the type of investigation that never has been or is intended to be investigated by other sectors. When the sources of funds are broken down by class of research, it is seen that government is primarily involved in

Dollars in Millions

Academic Year	Total Expenditures			Federal Government 1/			Universities & Colleges 2/			Other 3/		
	$	Change	%	$	Change	%	$	Change	%	$	Change	%
1961	969			500			371			98		
1962	1143	174	17.9	613	113	22.8	424	53	14.2	106	8	8.1
1963	1359	216	22.2	760	147	29.4	485	61	16.4	114	8	8.1
1964	1595	236	24.3	916	156	31.2	555	70	18.8	124	10	10.2
1965	1822	227	23.4	1073	157	31.4	615	60	16.1	134	10	10.2
1966	2085	263	27.1	1262	189	37.8	673	58	15.6	150	16	16.3
1967	2329	244	25.1	1409	147	29.4	753	80	21.5	167	17	17.3
1968	2599	270	27.8	1572	163	32.6	841	88	23.7	186	19	19.3
1969	2705	106	10.9	1600	28	5.6	900	59	15.9	205	19	19.3
1970	2856	151	15.5	1658	58	11.6	970	70	18.8	228	23	23.4
1971 4/	2950	94	9.7	1700	42	8.4	1020	50	13.4	230	2	2.0

1/ Federally Funded Research excluded,
2/ State and local government,
3/ Industry and other non-profit institutes,
4/ Preliminary

Table 3-2 Expenditures for R&D in universities and colleges by sources (1961-71)



----- Basic research expenditures
..... Basic research performance
-·-·- Total basic research expenditures

Figure 3-3. Basic reséarch expenditures and research performance.

"AD" activities (refer to Figure 2-1), industry in "BAD", university and other non-profit research institutions in "BA".

The ultimate hope of research management at these academic research organizations lies in attracting contributors to finance performance of basic research. If these institutions do not do it who else will? Attracting different sources of funds for purposes of investment in, for example, increase of knowledge, depends on the amount of benefits these donors may eventually receive, or at least hope to receive in the future. This return can be accomplished through potential contribution of applicable knowledge to the areas in which these segments of society are interested. This concept will serve as an important criterion which is the subject of our discussion in Chapter VI.

Internal Budgeting

Earlier materials in this chapter related the expenditures of research funds to research performance. Internal budgeting concerns the distribution of funds according to their utilization within research projects. Since the list of such expenditures originally is prepared at the project level by principal investigator(s) at the time of proposal submission, it seems that top management has no practical control over this matter. The following discussion is intended to assist management in this regard, and the given information may also be useful for constructing predictive models concerning any possible change in external funding.

The factors involved in internal expenditures can be observed in Figure 3-4. Each research proposal's budget section contains such a

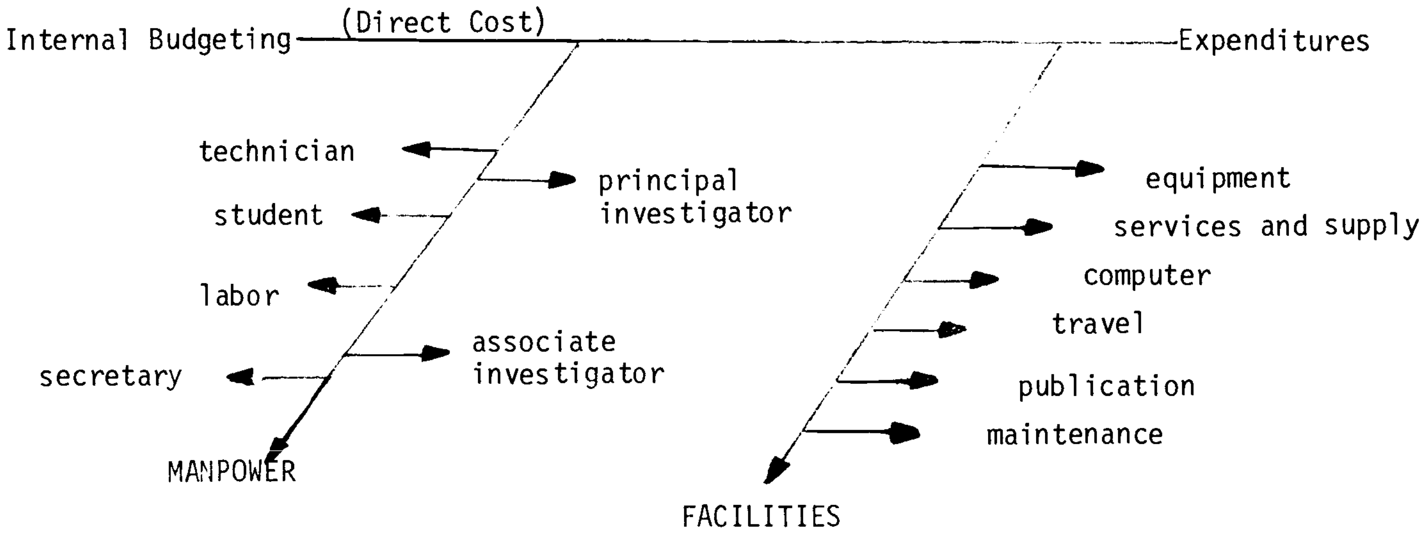


Figure 3-4. The cost items covered by internal expenditures.

list of pertinent cost items (the list, however, may not be as detailed as it is shown in the figure, e.g., maintenance may be included in service and supplies, etc.). Figure 3-5 (OSU Sea Grant (S-G) is used as an example) shows the trend of research expenditures for selected budget items over five years. This type of figure helps research management to have knowledge of funds utilization according to different cost factors. Some of the types of observations and interpretations which may evolve from such a figure are as follows:

(a) Distribution of expenditures associated with each factor from government and university (matching funds) sectors should be observed.

(b) Equipment shows a continuous increase for the first three years, and a decline over the last years.

(c) Publication follows a path in some contrast to that of equipment.

Considering that the number of research proposals had been increasing for the first three years and leveling off for the remaining years, the relationship between (a) and (b) is a prime indication that research funds should be allocated on longer basis (rather than yearly). The figure also discloses that itemized research expenditures do not necessarily follow the change in total research program funds.

Another basic tool which can be of great help for determining the distribution of internal expenditures throughout research projects when the projects are associated with different disciplines is the construction of a table such as Table 3-3. The table shows the average, median,

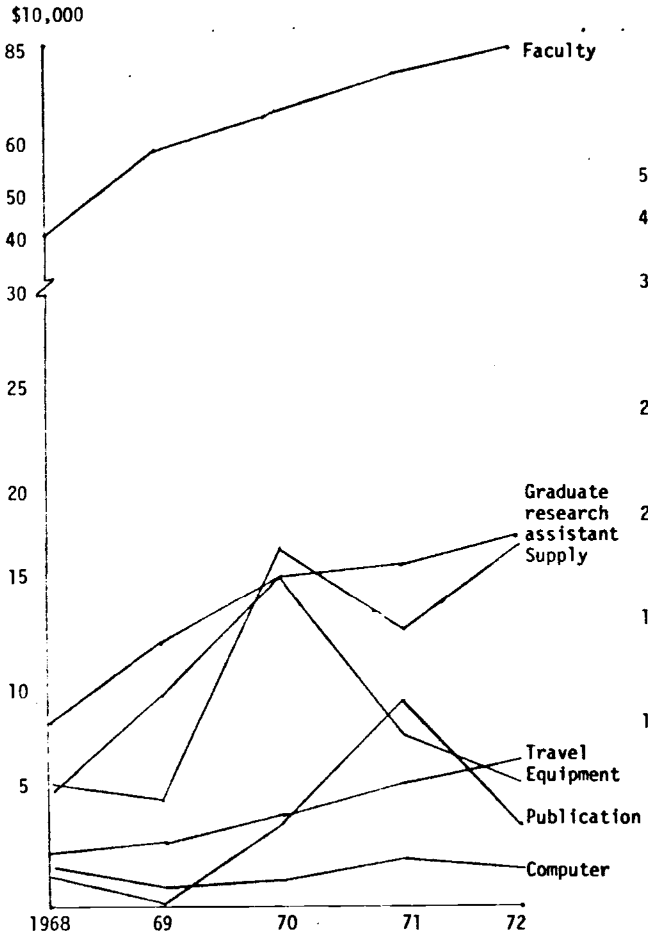


Figure 3-5a. Expenditures by Budget Item (Government and university sectors combined.)

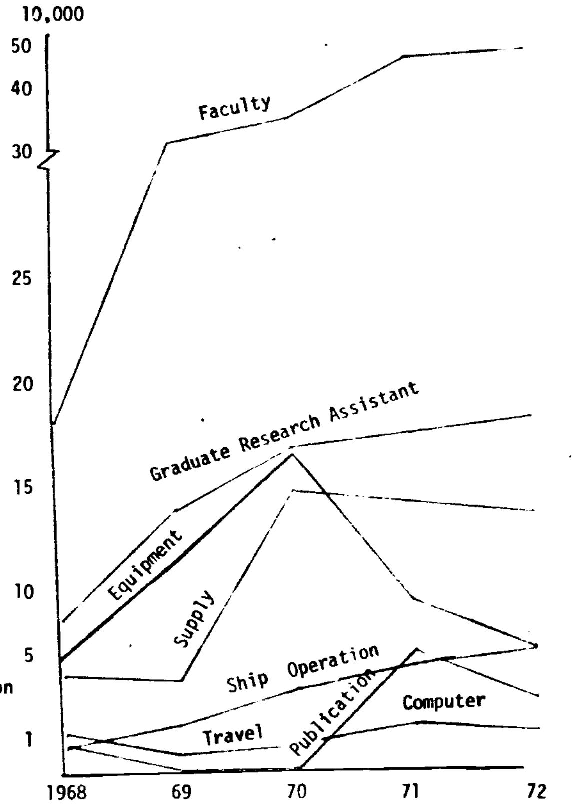


Figure 3-5b. Expenditures by Budget Item (Government sector)

Source: Data obtained from Mr. Steve Covey, OSU Sea Grant Office.

	(A) Total Program			(B) Education and Training			(C) Advisory			(D) Research and Development			(E) Basic Research		
	Average	Median	Range	Average	Median	Range	Average	Median	Range	Average	Median	Range	Average	Median	Range
No. of principal investigators	3.34	3.00	8.00	2.20	2.00	4.00	3.85	4.00	1.00	3.60	3.00	8.00	4.25	4.00	6.00
No. of man-month (prin. invest.)	13.70	13.00	36.00	10.40	6.00	30.00	20.42	18.00	31.00	13.23	13.00	35.00	14.65	13.50	33.00
No. of associate investigators	4.70	3.00	28.00	5.90	2.00	28.00	3.14	0	18.00	4.66	4.00	16.00	4.35	4.00	15.00
No. of man-month (assoc. invest)	20.00	12.00	99.00	17.50	8.50	99.00	12.85	0	70.00	22.73	16.00	91.00	24.85	16.00	91.00
No. of non-academic staff	4.65	4.00	15.00	2.00	1.00	6.00	7.42	8.00	5.00	4.90	4.00	15.00	4.95	4.50	15.00
No. of man-month (non-academic)	14.19	7.00	66.00	5.50	3.00	23.00	25.42	15.00	44.00	14.46	6.00	66.00	13.50	4.50	66.00
Equipment	3301.70	1323.00	47257.00	3373.20	1188.00	16488.00	697.14	300.00	2457.00	3885.60	1915.00	27257.00	5282.75	2456.00	47257.00
Services and supplies	8308.87	5561.00	55191.00	4574.50	4939.50	5928.00	5367.28	5456.00	7949.00	10240.00	6388.00	55191.00	9948.15	7498.50	53790.00
Travel	2331.65	1603.00	17804.00	1292.00	1360.50	2726.00	4597.00	3230.00	17804.00	2149.53	1594.50	13481.00	2410.90	1646.00	13110.00
Computer	733.14	300.00	4417.00	143.10	0	903.00	916.71	200.00	4417.00	949.66	561.50	3933.00	1152.50	762.50	3933.00
Publication	692.68	0	7999.00	91.00	0	910.00	2628.42	2000.00	7999.00	441.56	0	4500.00	412.35	100.00	2000.00
Indirect cost	84797.63	20762.00	95434.00	31021.20	22479.00	94804.00	23651.71	14704.00	55933.00	22990.50	21420.00	91039.00	24613.95	22043.50	88507.00
Total expenditures	97995.19	88422.00	369833.00	4010.00	89412.00	315281.00	92913.28	58105.00	226711.00	93842.70	88772.00	369833.00	101174.10	93378.50	364360.00

Table 3-3. Example of constituent budget factors in utilization of research funds associated with different research classifications and the aggregated total. (Data is tabulated from Appendix I which is the sum of two selected years for OSU Sea Grant Program expenditures)

and range of selected budget items according to a research project classification at use in the OSU Sea Grant Program. With a little observation and a few arithmetic calculations, management will be able to draw many useful inferences regarding internal budgeting from this table. The following are some examples:

(a) In Table 3-3 (D), a zero median under publication indicates that at least half of the R&D projects had spent no amount for publications!

(b) In Table 3-3 (B), the high range under number of associate investigators (comparing with the average and the median), indicates that one project had around 14 associate investigators (28/2 years = 14).

(c) A typical project differs considerably depending on its classification (A,B,C, etc.). And also, it is apparent from (E), that a true picture of a typical project in different disciplinary areas can best be observed at its final broken classification. This can be of interest especially for new proposals.

(d) When similar tables are made for subsequent years, then the ratio of travel/man-months or publication/man-months, etc., can be revealing by comparison.

It is not the subject of our discussion to draw inference in regard to interpretations of the given information. However, when looking at Table 3-3 (E), management may ask whether one and a half (=13.5/8) man-months by principal investigator, two man-months by associate investigator(s), and 15 days of non-academic staff per year would be sufficient for at least half of the basic research projects, considering that time is also utilized for travel, preparation of progress reports, installation of equipment, publications, etc. (for observation, note that the data represents the sum for two years).

Any possible change in R&D external funding is felt drastically in internal expenditures. One of the ways which has been devised to assist management in coping with such an eventuality is the use of predictive models in internal budget decision making. Predictive models are based on historical data, and the validity of prediction is grounded primarily on the quality of input information and the ability of history to repeat itself. Also, such elements as cyclic variations should be accounted for if they are present. The concept of correlation coefficient between variables is of basic use in constructing such a predictive model. The data in Appendix I has been used to construct in Figure 3-6 correlation matrices for different classes of research activities based on historical information. The value of coefficient can be tested for significance[1/] and the linearity can be observed before attempting to construct a predictive model. In other words, it can easily be observed by way of comparison whether two items can yield identical predictive models in different classes, and whether there is any linear relationship between variables. For example:

[1/] Using $t = \frac{r}{\sqrt{1-r^2}} \sqrt{n-2}$ with n-2 degrees of freedom.

TOTAL PROGRAM

A	1	2	3	4	5	6	7	8	9	10	11	12	13
1		.50	-.10	.01	.04	-.04	.26	-.01	.16	.39	.16	-.13	-.05
2			-.20	-.08	.03	.20	.14	.07	.33	.13	.29	.03	.11
3				.87	-.03	.16	.05	.27	.37	.21	.14	.80	-.77
4					-.02	.21	.23	.45	.46	.28	.09	.83	.85
5						.74	-.09	.11	.21	.28	.17	.16	.15
6							-.06	.43	.47	.13	.23	.46	.48
7								-.25	.11	.18	-.05	.10	.84
8									.52	.13	-.04	.45	.58
9										.44	.65	.50	.60
10											.41	-.12	-.19
11												.13	.17
12													-.97
13													

EDUCATION AND TRAINING

B	1	2	3	4	5	6	7	8	9	10	11	12	13
1		.90	-.71	-.73	-.29	-.21	.06	-.24	.65	-.06	-.79	-.66	.59
2			-.53	-.49	-.26	-.18	.83	.05	.76	-.19	-.13	-.42	-.32
3				.96	.21	.45	-.31	.51	.47	.02	.12	.91	.82
4					.18	.37	-.28	.56	-.45	-.06	-.02	.93	.91
5						.69	-.18	.37	.33	.82	.51	.48	.47
6							-.05	.43	.17	.84	.85	.59	.61
7								.08	.68	-.14	-.03	-.23	-.13
8									.35	.12	.15	.68	.72
9										.29	.20	-.19	-.11
10											.83	.23	.23
11												.17	.17
12													.98
13													

ADVISORY

C	1	2	3	4	5	6	7	8	9	10	11	12	13
1		-.66	.13	.01	.42	.54	.34	.01	.33	.25	.42	.22	.14
2			.42	.50	.66	.80	.01	.54	.36	.40	.31	.77	.72
3				.99	.19	.40	.27	.71	.95	.96	.83	.87	.90
4					.15	.46	.23	.71	.91	.93	.78	.90	.92
5						.50	.03	.29	.08	.07	.03	.22	.18
6							.51	.63	.35	.43	.43	.77	.73
7								.44	.41	.42	.64	.36	.40
8									.72	.73	.75	.79	.81
9										.98	.94	.82	.86
10											.93	.86	.90
11												.76	.82
12													.99
13													

RESEARCH AND DEVELOPMENT

D	1	2	3	4	5	6	7	8	9	10	11	12	13
1		.49	.20	.21	-.05	-.17	.25	-.07	.08	.41	.11	.10	.13
2			-.08	.03	-.15	-.01	.07	.08	.16	.02	.13	.22	.24
3				.83	.00	.18	.19	.40	.50	.07	-.09	.68	.66
4					-.04	.20	.37	.53	.61	.15	-.10	.83	.83
5						.75	-.05	.09	.16	.25	-.03	.24	.19
6							-.04	.49	.51	-.02	-.15	.59	.56
7								.24	.18	.24	.31	.23	.36
8									.79	.05	-.09	.65	.75
9										.08	.16	.81	.85
10											.08	.00	.06
11												.07	.02
12													.97
13													

BASIC RESEARCH

E		1	2	3	4	5	6	7	8	9	10	11	12	13
Investigator – Manpower	1		.38	.38	.20	-.21	-.24	.17	-.04	-.07	.39	.01	-.09	.03
Investigator – Man-months	2			-.05	-.08	-.46	-.17	-.02	-.09	-.03	-.06	-.09	.08	.07
Associate – Manpower	3				.87	.12	.43	.27	.63	.64	.05	-.14	.80	.80
Associate – Man-months	4					-.03	.33	.38	.67	.54	.10	-.05	.85	.86
Non-academic – Manpower	5						-.70	-.65	.28	.18	.36	-.21	.17	.15
Non-academic – Man-months	6							-.02	.74	.67	-.02	-.27	.66	.64
Equipment	7								.31	.15	.18	.53	.21	.35
Services and Supplies	8									.92	.06	-.04	.85	.87
Travel	9										.03	.01	.84	.86
Computer	10											.06	-.04	.01
Publication	11												-.17	-.08
Indirect Costs	12													.98
Total	13													

Figure 3-6. Correlation matrices of constituent budget factors in utilization of research funds associated with different research classifications and aggregated total (OSU 5-G, Appendix I).

In matrix (B) items one and two have a high correlation while the same is not true in matrix (E). Publication and associate man-months in (C) shows a much higher correlation than in (E), (B), or (D). Thus a linear relationship between publication and man-months might be used in adjusting budget items in the face of funding cutback.

Summary

1. Research activity and funding are increasing rapidly in U.S.
2. In external budgeting management should be aware of the distinction between funds spent by a particular economic sector and research actually performed by that sector.
3. Universities and colleges have been primarily responsible for the performance of basic research, and should continue in this role.
4. Management's role in controlling internal (project) budgeting could be enhanced by a better understanding of
   (a) what is par for budget item expenditure in a particular research classification;
   (b) to what extent a particular expenditure is dependent on, related to, or necessary for expenditure in a different budget category.

CHAPTER IV

RESEARCH PERSONNEL

Another important area of concern to management is proper selection of personnel and the assurance that successful performance of the predetermined research task lies within capabilities of the chosen personnel. The factors which usually have been foci of concentration in this regard, are shown in Figure 4-1, and are discussed below.

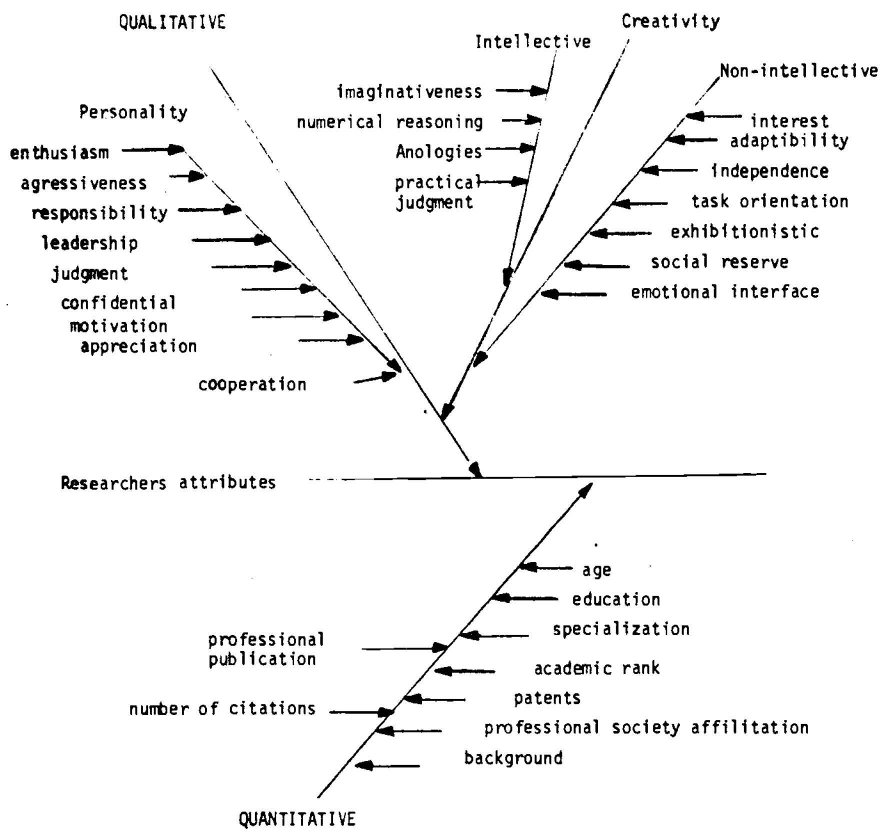


Figure 4-1. Factors considered in the evaluation of personnel qualifications.

Attributes of a Researcher

There are two points to be considered in a decision making process regarding research personnel attributes. One deals with awareness of what characteristics a researcher is expected to possess, and the other with the measurement of these characteristics and determination of their presence among the research staff.

Jackson and Spurlock (1966), along with many other successful researchers, believe that the cause of success for a researcher in his technical work is reflected by Thomas Edison's declaration that research "is 90 percent perspiration and 10 percent inspiration". Generally speaking, a person with scientific and/or technical knowledge who passes the test of creativity (i.e., is a creative person from the managerial point of view) can be considered qualified for research work. However, there are other factors to be found in any scientific organizations' appraisal form for research workers.

Hiscocks (1956), after discussing particular qualities of scientists and engineers with departmental managers of a laboratory (National Physical Laboratory, in Teddington, Middlesex) concerning their possibilities of advancement, and after comparing his results with draft lists used by other similar organizations, arrived at the following list of attributes:[1/]

1. Scientific ability
2. Judgment and common sense

[1/]The rating system was based on a five point scale ranging from Very Good to Unsatisfactory.

3. Initiative and drive
4. Speed, accuracy, and method
5. Power of expression
6. Leadership and personal relations.

Two additional factors were considered to be of importance in other organizations which he reviewed, and can be added to the previous list: special experience, and attitude and cooperation.

Another form, cited by Hiscocks, divides attributes into three major classifications, they are:

Professional Qualities

1. Scientific and/or technical knowledge
2. Application of knowledge
3. Interpretation of data or experimental results
4. Reliability and accuracy
5. Output quality/quantity

Personal Qualities

1. Leadership
2. Initiative
3. Personal relations
4. Directness and orderliness of methods
5. Quality of expression orally/in writing
6. Judgment and common sense

Administrative Qualities

1. Control of staff
2. Readiness to take decisions
3. Organizing ability

How the above classifications are actually used by management was not described. A closer look, however, makes it apparent that the first set of characteristics describes the ratee as a researcher while the second set rates him for possible promotion or active participation in an area of management mentioned in the last category.

Addison et al. (1961) conducted a nation-wide study on the frequency of occurance of factors used for performance evaluation of engineers and scientists in academic settings. Since the study was based on the idea of evaluation of job performance for the purposes of academic promotion, and also involved consideration of both rater and ratee, it was called "Dual Evalaution Plan". The study consisted of two stages. The first stage was a survey of old methods being used by the laboratories, it dealt with the need and use of performance ratings conducted through interviews and conferences with technical and administrative managers and other scientists and engineers. The second phase of study was to secure the laboratories with an evaluation list based on the results of phase-I study. Some of the outcomes of that survey and the frequency of responses are shown in Table 4-1. Another interesting study, and one of the earliest attempts at determining significant measurable factors relative to employment standings of scientists and engineers engaged in R&D activities, consisted of a set of models presented by Martine and Pachares (1957). Statistical analysis was made on the data which had been obtained from a 15 percent random sample of scientists and engineers of an R&D laboratory having a total of 1800 scientific personnel. Eight out of 27 factors involved in the determination of employment entrance ratings in order

JOB PERFORMANCE		PERSONAL CHARACTERISTICS		SUPERVISORY ABILITIES	
Job knowledge	51 [1/]	Cooperation	46	Planning and directing work of others	48
Quality of work	47	Attitude	20	Economy of operation	11
Dependability	45	Emotional stability	14	Training of others	23
Initiative	43	Physical vigor	14		
Creative ability	39	Personal habits	14		
Judgment	40	Personality	10		
Adaptability	36	Loyalty	11		
Reporting results	31				
Coordinate own activities	25				
Safety	5				

[1/] Numbers indicate frequencies

TABLE 4-1 Factors involved in evaluation of scientific personnel in an academic setting

of their significance are as follows:

level of academic degree

number of professional publications

number of honor societies to which selected

major in physics

major in other than ME, EE, or physics

major in EE

number of patents prior to employment by the laboratory

number of fellowships

Martine and Pachares claim that results of similar studies at other leading universities have yielded the same conclusions, i.e., that the number of publications, fellowships, and patents are statistically significant for employment entrance rating of scientists and engineers in R&D laboratories.

Attributes of a Researcher From the University Viewpoint

The evaluation of faculty relative to their employment involves a great deal of subjective judgment. Criteria for promotion and/or tenure of the faculty at Oregon State University, for example, is primarily based on the following:[2/]

1. Teaching
2. Research and Creative work
3. Public service
4. Professional competence and activity
5. University service

The recognition and appraisal of such activities solely rest with the appropriate department head and school dean before credentials are presented to the president for a final decision.

Most departments have their own written policies regarding the evaluation procedures. In most cases, however, it is not clearly stated whether any particular aspect of research activities or its result should be weighed on different scales or not. Publication is mentioned as an important part of a research project but the value judgment on technical article, textbook, or a research book, for example, is not well differentiated (except within one department). Departments may have their own procedures, but they are not written and/or not publically available.

[2/]General Instruction: Annual review and recommendations for promotion and/or tenure, OSU, Executive Office (Revised 10/25/71 and November 1972).

After reviewing the available written policies[3/] of nine departments and schools.[4/] The criteria and frequencies of their occurence are shown in Table 4-2.[5/] Referring to Table 4-2 it seems illogical to distinguish originality from creativity, as if they are two separate qualities. Moreover, other factors such as making significant change in teaching, implementation of modifications, and curriculum development and improvement require a good deal of creative ability.

We now examine creativity to see whether such a quality can be clearly distinguished from other ones, and if it can, what aspects of it are pertinent to our discussion on research capabilities.

Research Management and Scientific Creativity

The work of psychologists along with other studies done on creativity has led many people to the view that we can scrutinize and analyze it as a separate entity. Creativity is a noun and supposedly should be the quality of being creative, or having the power to create. This quality as cited by Hyman (1969) may belong to things, persons,

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[3/] Information obtained from personal file of the OSU Dean of Faculty.

[4/] Agriculture
Business Administration
Health and Physical Education
Home Economics
Humanities and Social Sciences
Forestry
Education
Engineering
Oceanography

[5/] Others having only one occurence have been omitted from Table 4-2.

Research 8 [1]

Quantity		Quality	
Research awards	4	Publication	3
Productive	2	Effectiveness of research	2
[2] dissemination	4	Cooperation	4
Books	2	Creativity	6
Seminars and conferences	2	Originality	2
Papers	3		
Journals	6		

Teaching 9

Quantity		Quality	
Number of years and academic rank	6	Effectiveness in class room	4
Awards	2	Enthusiasm	3
Course development	2	Significant change in teaching	2
Classroom performance	3	Ability as a team member	2
Curriculum development	5	Improvement, implementing modification	2

Services 7

Community services	7	Professional Consultant	2	Academic student advising	7
Extension activities	2	Committee member	2	Counseling	4
Service requiring professional competence	2	Paper presentation both National and regional	2	General advising	3
Advisory	2			Graduate advising	4
Service in special board	2			Program advising	3

Other: Participation and affiliation in professional societies and/or Committee: Local, State, National 2

Special assignment accepted or completed 2
Honors and other awards 3

[1] The numbers indicate the frequency of occurence
[2] The terminologies have been cited as they have appeared in references; for example, "dissemination of knowledge" sometimes has been referred to as "books, seminars and conferences, papers, etc.

Table 4-2 Factors considered in evaluation of scientific personnel at the university.

behavior and performance, or products.

A survey made by Sprecher (1959) for determining the meaning of creativity made the point that there is disagreement among different professions since different people assign different meanings to the word. His study was conducted with five psychologists and four engineers. Creativity revealed itself to be a combination of elements such as "ideas, work habits, and opportunities". Sprecher also remarked that to managers, creativity, as related to the company's productivity, is likely to be defined from different perspectives.

Long before arriving at the technological era, creativity was defined as the art of supernatural powers; later it was applied to describe artistic talents both in non-verbal languages such as painting, weaving, sculpture, and in verbal languages such as poetry, religion, and song. Today in science and technology it is considered to be an important entity in research management.

Generally speaking, from both a research and an industrial perspective, creativity is intelligence, originality, and cleverness which will result in discoveries, inventions, innovation, and productions. From a psychological perspective it is considered to be a behavioral quality. In the latter case we are referring to a gifted mind or a mind with some creative capacity based on intuitive grounds and/or existence of some ideas based on divine inspiration which is called Artistic Creativity and is stimulated by the creator's desire. In the former case we refer to Scientific Creativity which is stimulated by the investigator's desire and societal needs.

Numerous studies have been done on creativity in which each provides its own definition of the word. Few have distinguished between the artistic and scientific aspects of the concept. According to Orth et al. (1964) "we are beginning to have many measures of 'creativity' but we do not really know what we are measuring."

Neidt-Drebus (1964) conducted an investigation on scientific creativity in an industrial center having 600 employees. The scientists tested for this purpose had all been employed by the center for at least two years and were classified as "group leader, senior scientists, or above". The study was based on the following definition of creativity: Demonstrated ability to initiate, evaluate, and sustain original thought of action to reach a desired goal. The elements were classified into "descriptive characteristics" such as educational background, and number of patents they hold; "intellective characteristic" such as adaptability, analogies, and practical judgments; and "non-intellective characteristics" such as task orientation, exhibitionism, and independence. No significant relationships were found between creativity and descriptive characteristics (also refer to Figure 4-1; qualitiative portion) except the number of patents with which it proved to be significantly correlated. The final outcome of the study was that a creative scientist is "... a well adjusted individual who possesses especially high ability to perceive relationships".

A study made on Air Force scientists, reported by Taylor-Ellison (1964) under different classificatory analysis, yielded the same result in a similar context. According to this study, creativity occurs when a combination of factors is present in a man in an unexplainable form, and no single factor is considered to be of greater importance than another.

Kneller (1965) breaks creativity into qualitative factors such as intelligence, awareness (sensitivity to his environment), fluency (to generate ideas), flexibility (to try a variety of approaches), and originality (capacity to produce unusual ideas and ways, and use things in an unusual manner). Kneller makes no distinction between scientific and artistic creativity. However, he considers a high IQ to be more important for a scientists than for a painter. Likewise, De Simone (1968) regards scientific creativity in an engineering framework as being broken down into eight qualities, namely:

> recognize important situations, analyze factors, perceive relationships between problems and technology, imagine solutions, plan practical embodiments, realize working arrangements, demonstrate satisfactory operation, and bring an innovation into the effective service of society.

Summary and Recommendations

In research and development, technical knowledge along with awareness of the environment is one of the main factors of any creative work. In discoveries and inventions which have occured accidentally (such as the example given in the previous chapter about a researcher who is engaged in applied research and discovers something along the line of basic sciences) one would not be able to make the discovery if he did not have the appropriate and necessary knowledge for recognizing such an incident when it occured. In doing basic research, for example, the investigator is not quite sure of what exactly is going to be discovered and because of this state of uncertainties there will usually be no attempts made to facilitate such discovery. His final product, if successful, has been as the result of his intelligence and his state of cleverness for grasping discoveries when they show up.

In applied research and in development, society plays an important role in serving as a casual connection between the researcher and his creative work. In this respect, creativity is weighed and evaluated subjectively according to its economical feasibility and/or societal needs. Any discoveries, inventions, or innovative processes found economically not fruitful or for which a potential use is not foreseeable, will not be considered as creative work from any rational managerial outlook.

As far as management is concerned, there is no formal way to know how an individual may acquire insight into specific subject matter or adapt himself within the organizational structure. He can rely solely on the researchers' past experience and on the fact that he will again do successfully in his new area of work as he has done in the past. In this case, there would be little or no opportunities for other young energetic researchers with little or no background of support to prove that they can also do as well if not better.

In Universities and other non-profit research organizations, scientific personnel, just for being a part of that institution, are qualified to a great extent to do research work. And whenever there is competiton for obtaining research grants through submission of research proposals, researchers have already worked out a presupposed system for approaching the proposed problem. Therefore it is not wise for management to place as much importance on who is proposing as on what is being proposed.

CHAPTER V

EVALUATION OF RESEARCH AND SELECTION OF PROJECTS

Evaluation of research proposals for allocation of resources is one of the most basic and crucial responsibilities of research management. All industrial organizations engaged in R&D activities must contінously evaluate their programs to meet the future needs of their organizations and of society.

In academic institutions the role of research is somewhat different than in industry. Industrial research is profit-oriented, while research performed in non-profit institutions is mostly directed toward the increase in knowledge. Nevertheless, these institutions also perform contract research sponsored by government, industry, or private sources which is expected to eventually produce profit.

Since basic research is most logically done in non-profit institutions, the government has preferred the idea of giving grants rather than contracts, for this purpose:

> Where the Government desires to engage the services of an educational or non-profit organization for the conduct of a specific piece of research directed toward a specific problem, the use of the contract form is obviously in order. On the other hand, where it is the desire of the Government to stimulate and support fundamental research in a given field, with the perimeters of inquiry limited only by the curiosity and creativity of the scientific investigator, the use of the grant form has several marked advantages. U.S. Congress Act of 1958, p. 301.

Many attempts have been made to evaluate research and development projects. Differences of opinion have arisen concerning the expectation and interpretation of results of particular investigations, even when they treat identical lines of production.

These efforts usually originate from industrial application. Since the ultimate goal of industry lies in economic productivity and is profit oriented, evaluation methods tend to forecast production rather than research products. Consequently, the value of research is assessed according to its rate of return relative to production, and termination or continuation of a research project is governed only with respect to profits.

Moranian (1963), for example, discusses the control of output in regard to its input. This pattern can be controlled in production to some extent, but due to uncertainty of the use or result of most research activities it is not possible to forecast such outcomes as a base for future profitability. In a similar context, Pappas et al. (1961) have argued the point that:

> ... it is imperative that the input information reflect a sound and well informed point of view and that the output be weighed carefully in the light of intangible factors. p. 69.

Another discussion about the evaluation of government sponsored projects presented by Rubin (1966), points out the impossibility of determining specific objectives or performance measures because requirements are not the same for all projects. Speed, for example, might be expected from one project while reliability could be crucial in another.

Quality of a Research Proposal

The concept of the quality of a research proposal has received considerable attention over the last two decades. Every research proposal has to be evaluated before it is granted support.

Evaluation of R&D is influenced by two schools of thought. One is the perceptive understanding of the value (as it was discussed in Chapter II), and the other is the conceptive understanding of the value. The former is based upon our past experience, the present conditions, and what appears to be matters of fact. The latter can only be justified by knowledge about the future or knowing in advance what the future needs of society will be. According to Creutz (1971) "At this time no one can predict what all or even the most important future problems of society will be". Thus, the results of certain research, no matter how unimportant they may look at the present, may serve as a remedy for future problems.

In relation to conceptive understanding of value, let us consider the following questions which are from the President's Science Advisory Committee on the space program that consumes $5 billion a year.

1. Does life abide in places other than on earth, and if so what is its nature, how did it evolve, and what are its probable forms?

2. What is the origin of the universe and its ultimate destiny?

3. What are the living conditions on the moon and how did our solar system evolve?[1/]

Cook (1967) argues, that these three questions, despite so many dollar consumption, do not create any excitement among members of the National Academy of Sciences, the Physics Society, or the physics and chemistry department at Harvard, Princeton and Cornell.

[1/]Taken from Leslie Cook, Keynote address: Research in Revolution. 21st National Conference on the Administration of Research. 1967. p. 8.

A further step is the evaluation of importance of any proposed research compared with other ongoing research. A few examples are in the chemical industry for improving the cleansing products, research in agriculture for making substitutes for insecticides, research in social sciences about drug abuse and crime prevention, research in medical sciences to prevent child defects, and research in engineering to improve the traffic patterns and communication systems, and so on. The commonality among the mentioned fields of investigation and the importance of each cannot be evaluated relative to societal needs or from any interdisciplinary outlook. As Bass (1965) has pointed out, "... There are no yardsticks for measuring research productivity." This is a true philosophical debate on the value and distinction between human needs and human wishes.

Models for Selection of R&D Projects

Models have been constructed either by insiders who have seen the research difficulties and have experienced the problems of decision making and allocation of resources, or by professionals who have observed difficulties of organizations from outside of the research environment. From both perspectives, the formulation of any evaluation models takes place within a limited frame of reference. This contributes to narrow applicability. Therefore, models tend toward a humble nature which make universal application unsatisfactory.

Let us consider the problem from different angles. A physicist's success in his research work in the area of theoretical physics, for example, is not caused by the same ingredients used by a biologist who is studying the reproductive cycle of an animal, nor is it comparable to that of an engineer who is doing research on the concepts of dredging. As Bass has pointed out:

> Organizations and procedures that prove successful in one case may be inappropriate in other conditions because of differences in objectives, organization, personnel, cultural background, resources, state of technology, competitive factors, etc. (Bass, p. 7).

Causes of success in investigation and allocation of resources are not identical in different disciplines, and may not be the same for two competing organizations which are engaged in the same type of research activities and producing identical products. Similarities in regard to the nature of these organizations do not provide enough justification for formulation of a model to be substantiated in different areas of research activities.

The models whose origin have sprung out of perceptive understanding of the value, and have been rooted in a specific field of research will have a burden only to the extent of accomodating the area of "AD" (refer to Figure 2-1). This makes the model usable as a formal tool of allocation of resources for that particular organization. The applicability of such a model is subject to modification when a new area of research is being introduced, or when a major change in management and/or objectives of the organization occurs. Therefore, generalization of such model for ameliorating problems of other research organizations remains questionable.

Formal Classification of Models

The first classification of models in regard to the use of optimization criteria and the nature of their formulation was presented by Baker-Pound (1964). These classes were: decision theory, operations research, economic analysis, and a mixture of economic analysis and operation research. An investigation by Cetron, et al. (1967) added four more features to that classification: decision theory-operations research, economic analysis-decision theory, mathematical, and comparative method. Moore (1968) introduced another aspect of classification as follows:

1. Economic and financial analytic models
2. Project scoring models
3. Linear and integer programming models
4. Dynamic programming models
5. Stochastic programming and game theoretic models
6. Long range planning operations research models
7. Information conversion process models

Consequently, models such as the one introduced by Hess which was considered to be an operations research approach with use of a dynamic programming is classified as a programming model. Other models such as Mottley-Newton (1959) and Gargiulo et al. (1961) which were considered to be decision theory type, would be placed under project scoring models of Moore's classification, and Soberlman's (1958) model, which was recognized by Baker-Pound and Cetron et al. as an operations research approach, belongs to economic and financial sector of Moore's classification.

The advantages or disadvantages of the above classifications are not apparent. The utilization of any model is not associated with its formulation, approach, complexity of methodology, or the attributes of its classification; bur rather is grounded upon the importance, soundness, and effectiveness of input information, and justification for selection of such criteria when they can be substantiated by those research organizations who want to use them as an unbiased and consistent system to evaluate their research program. For example, the probability of success is assumed by Hess to be of an exponential nature and independent of the past expenditures (this was used in the first part of his model). In contrast Mottley-Newton's is on experts' opinions about past experiences to arrive at such promise of technical success.

Examples of Models

Some of the models which were presented formally as an aid of research management will be reviewed briefly.

The first model presented as a scoring model, is contributed by Mottley-Newton (1959). It takes five main criteria into account, they are:

1. Promise of success
2. Time of completion
3. Cost of the project
4. Strategic need
5. Market gain

Each criterion is weighed on a four point scale, and the ranking priority is generated by a multiplicative index. A project with score of six

(1x2x1x3x1 = 6), for example, falls below a project with score of eighteen (2x3x1x3x1 = 18). It has been claimed that technical staff find this method of assigning arbitrary values to be satisfactory as a tool for their managerial judgments.

A stochastic model was presented by Freeman (1960) for allocation of research budgets. The model presents an analytical method for allocating the research budget to competing projects. This is done by determining the optimal amount to spend on research activities through construction of a value function. The model considers factors such as the characteristics of the project, cost of the project, total allocation, availability of resources, estimate of the probability of success and/or the net worth. The last estimate is established by different experts using their past experiences with the firm.

Hess (1962) in his dynamic programming approach, debates the concept of criteria selection. According to him, project parameters such as project life, project cost, expected payoff, and probability of technical success are not the only ones which should be considered in a model for project selection, since they all assume that the present selection procedures are going to substantiate future decisions. There is no evidence that the present success of a certain project would establish enough justification for its support at some later time.

There are two stages involved in Hess' model. The first step assumes that probability of technical success is exponentially distributed and in any period to be independent of the past expenditures. In the second part, the model considers cases in which the probability of success in any period is dependent of the previous research outlays.

On the first period the expected discounted net value can be established and is subject to a budget constraint.

Summary and Discussion of Models

Generally speaking, models fall in two major categories. One treats R&D activities as if they are in an static state. These models usually require a limited amount of information as their inputs. The second category consists of more complex models of a theoretical nature and they assume the R&D activities are in a constantly changing state. These models require more input data, often unavailable. Important features of some selected well known models which frequently are cited in research literature are shown in Table 5-1.

Key Features of the Models[2/]

Sobelman (1958), Discounted net value

Mottley-Newton (1959), Ordinal ranking, promise of success, time of completion, cost of the project, strategic need, market gain, program balance.

[2/] A survey of research and development made by Baker-Pound (1964) revealed that among eighty published articles reviewed, ten were constructed by management science and operation research professionals. These ten models were presented since they treat all aspects of the problems involved in decision making. Four of these models proved to be "fairly well known", but had one or no industrial applications. Another investigation of similar nature by Cetron et al. (1967) increased that number to thirty models. Their studies on the criteria and methodology claimed: "The various methods are compared and contrasted with each other relative to a standard set of features which they may possess, to a standard set of characteristics relating to ease of use, and to scientific or technical area of applicability." The paucity of these thirty models that have become widely known still remain with no or very limited areas of applicability.

	Models Classification						Areas of Applicability		
Authors	Ec 1/	Sc	Lp	Or	Dp	Dt	B	A	D
Sobelman (1958)	X			X					X
Mottley-Newton (1959)		X				X		X	X
Dean-Sengupta (1960)	X		X						X
Freeman (1960)			X	X					X
Pappas-Maclaren (1961)	X								X
Gargiulo et al. (1961)						X		X	X
Asher (1962)			X	X					X
Hess (1962)				X	X				X
Disman (1962)	X			X					X
Cramer-Smith (1962)	X	X						X	X
Nutt (1965)			X	X					X
Rosen-Souder (1965)				X	X				X
Dean-Nishry (1965)	X	X						X	X
Berman (1965)	X					X			X
Dean-Roepche (1969)			X						X
Atkinson-Bobis (1969)			X		X			X	X
Moore-Baker (1969)		X						X	X
Joyce (1971)	X							X	
Cochran-et al. (1971)			X					X	X
Howard-Yule (1972)		X	X						X

1/ (Ec)onomic analysis, Scoring method, Linear programming, Operations research, Dynamic programming, Decision theory, (B)asic, Applied, Development.

Table 5-1 R&D evaluation models associated with classes and areas of application.

Dean-Sengupta (1960), Discounted net value, budget

Freeman (1960), Discounted net value, budget, manpower, facilities

Pappas-Maclaren (1961), Estimates of the present worth, delay penality

Gargiulo et al. (1961), Ranking, budget, manpower, facilities

Asher (1962), Discounted net value, manpower, raw materials

Hess (1962), Discounted net value, budget

Disman (1962), Discounted net value

Cramer-Smith (1962), Discounted net value

Nutt (1965), Ranking, expected value, cost benefit analysis, budget, manpower, facilities

Rosen-Souder (1965), Cost-benefit analysis, profitability, discounted net value, budget

Dean-Nishry (1965), Ranking, profitability, market and technical factors, product life, development cost, annual sales, costs

Berman (1965), Incremental costs

Dean-Roepche (1969), Cost-effectiveness, Technical knowledge, the criticality of the methods

Atkinson-Bobis (1969), Expected value of return, program balance, budget probability model, commercial information, rate of expenditure

Moore-Baker (1969), Cost, budget, skill

Joyce (1971), Cost, expected value, budget

Cochran et al. (1971), Cost, expected value, number of development years, time

Howard-Yule (1972), Cost, budget, time, estimate of probability of success

Most models known as an operations research models utilize linear programming. What makes them distinct from other linear programming models is that they are associated with military affairs and the selection is made with a long range planning horizon.

Any linear programming model considers information from which estimates are made on commercial and/or technical success, economic life of the project, and other cost resources constraints. Since the model is concerned with the maximization of some expected value over a specified time, then this attribute makes the model paralyzed in cases of any possible changes due to the advancement of any project activities (e.g., when additional capital is requested, or when project considers different rate of commercial success), or any other changes in research program budget. The advantage of this type of modeling lies with the use of an objective function, the determination of the optimal research budget, and the observation of additional information such as shadow price and other cost alternatives on each interval.

When the objective function is an expected rate of return or expected utility function, then it is considered to be an economic model. Such outcomes can be ranked on a rate of return index. Estimates of each project rate of return is to be supplied by the users. The accuracy of such a model depends on the validity of its input information such as estimates of the probability of economic and/or technical success, rate of individual project return, etc.

In a dynamic programming approach, the model can be integrated into various subsystems, each of which yield different alternatives over any given period. A project may also undergo periodic evaluation during its duration and this aids control over the program at different intervals. Such models require generally unavailable information about resource availability and other possible upcoming restrictions.

In the decision theory approach each model is evaluated through the selection of chronologically sequenced alternative criteria, and the final decision is made through the selected objectives and rated according to alternative criteria. The resource availability is considered and the overall score determines the feasible choice for adoption.

A scoring model is more practical because none of the economic factors are being used (note that all economic factors are estimated). In scoring models the only estimate to be supplied by the experienced personnel is the probability of technical success.

All of the models are highly oriented toward the commercial environment; they seem to be pinpointing profitability in terms of dollars. They also indicate the role of research as a profit-making process.

We must carefully differentiate between fact and fancy. It seems that the theoretical models lean toward abstract mathematics and complicated problems in probability instead of scrutinizing the existent problem and trying to seek a more practical approach to decision making processes.

CHAPTER VI

PROPOSED METHODS FOR EVALUATION OF RESEARCH PROJECTS AND ALLOCATION OF RESEARCH FUNDS PERTAINING TO ACADEMIC INSTITUTIONS

The difference in philosophy behind government support of contract or sponsored research was briefly discussed in Chapter V. Also discussed, were the criteria and evaluation tools designed for accommodating the area of "AD" (refer to Figure 2-1).

The area of activities for non-profit research organizations lie in "B" or possibly "BA" zones. Since the motivation and philosophy of such research activities are essentially identical, they both fall into one category with similar attributes as explained by the following:

> Government-university relations are indeed quite different from those between government and business. Since business is oriented toward the (private) profit motive, the chief problem in government-business relations is to reconcile the performance of public functions with the profit motive. Universities, on the other hand, exist for the dissemination of knowledge - more plainly, for the teaching and research that together make up higher education... to the extent that government support of research (or of manpower programs) comes close to the universities' ideal, it contributes to the public service of higher education... (Dupre-Lakoff, p. 44-45).

Selection of criteria for purposes of evaluation can best be understood through observation of the many possible end results of research efforts. Figure 6-1 is designed for that purpose.

A closer look at Figure 6-1, reveals that research funds are utilized to achieve certain goals contributing to the public, university, industry and government's original philosophy.

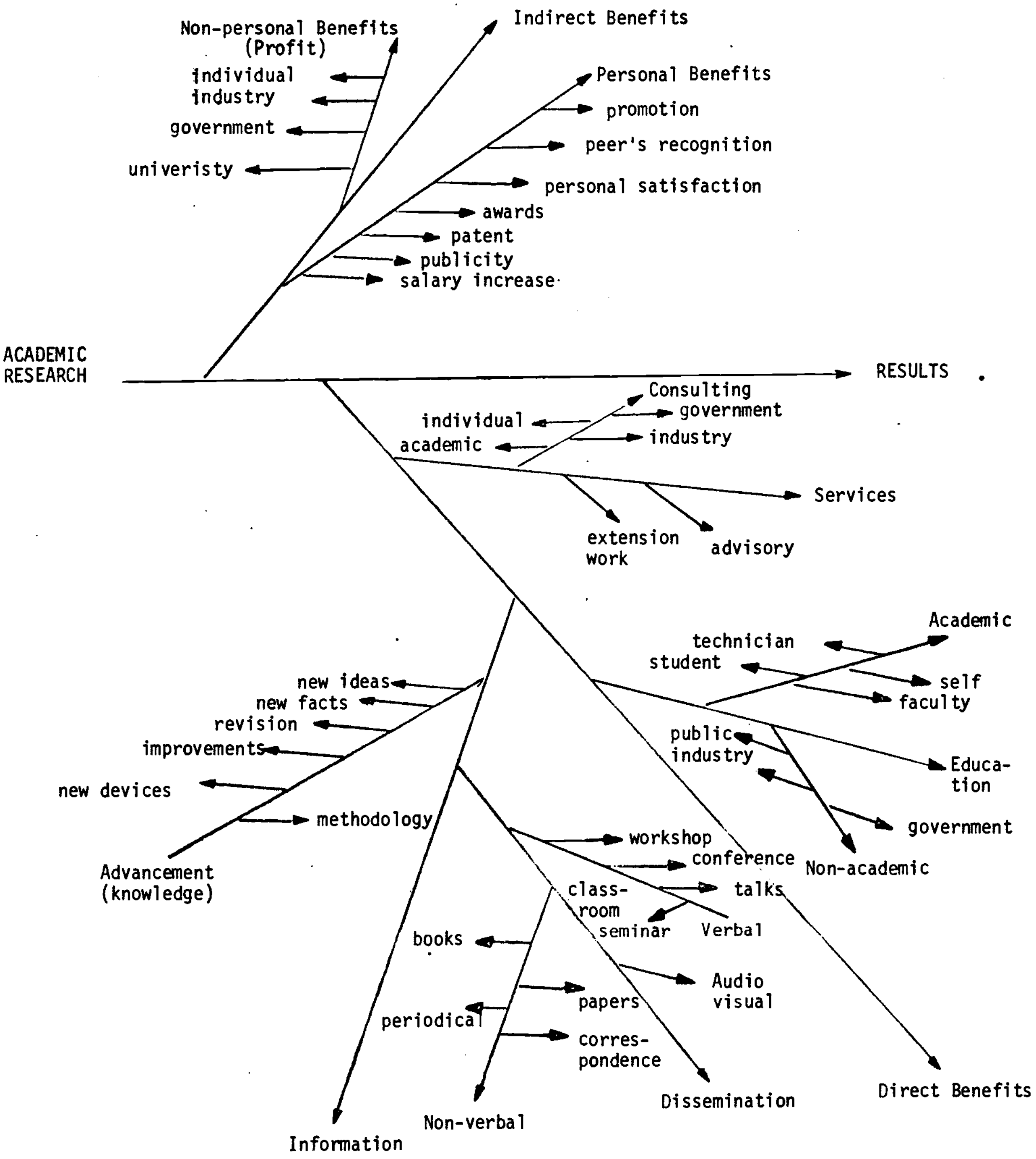


Figure 6-1 Academic research results

Therefore, it is logical that any criteria for evaluation of research projects performed in non-profit research organizations should be grounded on the basis of research contributions to different segments of society. Nonetheless, profit (in terms of dollar) may very well result from some of the research efforts. Some projects may receive support for having such attributes, but this cannot directly be considered as a criterion for evaluation purposes because it is not one of the prime factors in the program's objectives and, secondly, it is indirectly taken into account in following proposed methods.

Proposed Steps in Evaluation of Academic Research

1. Analysis of the outputs of ongoing research projects.
2. Identification of research objectives.
3. Formation of an Objective Table.
4. Comparison and determination of individual research outputs according to the objectives.
5. Construction of an inter-communication matrix.
6. Possible redesign of the matrix for consistency and verification.
7. Selection of criteria for purposes of evaluation.
8. Measurement of criteria
9. Design of a consistent evaluation system for research proposals and allocation of resources.
10. Possible redesign of the evaluation system.

Overall Analysis of the Outputs of Ongoing Research Projects

The purpose of analysis is to determine the main accomplishments of individual research projects. The information informs management of weaknesses which can be rectified. Appendix II is an example of how pertinent data can be acquired and analyzed without technical knowledge peculiar to distinct disciplinary areas. Each item on the list points out one of the main research efforts and consequent steps which should be taken if the project is to be continued.

The research and development section of the Oregon State University Sea Grant Program is used here to illustrate the analysis and some of the outcomes which may result from this procedure.[1/]

Observations from the analysis include the following:

1. Projects such as Ship Operation and Weather Information do not belong in this section and cannot be classified either as research or as development. They may be classified as operating costs, or be integrated as a portion of those projects which are using the facilities.
2. Projects 15 and 30 are doing identical work. Either they should be combined or one should be eliminated.

[1/]The data in Appendix II is accumulated only for the purposes of familiarizing management to the proposed procedures. And in no way is the presentation of OSU Sea Grant Program. The validity of the information extends only to the available references at hand and the contents which were written by the principal investigators.

3. Many projects are counting "statistical analysis techniques" as a part of their outcomes. This indicates a need for statistician to be a part of the program (example: projects 17, 13, 27, 32) either to analyze the obtained data from particular projects or to act as consultants for all projects.
4. Some projects results indicate a shortage of equipment use, services and/or supplies, although a sufficient amount of money was allocated for those purposes. This condition may arouse management's curiosity whether the amount has been wasted or recorded mistakenly by the accountant. (Example: projects 18, 17, 19)
5. There is a need for interdisciplinary sub-programming because:
   a) Some projects are using the same data (such as measuring temp. salinity, and other qualities of water) but are collecting the data separately.
   b) The line of investigation in some cases has extended deeply into another disciplinary area.
   c) A few projects have indicated installation of equipment as their outputs. This requires cooperation from engineering. (Example of the above statements are projects 15, 27, 32)

6. Most projects (all basic research projects) show that the investigation has extended two or three years before showing accomplishments. This is a prime indication that research funds should be obtained and allocated on long-term basis. Such fundings also may improve the quantity of publications which are of the utmost importance for the preservation and dissemination of knowledge. It also will help government and other academic institutions to eliminate any duplicative efforts which may exist.
7. Some projects show as their outcomes the preparation of manuscript or bulletin, but no amount of money was allocated for that purpose. The logic here is as same as number 4.
8. Some projects' results also show that the investigation is completed but somehow no publication is mentioned. (Example: projects 37, 38, 39)

Identification of Research Objectives

Each research grant carries its own objectives. In the case of government sponsored research support, the objectives are very broadly stated in terms of research philosophy. However, the areas of activities are clearly differentiated. More detailed objectives are set out by institutional grantees. Examples of the above information may be observed in Appendix III. Also included in the same appendix are university objectives and expectations from research activities, and industrial research objectives. The purpose of this presentation is not to establish guidelines for universities and/or industries, but simply to show how a list of objectives which benefit segments of society can be prepared.

Construction of an Objective Table[2/]

Table 6-1 shows project locations according to the institutional objectives. The table serves three major purposes; it shows:

1. Distribution of projects according to divisions, programs, and other specific goals.
2. Density and absence of projects at different locations throughout the table.
3. Initiation areas of possible interdisciplinary research programs.

[2/] How to construct and/or read the table:

Example: Number 11 in the top box and first column stands for project number 11, and it belongs to the first division; Food from the Sea (looking on the bottom), is also a part of "A" program; Evaluation and Biology of Stocks, and is fulfilling goal number 5 (from the same box looking parallel to the left).

Note: The table is constructed only for institutional objectives present in Appendix III, and is tabulated according to research results analyzed in Appendix II.

SPECIFIC GOALS	FOOD FROM THE SEA				COASTAL ZONE ENVIRONMENTS				HUMAN RESOURCES		
PROGRAMS	A	B	C	D	A	B	C	D	A	B	C
7			16, 17								
6			16, 37								
5	11, 12		34, 37, 38, 39								
4	11, 21		38, 39	11, 22, 21, 23,28	29,31, 22,13, 12,19	12, 20, 14		13,18, 14,19, 31, 22,26			
3	24, 26, 27	35,15, 17,33, 18,30, 20	16, 40	11	29			14		25	25
2	25	15, 30	38, 39, 40	11	29						
1	24, 32, 26, 27	15, 30	38, 39, 40	11, 28, 24	14, 29			14	34		25

DIVISIONS

Table 6-1 Example of research projects classifications according to institutional research objectives. (Data is obtained from the Appendices II and III)

Comparison and Determination of Individual Research Outputs According To The Objectives

Table 6-2 presents one portion of the research outputs (dissemination and preservation). Data are collected from OSU Sea Grant College Programs. The purpose of this presentation is to show empirically the feasibility and possibilities of obtaining and accumulating sufficient data for determining contributions to other segments of society. In other words, to show how the obtained information can fulfill other objectives mentioned in Appendix III. Column three for example, (Table 6-2) complies with objectives number 4 and 6 of "Objectives of Higher Education". Similar information may be obtained to comply with objectives number 9 and 10 of the same section.

Table 6-3 presents individual projects with their possible contributions to different segments of society.

Column one is the project number

Column two identifies projects according to definitions discussed in Chapter II

Columns three through six show the objectives which are fulfilled by the projects. The numbers in those columns correspond to those given in Appendix III.

Example: Project number 11 is classified as B (Basic research) and falls in objectives 4 and 3 of government, 1, 4, and 2 of institutional research program, 1, 2, 5 and 7 of university, and number 2 of industrial research.

	Book	In-house	Theses	Tech. Report	Journal	Conference	Paper	Films
1			11			1		
2			1					
3		1	5	1			1	
4			6					
5			2					
6				1	1			
7								
8								
9								
10								
11				1	2	5		
12				1	1	1		
13		1		3	1,1	3	2	
14			1				3	
15		3						
16				1				
17				1		1		
18		1	1	1	3t 1/	1		
19		1						
20		1		1				
21		1		1	2t			
22					8t			
23		1		1				
24			3	1		1		
25					1t,1			
26			1			4	2	
27	3	1	4		2	2		
28								
29		1			2t,2	1	4	
30		1		1				
31			2	1		2	1	
32		1	1			2	1	
33				1		1		
34			1		2t,1	2	3	3
35		1	2	1				
36								
37								
38								
39					2t			
40					1t		4	
41		4		8	2t,2	7	4	2
42					1t		2	
43								
44				1	1t	1	5	
45								
46		1		2			2	
47						2	6	

Research and Development Section

1/ Technical Journal

Table 6-2 Example of number of occurrances of research outputs for two selected years (OSU S-G)

No	Type	Government (sources)	Research program	University	Industry
		OBJECTIVES			
11	B	1 , 4 , 3	1 , 4 , 2	1 , 2 , 5 , 7	2
12	B	4	5 , 6	10 , 2 , 7	0
13	A	1	5 , 8	2 , 10 , 8 , 7	0
14	A	3	5 , 6 , 8	2 , 5 , 8 , 10	0
15	A	3	2	2 , 1 , 10 , 5	2 , 4
16	B	1	3	2 , 10	0
17	D	1	2	5 , 2 , 10	4
18	D	1	2 , 8	5,8,10,2,6,7	0
19	D	1	5 , 8 , 2	5 , 2 , 10	0
20	D	4	2 , 1 , 6	5 , 10 , 2	4
21	B	4	4 , 1	10 , 2 , 7	0
22	B	4	4 , 5 , 8	10 , 2 , 7	0
23	B	4	4	10 , 2	0
24	B	3	4 , 1	10 , 2 , 6	0
25	B	4	1 , 11 , 10	10 , 2 , 5 , 7	0
26	B	4	1 , 8	5 , 2 , 10 , 6	0
27	B	4	2 , 1	4 , 2 , 10 , 6 , 7	0
28	B	4	4	2 , 10	0
29	B	3	5	2 , 10	0
30	A	3	2	5,10,2,1,7	4 , 2
31	B	3	5 , 8	2 , 10 , 6	0
32	A	3	1 , 5	2 , 10 , 6	0
33	B	3	2	2 , 10	0
34	A	1 , 4	3 , 9	5,10,2,1,6,7	1,2,4,5
35	B	3	2	5,2,10,6	0
36	Not a research Project				
37	B	1	3 , 1	5 , 2 , 10	2
38	B	3	3	5 , 2 , 10	4 , 1
39	B	3	3	5 , 10 , 2 , 7	1 , 2
40	A	1 , 4	3	5 , 10 , 2 , 7	3

Table 6-3 Example of R&D projects fulfilling certain objectives associated with different segments of society.

<u>Construction of an Intercommunication Matrix</u>

Another important feature of any research program is the contribution of projects to each other. This internal cooperation resembles an unidentified interdisciplinary sub-program through which the flow of information is accomplished by the means mentioned in Figure 6-1 (Direct Benefits). The flow of information, however, does not indicate utilization of basic research results or its extension to development. The transfer of information from basic research to development projects through applied research does not exist. The concept may be clarified by the following observations:

A. Nourishment and utilization of basic research results usually take place in profit-oriented research organizations. It increases knowledge in non-profit research institutions. (This is when research results extend to production)

B. Academic applied research projects are not based on seeking applications to basic research outputs. They are independently originated, but they may utilize some specific research results.

C. There are few development projects in such institutions. The so called development projects are of the kind of exploratory economic development which have attributes of basic research, or they are in the form of an advanced applied research. (Projects that carry the word "development" as a part of their titles do not necessarily classify them as development project.)

D. Exploratory projects are independent and in no way related to the extension of either basic research or applied research. This can easily be noticed by analyzing research outputs (refer to Appendix III).

E. There is no immediate flow of information from basic research to development through an applied research project. This has no practical value because many other factors can influence the process, such as the existence of a variety of inputs for application of certain basic research results, the need for development, and the connection of development to previous basic research.

The data pertaining to this portion was originally tabulated from information listed in OSU Sea Grant's research proposals under the title "related projects". Since it was not intended to determine the input-output relationships throughout the research program, the constructed matrix must be symmetrical. A closer look at Matrix 6-1 shows the contradiction (one way communication).

Possible Reconstruction of Matrix for Consistency and Verification

By comparing each column with its corresponding row, Matrix 6-2 can be constructed. It is a symmetric matrix and validity of its input information can be verified by each pair of projects claiming to be related. The matrix serves three purposes:

A. It shows the relevancy of each individual project with others. This can be observed by selecting a project on the numbered row and whenever there is a dot on that row, the corresponding projects on top of the matrix are claimed to be related.

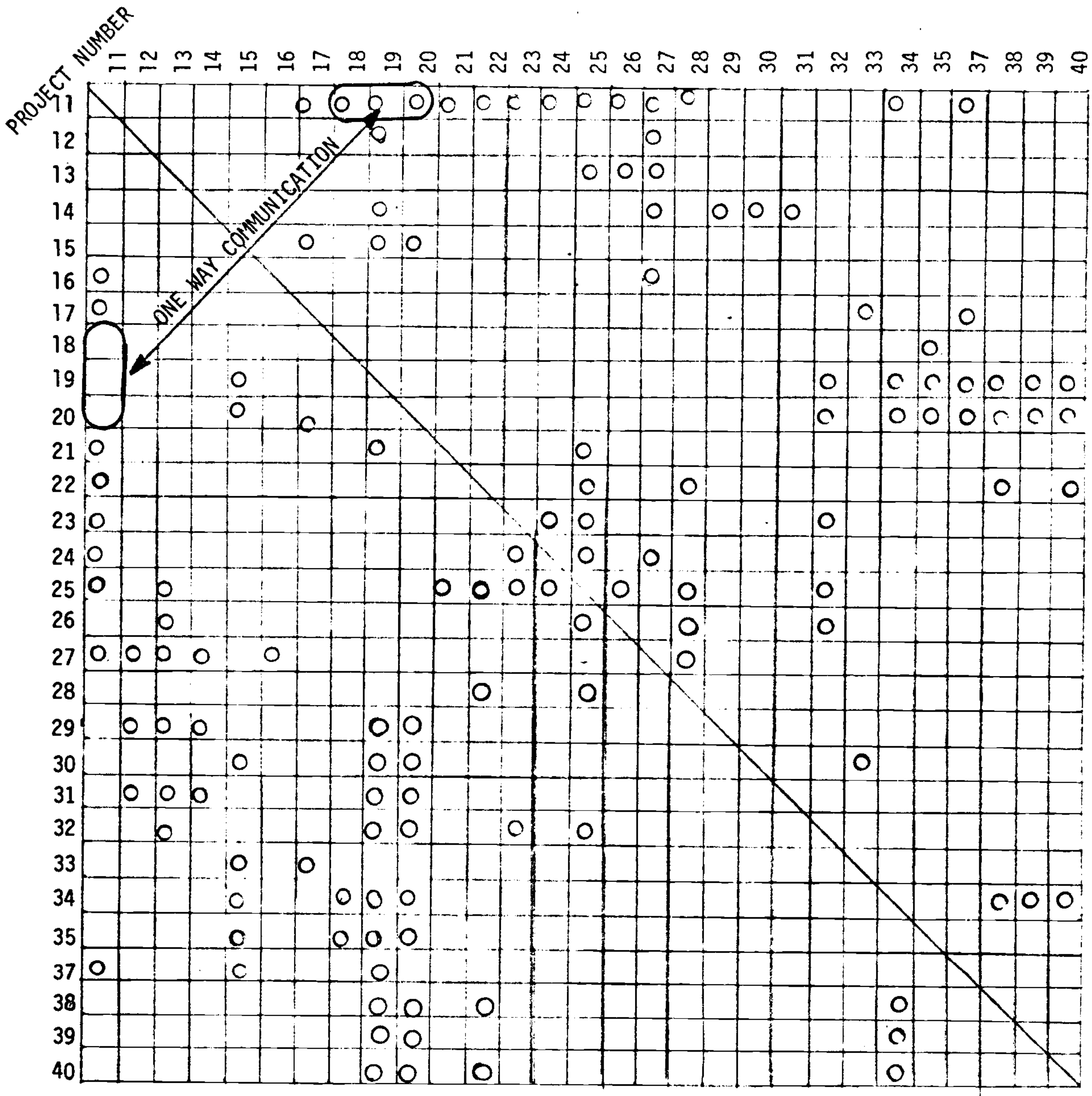
B. It may show the need for more interactions throughout the network. If the program is considered to be internally connected from management viewpoint, the connection or, in other words, internal communication throughout the program, can be observed as follows: Select any project (on numbered rows). The number of dots on that row indicate the number of related projects (the name of a project can be read on its corresponding columns). This shows the direct communication. Follow any dots on its column till they meet the diagonal line. Then the corresponding row (where the column and row intersect) may indicate two things:

   1) The selected project is connected to the dots on that row via the project on that column (indirect communication) or;

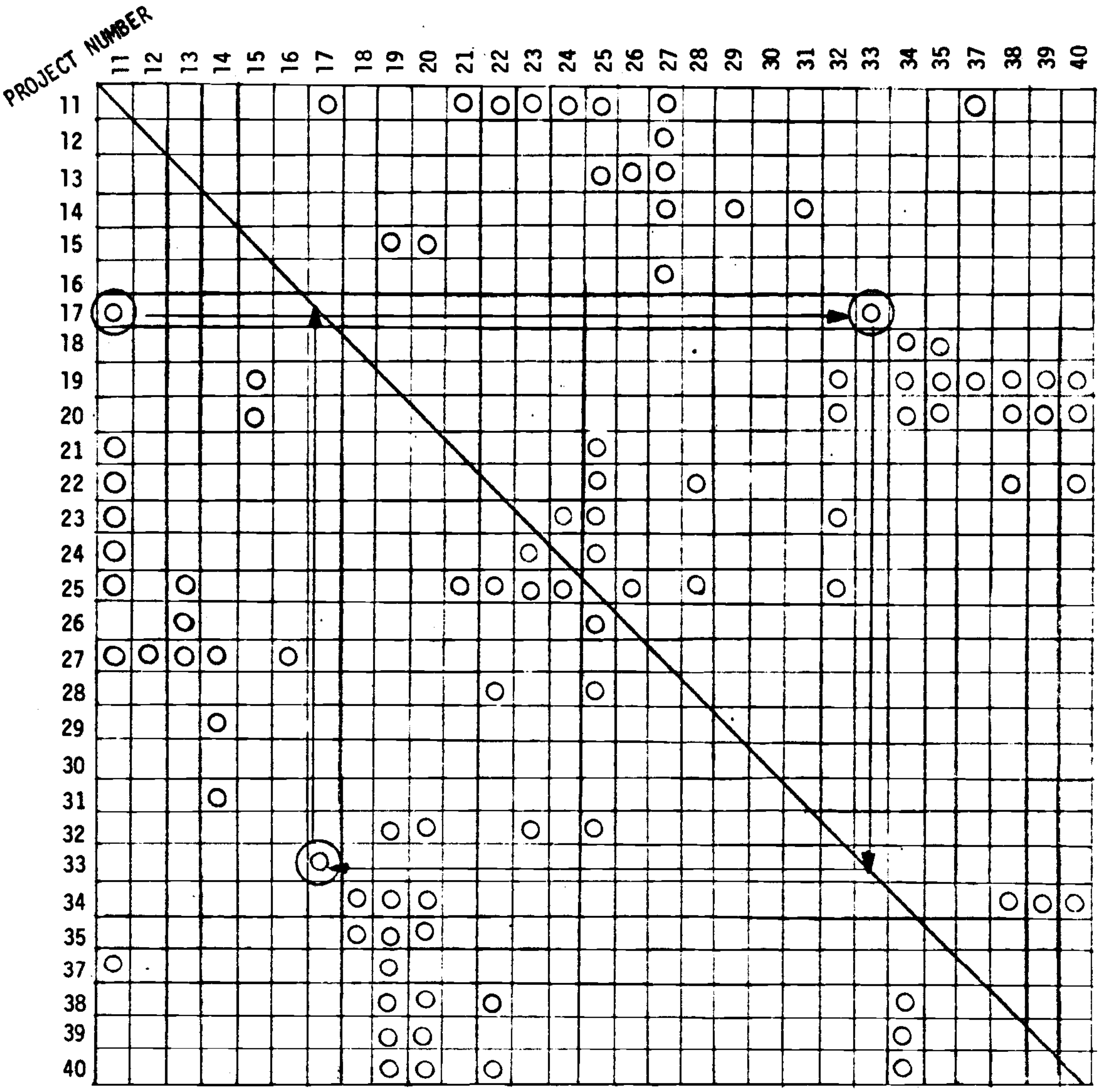
   2) The connection ends with the corresponding column.

   For example, project 17 shows connection with project 11 and 33. Follow 33 (the dot on the same row) straight down where it meets the diagonal line (it meets at row 33), the row shows no connection with other projects except project 17.

C. It shows the need for an interdisciplinary sub-programming. The accumulation of dots around a particular area shows the close intercommunication among those projects. Examples are,



Matrix 6-1. Example of internal communication among various projects (OSU Sea Grant Program, R&D section)



Matrix 6-2. Modified version of Matrix 6-1

projects 18, 19, 20, with 34, 35, 36, 37, 38, 39, and 40.

Selection of Criteria for Purposes of Evaluation

Discussions in Chapter V suggest that the criteria being used for evaluation of research and development in profit-oriented research organizations cannot be applied to non-profit research institutes. An earlier discussion in this chapter was intended to show the inadequacy of previously proposed criteria for evaluation and allocation of research funds in academic research institutions, especially when they are engaged primarily in basic research activities. The importance of any academic research proposal is based on the following criteria:

1. Relevancy of the proposed project with original goals (in case of government's sponsored support, accordance to National Goals).
2. Relevancy and the need for the proposed project in regard to the institutional research objectives.
3. Intercommunication power among internal projects.
4. The cost of the proposed project.
5. Promised contribution of the proposed project to different segments of society:
    a. Institutions at which research is performed
    b. Public
    c. Industry
    d. Others (such as governmental laboratories, state science agencies)

Measurements of Criteria

The value and importance of the above criteria depends on managements' subjective judgment with respect to attracting industry for future research investment, winning publicity from the public, or proving technical specialities in a certain area of research for more support from government, etc.

Design of a Consistent Evaluation System for Research Proposals and The Allocation of Research Funds

One of the most commonly used systems for evaluation of personnel and research proposals (refer to Table 5-1) is a numerical rating system. Ratings are usually obtained on an alternative basis (such as poor, average, above average, and excellent) with a numerical value given to the alternatives. Since the true value of the subject matter cannot be evaluated due to the nature of unqualified predictions performed by man and the nature of subject under investigation, the answers are sought on an interval basis (such as poor to average, average to above average, etc.).

The following rating system is not unlike that proposed by Mottley-Newton which was briefly discussed in Chapter V. (Slight modification is made for assigning the numerical values.)

Criterion	Sources of Decision	Numerical Value
1. Relevancy to original goals.	Appendix II, Table 6-2 (columns 2,3)	0,1,2,3,4
2. Need for such project.	Table 6-1	0,1,2,3,4
3. Internal communication.	Matrix 6-2	0,1,2,3,4
4. The cost of project.	Chapter III (internal budgeting)	0.1,2,3,4
5. Contribution to other segments of society.	Table 6-2; column 4-6 Chapter III (external budgeting); Table 6-2	0,1,2,3,4

The scoring is based upon a multiplicative index. Results which are not in accordance with criteria one through five will score zero and will be eliminated from the program.

Redesign of the System

The purpose of the system was to show the importance of criteria and the effect of arbitrary value assignment as the result of multiplication. However, should most projects propense toward zero in regard to criterion number five, for example, then the ranking system may be replaced by an additive index, or slight modifications in numerical value assignment can remove the burden.

Let us consider the following example for evaluation of R&D. Table 6-4 shows the final evaluation portion of research projects associated with their final scores and requested budget for the coming year. Each criterion and the means for arriving at its numerical value

Project number	Rating of Criteria[1]					Final Score	Requested funds for next year
	1	2	3	4	5		$ thousand
5	3	3	2	3	4	216	40
10	3	3	3	2	3	162	20
11	1	4	3	4	3	144	10
14	4	3	1	4	2	96	12
20	1	3	4	2	3	72	24
17	3	2	1	3	4	72	40
4	2	1	3	3	3	54	30
8	4	4	2	2	3	48	27
7	1	2	2	3	3	36	22
2	3	2	2	3	1	36	20
3	2	2	2	3	1	24	18
12	2	1	4	3	1	24	35
1	1	1	2	4	3	24	12
13	4	2	3	1	1	24	10
15	1	1	2	2	2	8	15
6	4	2	1	1	1	8	30
16	3	1	1	1	2	6	37
18	1	2	2	1	1	4	50
9	1	1	1	2	1	2	20
19	1	1	1	1	1	1	20

1/ Each criterion is discussed on the following pages.

Table 6-4. Evaluation of research proposals with their requested budget for the next year.

is briefly discussed on the following pages. Finally, Figure 6-2 exhibits the research projects which the available resources (e.g., 225,000) can support.

Criteria

1. Relevancy to Original Goals:[1/]

Each research project must be in compliance with research objectives (see Appendix III) to be considered as a pertinent research project. A management decision is based on the data available in Table 6-3; columns 2 and 3 (assuming each goal carries equal importance in the rating system). Project 11, for example, scores 7 points ((2) + (4) + (1) = 7) which by the way of comparison with other projects score, can be assigned a value from zero to four.

2. Need for Such Project:

Table 6-1 reveals the project accumulation in each program and its specific research goals. A decision is made according to need: project 25, for example, is the only project which is fulfilling programs 10 and 11, while projects 15 and 30 are doing exactly the same thing and following the same path in regard to fulfillment of research goals. The scoring is determined through observation of this table and the analysis of the research contents if applicable (Appendix II).

3. Internal Communication:

Matrix 6-2 shows the projects' internal interaction throughout the research program. The indirect communication and contribution is traced

[1/]Note: The example is based on hypothetical data, and the reference to previous pages is made only for demonstration purposes.

traced by the method discussed on page 74 (b). The scoring is made on a relative basis.

4. The Cost of Project

The internal budgeting section of Chapter III exhibits a clear picture of project expenditures according to its area of activities. Observation of Table 3-3 discloses the needed information regarding a particular project's expenditures; whether it is utilizing funds relatively below average, average or above average (the given range and median should be of prime consideration in decision making. This is primarily to indicate when one project has caused an inaccurate picture of the average. If so, it should be eliminated before arriving at average figures).

5. Contribution to Other Segments of Society

The decision concerning this portion of the evaluation model drastically affects the external budgeting in a long-run period. The procedure must be carefully examined and should be focused on the given information in the external budgeting section of Chapter III to determine where the money came from and what future income may be expected from those sectors. Finally, columns four through six of Table 6-3 will reveal the eventual contribution of any research projects to different segments of society.

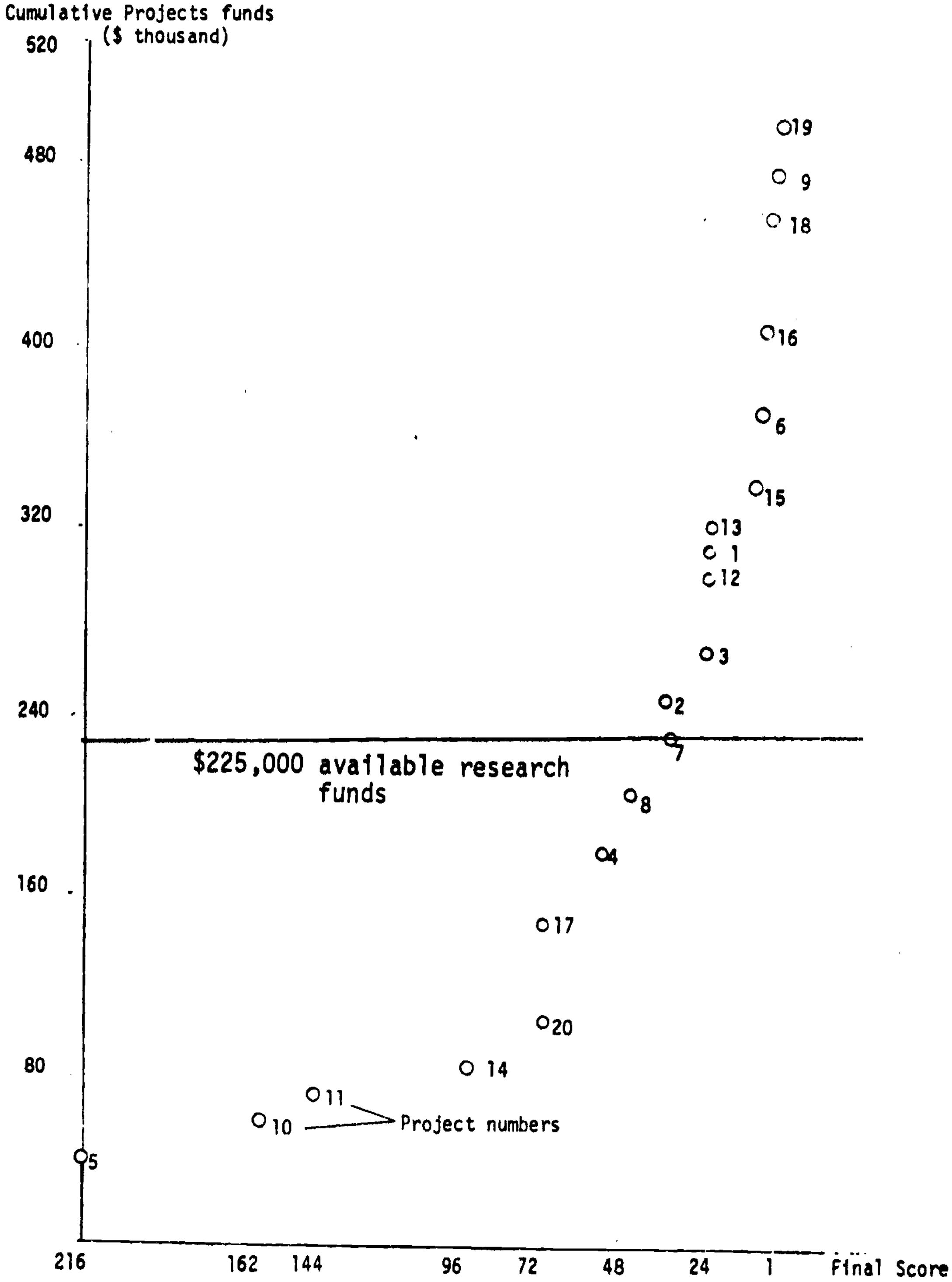


Figure 6-2. Cumulative request funds for next year versus final project scores.

CHAPTER VII

SUMMARY AND RECOMMENDATIONS

Summary

Our discussions have focused on input-output components of research performed in non-profit research organizations.

In Chapter I, we overviewed research management problems and the prime factors involved in an academic research institute.

The primary purposes of Chapter II were the explanation of various interpretations of the concept of research and a comparison of alternative classifications. The nationally accepted classification of research into Basic, Applied, and Development adopted by the National Science Foundation is somewhat similar to other definitions given previously by various researchers. Other prototype classifications and various terminologies, some of which are only substitutes for the above classes, are coined because of specific industrial applications which they may possess. They seem to have no practical use as a means of communication for academic research organizations. The NSF classification serves no purposes at the investigators' level, but it may be useful to top management for purposes of drawing funds from the federal government or contributing industries.

In Chapter III, we discussed external budgeting and scrutinized the distinction between the spenders of funds and the performers of research. Also discussed was the internal budgeting concerning the utilization of research dollars and typical research project expenditures associated with different classes of research.

Chapter IV was devoted to discussion of various aspects of the characteristics of the researcher himself. The subject matter was reviewed from both academic and industrial perspectives. The contents of research proposals was deemed more important than the qualitative attributes of researchers.

In Chapter V the concept of quality of research proposals and various evaluation techniques were investigated. Evaluation models revealed themselves to be profit-oriented and designed with industrial application in mind, while extremely inadequate for non-profit research organizations. This was primarily due to the selection of criteria and the type of techniques used to measure research outputs as a dollar generating process.

New evaluation criteria pertaining to academic research institutes were introduced in Chapter VI. Their bases were logically grounded on the concept of materials discussed in previous chapters. The Oregon State University Sea Grant Program was used here <u>only</u> as an aid to demonstrate the procedures and to show the feasibility of its practical application.

Recommendations

1. Classification of research and development according to the prototype classes (basic research, applied research, and development) is of no value at the investigators' level. Top management may use it as a tool of communication for purposes of external budgeting. The concept should not interfere with research proposals.
2. Basic research remains a critical area of concern to these nonprofit research organizations and serves as a mechanism for drawing funds from the federal government and industries, provided that the line of investigation is compatible and runs parallel with the objectives of the contributing sectors.
3. To control internal budgeting, management should make a standard itemized expenditures list associated with specific disciplinary areas of research activities (with certain permissible variations, or a fixed figure for a total of several items' expenditures). This list will eventually result in savings at the investigator level and also will serve as a guide for new research proposals.
4. Management should prepare a list of equipments which are not being used and make the list available to researchers before submission of research proposals.
5. Management should promote the areas of research which are a part of a program but have received little attention (this is in reference to Table 6-1).
6. Management must make all research publications publicly available (this excludes classified research). This will eliminate duplicative

efforts in organizations engaged in similar activities, and after all, this is a prime responsibility in regard to the dissemination and preservation of knowledge.

7. Management should not attempt to measure the qualitative attributes of researchers in academic institutions. Evaluators should pay attention only to what is said in the research proposal, not to who is saying it.
8. The research funds should be allocated over two or three year periods. An academic year period, with the part time participation of researchers is not sufficient for research to show accomplishments. This is especially true in case of basic research and/or new research projects.
9. Evaluation criteria and techniques designed for profit-oriented research organizations cannot be used and are not applicable to non-profit research institutes. The evaluation criteria must be specifically grounded on direct research outputs rather than on research products as a dollar generating processes.
10. The analyses of research outputs (as it was shown in appendices) and the proposed ten-step procedures are ways for management of non-profit research organizations to get a clearer picture of the ongoing research program along with awareness of the research direction, and a solid tool for improving subjective judgment.

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APPENDICES

APPENDIX I

EXAMPLE OF ITEMIZED RESEARCH PROGRAM EXPENDITURES

(OSU SEA GRANT PROGRAM)

DATA OBTAINED FROM MR. STEVE COVEY, OSU SEA GRANT OFFICE

Sum of two years expenditures (1971 and 1972)

Project Number	Principal No.[1]	Principal M/M[2]	Principal Dollar	Associate No.	Associate M/M	Associate Dollar	Graduate No.	Graduate M/M	Graduate Dollar	Non-academic No.	Non-academic M/M	Non-academic Dollar
1	2	6	6468	2	12	17500	16	96	59898	6	8	3630
2	0	0	0	13	32	37885	16	88	53877	3	2	1131
3	2	4	5100	5	5	5811	4	23	14489			
4	2	6	7000	9	15	23125	17	88	53130	5	23	11108
5	0	0		28	99	111622	26	137	84453	2	12	4500
6	2	6	5910	2	12	14892	12	64	37697	1	1	120
7	4	30	34575	0						1	3	1300
8	4	27	31751	0						1	3	1300
9	4	23	25725							1	3	1300
11	3	13	18167	15	91	10067				7	66	72505
12	2	15	15242									
13	2	12	15808							12	56	30601
14	2	15	18000	3	18	11158				2	13	8534
15	2	18	16848	8	37	38252				5	30	13725
16	8	12	12060	11	22	24525				7	16	7241
17	4	17	19983	6	29	36507				13	28	16605
18	1	3	3451	16	48	49076				1	1	462
19	3	12	15156	6	12	19967						
20	3	3	5286	5	17	15473						
21	4	12	14634	4	28	17859				3	4	1988
22	2	17	17850	8	50	70002				6	11	10104
23	4	21	32201							1	1	500
24	4	18	21032									
25	8	16	20045	8	48	33675				1	2	885
26	6	16	23178	7	50	37466				3	3	1632
27	8	14	23937	8	54	36211				7	10	4704
28	4	24	31593							1	1	250
29	2	8	9832	2	12	13307				15	28	24216
30	2	2	3001							6	5	2322
31	5	9	11860	3	5	7723				12	30	21240
32	2	4	4852	5	15	13140				9	25	13274
33	3	6	8168							6	7	3974
34	4	20	30801	4	9	10066				6	11	5737
35	8	35	47466	4	13	13240				2	4	1800
36	0	0										
37	2	5	5910	4	14	16499				14	43	26612
38	4	13	13826	4	48	44002						
39	3	27	28218	2	18	17041				7	38	18901
40	3	10	12281	7	44	50708				1	1	140
41	4	31	42886	19	70	70167				7	43	21600
42	4	17	22372							8	13	5900
43	4	21	25659							8	12	5250
44	4	15	17975							8	15	7218
45	4	5	4822	2	8	6826				4	4	1225
46	4	18	20437							8	43	29232
47	3	36	32304	1	12	9600				9	48	28978

Research and Development Section

[1] Number

[2] Man-month

Project Number	Equipment	Service & Supplies	Travel	Computer	Publication
1	438	4430	1910	536	0
2	1358	5753	1101		
3	0	1295	43	2	
4	2855	5449	1879	903	910
5	1018	7223	1		
6		5561	1176		
7	16488	4358	2727		
8	6036	6751	2523		
9	4789	3186	1545		
10	750	1739	15		
11	8508	55191	13481		300
12	2831	5218	2777	623	800
13					
14	4383	29632	1603	1251	
15	1274	48342	5303	329	
16	2440	3175	853		
17	150	2843	2077		
18	1350	1866	881	1139	
19		8037	487	223	
20	9	2149	1114	300	
21	791	3981	1636	472	
22	2472	8945	3240	973	200
23	12	1401	371		
24	492	1882	662	902	300
25	2211	7764	3616	2556	1000
26	47257	17193	2550	2000	2000
27	5419	10228	1993	3869	0
28		1694	614		1066
29	2567	8278	2314	3933	250
30	1820	2036	753	250	500
31	6947	25281	4119	2930	0
32		1792	600	1198	500
33	2010	2689	1586	1006	1831
34	3747	5577	4206	1000	4500
35	500	6433	2627	2000	
36		8000			
37	610	9725	1200	500	
38	7513	11215	589	1000	
39	4522	9401	1482	36	
40	6734	7233	1656	0	
41	1323	10139	17804	4417	7999
42	100	2853	3230	700	2000
43	300	3507	3565	200	2000
44	400	7523	2400	200	2000
45	300	2190	1426	100	400
46	2457	5903	3754	800	4000
47	0	5456	0	0	0

Research and Development Section

Project Number	Assessment	Other	Indirect Cost	Total Expenditures
1	8169		41631	144600
2	8318		41089	143977
3	2398		12081	41223
4	8825		44422	158606
5	19309		95434	323560
6	5460		27063	87888
7	0	13593	17895	90936
8	0	15572	16485	80318
9	0	10686	13482	60713
10	0	3880	630	8279
11	17975		91039	377833
12	1419		7252	36163
13	4301		22081	72791
14	3487		17925	85953
15	6556	5000	32748	168387
16	4077		20762	75223
17	6868		34780	119814
18	4985		25212	88422
19	3251		16712	63933
20	1902		10978	42505
21	3306		16404	61077
22	9426		46608	169852
23	3231		15559	53275
24	2033		10008	37011
25	5089		25981	102122
26	5783		29631	167690
27	6043		30837	125240
28	3126		15151	52428
29	4598		23531	92741
30	509		2532	13473
31	3992		19424	94016
32	2948		14922	52826
33	1146		5767	26866
34	4316		22078	89168
35	5167		20389	104122
36	3000		0	8000
37	4740		23325	89122
38	5481		27515	111441
39	5953		30527	116130
40	5869		30037	117658
41	12264		62054	251275
42	2361		13450	52402
43	2368		11983	52085
44	1154		6121	24564
45	4601		23623	94807
46	7089		33726	117155
47				

Research and Development Section

APPENDIX II

EXAMPLES OF THE ANALYSIS OF ONGOING RESEARCH PROJECTS

(SAMPLES OF DISCIPLINARY AREAS OF RESEARCH)

Oregon State University Sea Grant Office, Sea Grant College Program, Corvallis, Oregon. (Proposals submitted to the National Science Foundation, 1968 first renewal, one Volume, 1970 one Volume Proposals submitted to the National Oceanic and Atmospheric Administration. 1971 two Volumes, 1972, third renewal two Volumes)

PROJECT 12 (1970-71)

1970

1. Study on aerial photography of the coast, and comparison between previous data with the present configuration to identify areas of erosion or construction.
2. Contribution to the beach of sediments eroded from the sea cliffs is being assessed.

1971

1. Investigation of the effects of rip currents on the shore line configuration completed and published.
2. Reviews of breaking wave criteria and prediction and sand transport are under investigation.
3. A general survey of the Oregon coast is under study.
4. The effects of the importance of one location by a bay are being motivated.

PROJECT 17 (1969-72)

1969

1. Collection of data on prices, inventories, imports, exports of salmon and wholesale price of canned tuna.
2. Documented data on shrimp processing.

1970

1. Investigation on measurement of consumer perception and preference for sea food.

1971

1. Analysis on the relationship of various promotional techniques to sales.
2. Preparation on marketing margins for 5 west coast seafood firms.
3. Development of econometrical model for seafood demand function parameter.
4. Use of computer algorithms in part of the work.

1972

1. Analysis of demand on salmon.
2. Preparation of report on pricing and marketing of selected seafood items.
3. Study on the effect of retail advertising of seafood.

PROJECT 18 (1969-72)

<u>1969</u>

1. Investigation on economic evaluation of Columbia river.

<u>1970</u>

1. Study on regional impact of commercial fisheries upon pacific northwest.
2. Investigation for identifying the relationships, and determining the potential for sea-based production.
3. Investigation on marine resources policy.

<u>1971</u>

1. Study on the hatchery operation.
2. Collection of data and their analysis on licence, gear, vessels, etc.
3. Investigation on major eco-political institutions which impinge the operation of Oregon commercial fisheries.
4. Study of production and consumption of commercial seafood in two firms.

<u>1972</u>

1. Investigation on human resources income and mobility.
2. Study on the Oregon commercial seafood industry.

PROJECT 19 (1969-72)

<u>1969</u>

1. Study of coastal economics at a particular geographical location.

<u>1970</u>

1. Complete list of business established economy was classified and some data were collected from one location.

<u>1971</u>

1. Development of a multiple-use conflicts; cost-benefits analysis of water pollution control measurement at one location.
2. Study on community economic structure for one county.
3. Investigation on present structure of one place's economic potential.

<u>1972</u>

1. Development of a bulletin for water quality relationships at one location.
2. Review of literature on economic issues of multiple-use planning.

PROJECT 22 (1971-72)

1971

1. Investigation on culturing alga that grows in the tissues of cockle clam is being experimented in the laboratory. Also initiation of the parasites study upon young fish.
2. Cataloging and collection of parasites being found in estuarine and near shore.
3. Study on the parasitology of local perches.

1972

1. Investigation on parasitology on the redtail perch.
2. Examination of new protozoan parasit of fish, and their identification.
3. Study of a copepod parasite of the sport fish, starry, and flounder.
4. Accumulation of the information on the activity and parasites of the english sole.

PROJECT 24 (1971-72)

1971

1. Partial accumulation of basic information for determining the relationship between oyster and other bivalve.

1972

1. Development of an algal-snail simulation model for forming the theoretical basis for analysis of plant-animal systems.
2. Initiation of an analysis of the oyster hatchery operation, also initiation of mathematical modeling subsystems of larva rearing.

PROJECT 27 (1968-69)

1969

1. Design and construction of quantitative beam trawl for purposes of the study on fauna off Oregon Coast for determining abundance and biomass.
2. Study of 50 miles and 500 fathoms, setting a buoy at each location and 3 satellite-station in a triangular pattern for determination of animal and sediment variability.

1970

1. Collection of samples during five cruises.

1971

1. Investigation on the analysis of 437 shrimp taken from 800 station along Oregon coast for determining the relationship between shrimp catch and sediment.
2. Studies on macro-infauna; and 45 species were identified.
3. Determination of the rate of catch for pink shrimp at different time.
4. Measurement of the turbidity and near-bottom-current at selected areas.
5. Establishment of 15 oceanic shelf stations and measurement of slope between two selected points.

1972

1. Investigation on distribution, abundance, etc. of foraminiferons, and their behavior relative to bottom water and sediments.
2. Study on distributional changes of pink shrimp and the change in commercial stock of shrimp.
3. Study on seasonal changes in ecological characteristics of bentic environment.
4. Analysis on the stomach contents of commercial bottom fish for describing the food sources and diet's information.

PROJECT 32 (1969-71)

1969

1. Collected data from different sources is being used in simulation of biological production under coastal upwelling conditions.
2. Completion of implementation of steele's model for phytoplankton production.

1970

1. Investigation on parameters for a model of productivity using data from different locations.
2. Discovered that variations in the vertical mixing coefficient of water column has pronounced short term effect on productivity.

1971

1. Comparison of dynamic simulation results with previous years.
2. Advancement of interdisciplinary research between oceanography and engineering schools.
3. Investigation, as the result of a Ph.D. thesis on systems approach to pelagic plankton in an estuarine environment completed.

PROJECT 31 (1969-1972)

1969

1. Displays of flows from density-stratified reservoirs and the flow into a tank have been obtained.
2. Experiments on accelerations, strians, forces, and behavior of model structure under investigation.
3. Theoretical and experimental studies of dynamic behavior of structural members.
4. Improved design of efficient dredge cutterhead action.

1970

1. Measurement of forces resulting from surface waves on a horizontal cylinder in a wave channel under investigation.
2. Complete write up of NUMAC (numerical unconfined marker and cell).
3. Installation of several automatic elevation recorders in the estuaries and boats used to measure water, temp. salinity, and currents in the estuaries.
4. Development of a well equipped fluid metrology laboratory in hydor-dynamics.
5. 80 percent completion of 30x35 feet wave basin.
6. General solution to napea stokes equation governing heterogeneous time, depth, dent in compressible viscous laminar flows sought through numerical means.
7. Collection of tidal data from three locations.
8. Development of 40 feet flume with wave generator and instrumentation in hydraulics laboratory for purposes of marine structure investigations.

1971

1. Development of predictive computer model, and completion of facilities for research laboratory regarding submerged pipelines and their structures.
2. Investigation on submerged pipelines centered on currents and wave forces, in steady and stratified flow systems.
3. Seeking application to the 2-point mooring system for TOTEM buoy as influenced by surface and subsurface hydrodynamics loading.
4. Development of numerical predictive technique and procedures.
5. Invention of hydraulic pump adaptation to the outboard motor operated winches, was installed on four fishing boats as a result the production doubled.
6. Development of digital computer model to simulate the hydraulics of an integrated bay with the ocean; river system.
7. Completion of the study on the flushing characteristics and water quality of one Bay area.
8. Completion of tidal studies in three locations in estuarines.

1972

1. Completion of tidal hydraulic studies.
2. Conducting several field studies on flushing characteristics and water quality of several estuarines.
3. Collection of raw data on tides and currents from two locations for explaining quantitative behavior of choked inlets and adjacent shores.
4. Development of hydraulic pump power takeoffs for outboard engines.
5. Investigation on developing water jet excavation apparatus for freeing buried crabbing gear.
6. Development of numerical predictive techniques.
7. Investigation on structure-wave interactions.

PROJECT 37 (1969-72)

1969

1. Preliminary taste evaluation of boil-in-pouch food item.
2. Development of fish sausage.
3. Evaluation of comminuted flesh of jack mackerel, and other species.
4. Preparation of patties out of comminuted flesh.

1970

1. Investigation on organoleptic acceptance of various species.
2. Evaluation of boil-in-pouch, and other convenient sea food.

1971

1. Comparative acceptance of fish portion with fillets.
2. Preliminary investigation on the preparation of pre-cooked mixed sea food products.

1972

1. Use of machine in separating flesh; an increase from 35% to 54% was observed.
2. Study on minced flesh and evaluation of portions being composed with shrimp.

PROJECT 38 (1969-72)

1969

1. Application of anti-oxidant and vacuum packaging in vapor-proof containers for fresh salmon was developed.
2. Study on microbiology of pacific hake is underway.

1970

1. Development of the application of packaging technique on dungeness crab, and pacific shrimp.
2. Study on frozen dungeness crab meat.

1971

1. Development of the application of packaging in oxygen permeable materials on salmon, cod, rockfish, and shellfish.
2. Investigation on frozen shelf life characteristics of cooked dungeness crab, pacific shrimp, and whole dungeness crab.
3. Development of methods of applying sodium tripolphosphate to dungeness crab meat.
4. Study on the post-extraction biochemical changes in hake, rockfish, dungeness crab.
5. Investigation on microbiological flora of fish and shellfish.

1972

1. Development of two stage cooking procedures for crab meat.
2. Investigation on post catch changes in crab with oxidative enzyme system.
3. Development of a rapid and selective gas chromatographic method.
4. Discovery of low mercury present in Oregon coastal food fish.

PROJECT 39 (1969-72)

1969

1. Study on blue discoloration of dungeness crab meat.
2. Development of a process method for crab meat.
3. Study of microorganism on shrimp processing.

1970

1. Study on the effect of can vacuum level and added antioxidant.
2. Determination of microbial spoilage characteristics of pacific hake.
3. Completion of study on the growth of mixed cultures of microorganisms from marine environment.
4. Quantitative and comprehensive evaluation of pacific shrimp processing
5. Study of accumulation of thermophilic bacteria in pre-cooking process in crab and shrimp industries.

1971

1. Study on microbiological sampling methods.
2. Investigation of the effect of U V-treated sea water on the shelf cleaning processes of oyster.
3. Investigation on the removal of bone and skin material from different species, both quantitatively and qualitatively.

1972

1. Adaption of replicate-plating techniques.
2. Continuation of study on the machine separation of bone and skin.
3. Study on water and salt contents and microbial counts in commercial smoked fish.
4. Continuation of studies on U V treated sea water.

APPENDIX III

EXAMPLES OF RESEARCH OBJECTIVES

OREGON STATE UNIVERSITY

Sea Grant College

DIVISIONS

Food From the Sea

- Aquaculture
- Evaluation and biology of stocks
- Exploitation of stocks
- Food product development and utilization

Coastal Environments

- Coastal management
- Estuarine management
- Recreational resources and facilities
- Transportation

Human Resources

- Professional education
- Public environment education
- Social and cultural development

Food From the Sea[1]

1 Evaluation and Biology of Stocks:

1. Identify stocks of fish and shellfish needing immediate attention because of evidence of overexploitation.
2. Identify stocks of fish and shellfish having a potential for commercial or recreational exploitation.
3. Develop appropriate vital statistics and exploitation model for those stocks of fish and shellfish requiring such attention.
4. Develop life history information for those stock of fish and shellfish where management could be improved on the basis of such information.

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[1] Source: Handouts from OSU Sea Grant Coordinating Committee Meeting, October 2, 1972. Handouts from OSU Sea Grant Conference at Newport, Oregon, November 1, 1972.

5. Develop food chain and other information pertaining to the capacity of marine ecosystems to produce particular stocks whose management could be improved on the basis of such information.

2 Exploitation of Stocks:

1. Provide the technical, economic and legal knowledge necessary to enhance stock extraction.
2. Develop new or improved commercial fishing gear and procedures.
3. Encourage the incorporation of new or improved gear and procedures into commercial fisheries.

3 Food Product Development and Utilization:

1. Develop uses for unexploited fishery resources for direct human consumption and industrial purposes.
2. Develop new product concepts that would be feasible to manufacture and appeal to consumers that would yield a greater economic return from fishery resources.
3. Improve the quality and utilization of sea goods through the development and application of information on the physical, chemical, nutritional and bacteriological characteristics of seafoods post-extraction and post-processing.
4. Development and improve methods for handling, receiving, processing, transportation and storing seafoods that would assist in maintaining a uniform and acceptable product until the time of consumption.
5. Characterize the chemical and nutritional nature of secondary marine resources and develop means for their conversion into material utilizable by man and animal.
6. Determine the nutritional requirements of commercial food species of fish and shellfish.
7. Formulate and develop processes for preparing nutritionally adequate and available rations for food species of fish and shellfish reared under controlled conditions.

4 Aquaculture:

1. Provide the biological knowledge necessary for the commercial culture of suitable aquatic organisms.
2. Develop technology for the practical culture of aquatic organisms.
3. Encourage the incorporation of this technology into commercial culture operation.
4. Assist planning agencies with problems relating to the prudent incorporation of commercial aquaculture in planning coastal development

Coastal Environments

5 Estuarine Management:

1. Provide knowledge necessary for the wise utilization of estuaries.
2. Develop technology necessary for the management of estuaries.
3. Assist planning agencies with problems relating to estuarine development.
4. Encourage utilization of information and technology appropriate to wise estuarine management.

6 Recreational Resources and Facilities:

1. Provide knowledge necessary for the wise utilization of coastal recreational resources.
2. Develop technology necessary for recreational development.
3. Assist planning agencies with problems relating to coastal recreation.
4. Encourage utilization of information and technology appropriate to wise recreational development and management.

7 Transportation:

1. Provide knowledge necessary for the wise development of transportation systems.
2. Develop technology necessary for the development of transportation systems.
3. Assist planning agencies with problems relating to transportation.
4. Encourage utilization of information and technology appropriate to wise development of transportation systems.

8 Coastal Management:

1. Provide knowledge necessary for the wise utilization of the open coast.
2. Develop technology necessary for the management of the open coast.
3. Assist planning agencies with problems relating to coastal development.
4. Encourage utilization of information and technology appropriate to wise coastal management.

Human Resources

9 Professional Education:

1. Conduct continuing evaluation of training needs.
2. Provide training in relation to needs.

10 Public Environment Education:

1. Provide knowledge for public understanding of marine resources base.
2. Develop techniques to improve public education on marine resources.
3. Educate public.

11 Social and Cultural Development:

1. Provide knowledge on social, cultural, legal (institutional) factors as influences on marine resources use.
2. Develop techniques to improve management or understanding of social and cultural factors in marine resources use.
3. Encourage utilization of social and cultural implications in the development of marine resources.

Objectives of Research Program (on National Level)[1/]

1. To achieve the gainful use of marine resources, including animal and vegetable life, and mineral resources.

2. To produce the skilled manpower necessary for the exploitation of marine resources, including scientists, engineers, and technicians.

3. To stimulate development of the facilities and equipment necessary for the exploitation of resources.

4. To utilize aquaculture, "as with agriculture on land" and to employ the "gainful use of marine resources" for the benefit of the United States through greater economic opportunities, enjoyment and use of the marine environment, new sources of food, and new means for marine resources development.[2/]

Objectives of Higher Education[3/]

1. Manpower and skill development.
2. Continued flow of new ideas and tools into society.
3. Diversity in program offerings and institutional arrangement.
4. Opportunities for graduate to work and contribute to society.
5. Recognition of and adaption to new societal demands.

University Objectives:[4/]

6. The education of undergraduate, graduate and post-doctoral students.
7. The preservation and dissemination of knowledge.

[1/]Plans and Policies for the National Sea Grant Program, Fiscal years 1971 through 1975. NSF Office of Sea Grant Programs, Revision I, January 1, 1970. 52 p.

[2/]The National Sea Grant Program; Program description and suggestions for preparing proposals. U.S. Department of Commerce, NOAA Administration. May 1972. 44 p.

[3/]Educational objectives in postsecondary education is analyzed as a part of research program supported by the Ford Foundation and they were accumulated by Paul Wing (1972) in a hierarchial five-levels of objectives. Among thirty items mentioned in his report there are five that can be influenced and contributed by research activities.

[4/]Primarily, objectives of research and education in universities and colleges are somehow similar in their context. The ones mentioned here, are Prime objectives of universities. Number six through eight was mentioned by Woodrow (1962). The contents also were emphasized by Chauncey Starr (1968). Number nine and ten taken from: Castle, Emery N. et al. Report to the President of Oregon State University; from the Commission on University Goals. Oregon 1970. 574 p.

8. The advancement and protection of the public interest and public welfare.
9. To encourage the communication of research methods and findings in the classroom.
10. To encourage the exploration of the consequences stemming from the application of new knowledge and technology.

Objectives of Industrial Research[5/]

1. To improve the quality of products.
2. To develop new materials, processes, or devices for existing or new market.
3. To develop new uses for existing materials, processes, or devices.
4. To effect savings in cost and to assist in standardization.
5. To abate dangers or nuisances in the work area and to prevent or cure troubles of production or use.

[5/] Taken from: Furnas, C. C. Research in Industry; its organization and management. New York, D. Van Nostrand. 1948. 574 p.