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ABSTRACT

This document presents a research effort intended to improve the economic information available for formulating politics and making decisions related to Information Analysis Centers (IAC's) and IAC services. The project used a system of IAC information activities to analyze the functional aspects of IAC services, calculate the present value of net benefits, and examine the sensitivity of the costs and benefits to changes in variables and to technological developments. The document includes eight chapters and five appendices. Chapter two examines IAC activities. Chapter three establishes the conceptual framework for modeling demand for IAC services. Chapter five describes an IAC user decision model. Chapter nine summarizes the findings and conclusion of the research effort. An executive summary is also presented. The study recommends that IAC's continue to improve accounting systems that provide meaningful cost allocation data, especially professional staff time.
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Development of Cost Benefit Methodology for Scientific and Technical Information Communication and Application to Information Analysis Centers

Metrics, Inc, Atlanta, Ga.

Prepared for

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DEVELOPMENT OF COST BENEFIT METHODOLOGY FOR SCIENTIFIC AND TECHNICAL INFORMATION COMMUNICATION AND APPLICATION TO INFORMATION ANALYSIS CENTERS

FINAL REPORT
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The project synthesized heretofore unrelated observations about behavioral characteristics of IAC users into an analytic model consistent with economic fundamentals. This model provides a conceptual framework for examining IAC service demand, for determining lower bounds on benefits, for establishing optimum service levels and prices, and for analyzing the impacts of changes in parameter values and technology. Electronic communications technology can increase the number of individuals having access to IAC's and may modify routine IAC operations. The study recommends that IAC's continue to improve accounting systems that provide meaningful cost allocation data, especially professional staff time.

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EXECUTIVE SUMMARY

Introduction and Highlights

This report summarizes the results of research effort undertaken as a result of a proposal submitted to the National Science Foundation's Division of Science Information in response to program solicitation NSF 74-38, Category 4 (Economic Characteristics of Scientific and Technical Communication). The effort focussed on the economic characteristics of information analysis centers (IAC's).

Definition of an IAC. An IAC is a specialized information center providing services in a particular technical area. More precisely, an IAC is "a formally structured organizational unit specifically (but not necessarily exclusively) established for the purpose of acquiring, selecting, storing, retrieving, evaluating, analyzing, and synthesizing a body of information and/or data in a clearly defined specialized field or pertaining to a specific mission with the intent of compiling, digesting, repackaging, or otherwise organizing and presenting pertinent information and/or data in a form most authoritative, timely, and useful to a society of peers and management." (See reference 1, Chapter 1.)

IAC Background and Recent Developments. (For a detailed discussion, see Chapter 2.) The IAC concept is not particularly new: as many as thirteen of what are now called IAC's were formed by the federal government before the turn of the century. However, many IAC's were formed in the 1960's, and the IAC concept achieved considerable prominence during the decade. The underlying motivation for establishing and continuing these Information Analysis Centers was the proposition that existing information systems were inadequate for users in other disciplines and frequently were inadequate even to meet the needs of users within the discipline. The publication of research and development results was leading to an explosion of data and concomitant difficulties of identifying which data were relevant to a particular problem and distinguishing between valid data and data of questionable validity. Another motivation to develop the specialized information collection and dissemination services which would be provided by IAC's was the increasing availability of automated equipment. Some individuals believed that the use of automated

data handling equipment could lower the cost of meeting the user needs for accessibility of relevant information and assurance of the quality of the information. However, the total cost of such equipment was high and the "market" was disaggregated. Consequently, sponsors of IAC's (many of them federal agencies such as the Department of Defense) were necessary in order to establish the IAC's.

Recently, the rationale for establishing and maintaining IAC's with federal funding has not been so clear. In the 1960's, the concept of information as a freely available commodity was dominant. Now, however, the IAC's, their users, and their sponsors are facing an increasing number of individuals who believe that information is a commodity for which users should pay. The Department of Defense, which originated and still sponsors many IAC's, instituted a policy in 1968 that called for centers to charge for their services and work toward the goal of recovering 50% of the contract face value by 1972 through user charges. The implementation of this policy emphasized the need for an understanding of the economics of IAC operation and financing. The research effort described in this report was intended to contribute to such an understanding.

Purpose of the Research. The purpose of the research effort was to improve the economic information available for formulating policies and making decisions relating to IAC's and IAC services. The objectives of the research were:

1. The development of a set of concepts and procedures which can be used to perform cost benefit studies of information service centers,
2. The application of these concepts and procedures to address crucial issues of mix, levels, and pricing of information services provided by IAC's, and
3. The determination of the sensitivity of the results of the applications to possible developments and innovations in communications technology.

The intent of the research was to develop a framework and tools for IAC managers and policy makers that are based on sound economic principles. The results should establish measures which can help resolve issues of optimum IAC service levels, mix, and prices.

Highlights. The remainder of this executive summary provides a brief synopsis of the results of the research. Highlights, each of which is described in more detail in a separate section below, include:

- IAC's have unique, distinguishing characteristics which set them apart from other centers offering information services. These characteristics involve the functions of data evaluation, analyses, and synthesis.
- The research effort produced cost and benefit models that illustrate interactions among IAC services. The models represent the first overall integration of observations about IAC's and IAC users with fundamental economic theory. Even with lower bound estimates of benefits, the models indicate that IAC benefits exceed costs.
- Benefit data are sparse, and there are both conceptual and practical difficulties with identifying the benefits of information services.
- There are complex factors associated with the utilization of IAC services. IAC service demand is consistent with a residual, risk averse demand model, and several descriptive characteristics of IAC services are judged to be important to the user.
- A mathematical formulation of optimum service levels indicates two optimal solutions: one from society's viewpoint and one from the manager's viewpoint. In general, these will not be identical, and there is a potential incompatibility between incentives for the IAC manager and for socially ideal investment in IAC services. The model provides the basis for designing IAC policies and decisions; however, implementation awaits extensive empirical research.
- Technological innovations can have significant impacts on IAC activities. The general area of electronic communications technology is expected to have substantial impacts on IAC operations, and these impacts are expected to be greatest in the time period 1980 to 1985. However, the impacts of the unique, distinguishing IAC functions are judged to be less than the impacts of other functions.

Functions of an IAC

Chapter 2 describes Information Analysis Centers and provides a background on their development and their potential users. The primary functions of an IAC, as shown in Figure 1, include:

- Identifying and acquiring documents, data and information;
- Scanning and screening;
- Evaluation of data and information;
- Performing research, data extrapolation, or data synthesis to fill identified gaps in knowledge;
- Indexing and storage;
- Communication with other data bases;
- Estimating the needs, demands, and costs of particular information dissemination opportunities; and
- The retrieval, screening, repackaging, and dissemination of the evaluated data.

The critical function of an IAC is the analysis or evaluation function. This function distinguishes an IAC from other information centers or libraries which may provide data collection, storage, retrieval, and repackaging services. In addition, an IAC may perform research, data extrapolation, or data synthesis to fill knowledge gaps which may be identified by the critical evaluation function. As a result of the evaluation, analysis, and synthesis functions, IAC's contribute to a field of knowledge by providing a synthesis and codification of knowledge which might not otherwise exist.

An IAC may produce both customized (individualized) services and products provided for a "mass market". Most IAC's provide several products and services generally falling in one or more of eight different categories.

Handbooks or databooks typically include data which may be numerical physical constants, materials properties, or techniques which have been established by research or practice. These books generally are intended to be used as reference books by a relatively wide audience.

State of the art reviews (SOAR's) summarize the state of development of a particular technology or technical area. Like the handbook, a SOAR typically is intended for a wide audience; it provides a snapshot of the limits of current knowledge in a particular field.

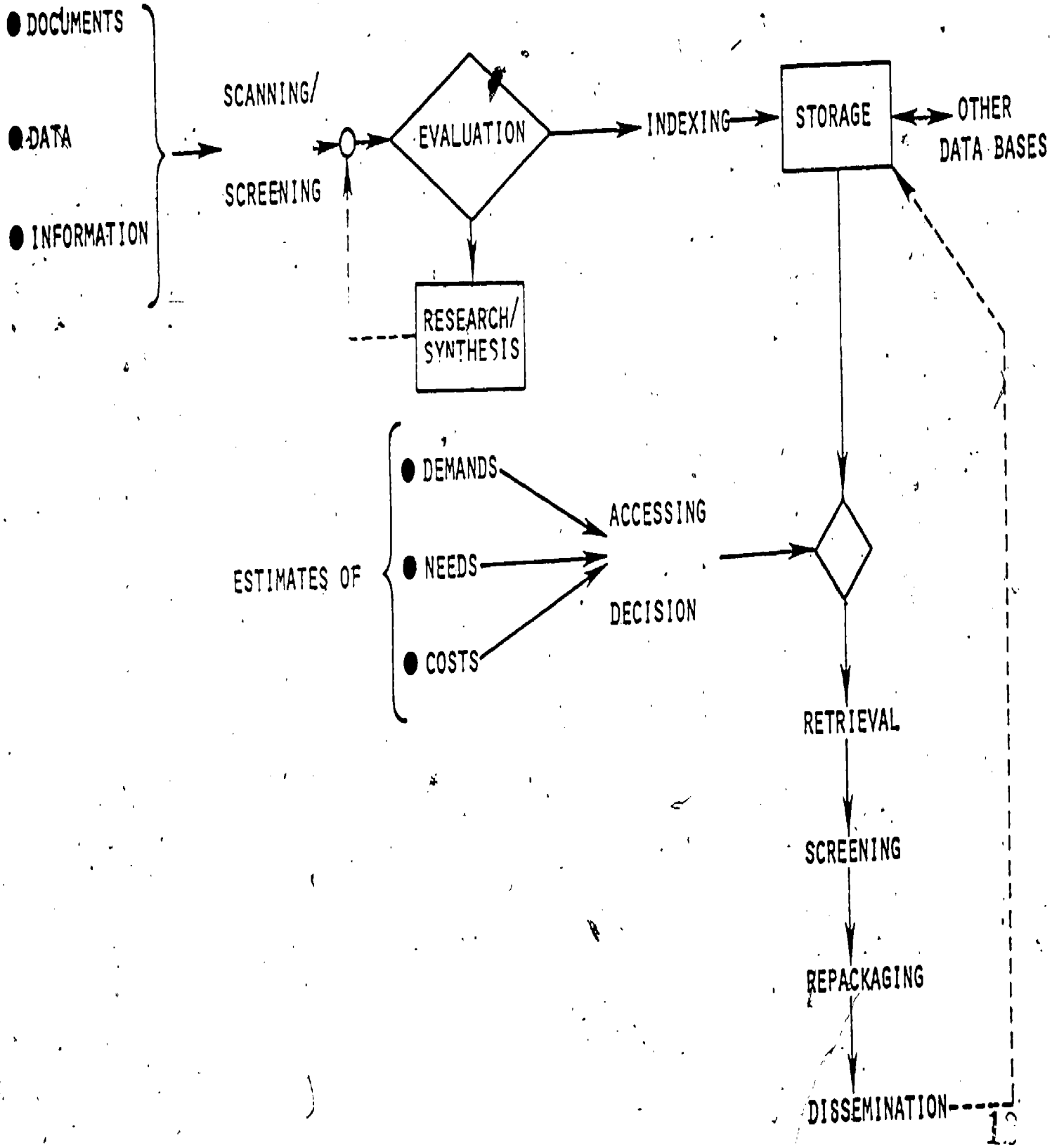

Figure 1. Diagram of IAC Functions

Critical reviews and technology assessments are similar to state of the art reviews but may go beyond evaluation of the current status of a technology. These reviews and assessments may include a critical analysis of the limited factors in a research or technical area. A technology assessment may include aspects of assessments similar to a technology forecast.

Bibliographies typically are annotated and may include brief abstracts. A bibliography may be prepared in response to a request from an individual, or it can be prepared by the IAC for a wide audience.

Responses to inquiries (the inquiry response service) is by definition a customized service. The capability to provide a customized response to a telephone or mail inquiry was a key motivating factor in establishing DoD IAC's.

Current awareness services/newsletters typically are aimed at groups of IAC users. In some instances, selective dissemination of information (SDI) services are provided to further screen the information that an IAC user receives on a regular basis.

Workshops/seminars sometimes are provided for IAC users and others to learn of new technical developments or to establish standards and achieve consensus of procedures or research needs. An IAC may undertake such a workshop or seminar on its own, or it may respond to a request by a particular group.

Symposia proceedings may be published for the IAC's own meetings or the proceedings may be published for some meeting in the field related to the IAC's operation.

Cost Benefit Models

Chapter 4 describes in detail the calculation procedures and cost and benefit models developed during the research effort. The chapter includes example calculations of costs and benefits and illustrates the sensitivity of the results to changes in parameter values.

The objectives of the cost and benefit models are similar. Both are designed to answer four questions:

1. What is the total benefit from (cost of) providing a specified level of the particular services offered by the IAC?

2. What is the change in total benefits (cost) which results from a change in the level of a particular service?
3. What are the relationships among the benefits (costs) of providing the various services? That is, (1) given that the IAC offers a particular set of services at specified levels, what is the change in total benefits (costs) resulting from an increase or decrease in the level of one service, and (2) given that an IAC provides a particular set of services, what is the change in total benefits (costs) resulting from the addition or deletion of particular services from the set of offered services?
4. What are the impacts on total benefits (costs) of implementing particular innovations?

The cost model is based on a structure of fixed and variable costs. Fixed costs are those associated with all services (i.e., not allocatable to a particular service) and costs which are invariant with the level of service provided. Variable costs are costs associated with incremental changes in providing a service.

The benefit model conceptually is based on supply and demand curve graphics. However, the calculation procedure is based on an estimate of time saved by the IAC user and permits calculating benefits using hand calculators. If one assumes that the IAC user can productively utilize the time, then this estimate of time saved amounts to an estimate of the lower bound of benefits due to using an IAC service. Both the cost and benefit models are structured to account for interactions among services.

The lower bound estimates of benefits (based on time saved by using the IAC service) provides a baseline calculation of IAC benefits; and typical cost figures were utilized for both inquiry response service and the handbook service. Even with the lower bound estimate of benefits, benefits exceeded the costs of providing the service.

These models accomplish a synthesis of economic theory with observations about the cost of supplying (and the demand for) information services from an IAC into relatively simple models and calculation

procedures. Because the models include a time rate of preference for resource flows (i.e., the measure is net present value (NPV) of benefits and costs), programmable hand calculators simplify the calculation procedure. In any case, however, the procedures are simple enough to permit frequent use by IAC managers and policy makers.

Sensitivity analyses were performed to determine the impact of changes in model parameters on the calculation results. The sensitivity analyses indicate that (1) costs are moderately sensitive to the assumed time horizon, the IAC professionals' salaries and time expended, and the allocation of fixed costs, and (2) benefits are moderately sensitive to the assumed time horizon and the number of users per year (of the handbook) and more sensitive to the (handbook) price charged by the IAC and to the annual benefit (time saved) postulated for the user. These results indicate additional effort and study spent on improving estimates of benefits would be valuable and that IAC accounting systems should provide for meaningful, consistent allocation of major cost items, including professionals' time, to particular service or product outputs.

Measuring Benefits

Data on the actual value of IAC service benefits are sparse. Moreover, there are both conceptual and practical difficulties with identifying and quantifying the benefits of information services.

Benefits from an information service are of two types (see the table below): (A) private or organizational, and (B) social or societal. Social benefits arise from second order effects and from the long term impacts of increasing technical knowledge. Such benefits derive from the IAC's acting to synthesize and codify a body of knowledge. These benefits are difficult (if not impossible) to measure or even to identify consistently. However, such social benefits are believed to be very real and are mentioned frequently as justification for supporting IAC's with public funds and for supporting other knowledge endeavors. Private or organizational benefits are benefits that accrue directly to the user of the IAC, and these benefits are judged to be only slightly more easily quantified. The usual measure of private or organizational benefit is the

user's "willingness-to-pay". However, as discussed in Appendix D, the concept of willingness-to-pay may not adequately represent the "actual" value to the user. Other factors such as social barriers or organizational variables (see the discussion in the latter part of Chapter 2) can invalidate willingness-to-pay as an indicator or private benefits.

Types of Benefits

Time/effort saving (compared with alternative ways to obtain information)	Codification of knowledge
Data quality (precision, accuracy)	Second order benefits* (e.g., arising from private benefits)
Data reliability (low risk to use)	
Data or service uniqueness	
Intrinsic value of the information (relative)	

* These might arise, for example, as private benefits to one firm or individual have subsequent benefits on other firms or individuals, resulting in a kind of "multiplier effect" which reflect the indirect benefits accruing to society.

There is at least some support for generalized propositions about social factors which influence potential IAC users. These social factors particularly are apparent when there are charges for IAC services.

A potential user, especially an engineer who has been hired to be a specialist in a particular technical area, may be reluctant to "reveal his inadequacy" by requesting information from an IAC. If there is a charge for the service, the engineer's lack of knowledge is made visible if he has to request authorization to expend money for the outside service.

Another social factor related to the user's organizational context is the concept of the information gatekeeper. There is evidence to support the notion that certain individuals in an organization act as

"information gatekeepers", providing information to other individuals in the organization. They perform this function without formal recognition of their status and with no formal spot in the organization chart. If an IAC charges a fee for its service and if an organization's gatekeeper does not have the authority to purchase information services, then the IAC service may tend to be underutilized. In this case, rather than facilitating the flow of technical information, the gatekeeper acts as an informal barrier to effective utilization of an information resource.

Another social factor related to IAC utilization is the possible resentment of IAC personnel to having to assess a fee for their service. Many IAC personnel may be reluctant to promote or encourage utilization of a service for which they must assess and collect a fee. This reluctance is a carryover from days when information was considered to be a freely accessible, freely available, public good.

Although any generalizations about IAC users have many exceptions, several observations summarize the criteria that a model of IAC service demand should satisfy. These observations include:

- Apparent low willingness-to-pay for IAC services by potential and actual IAC users;
- Apparent high elasticity of demand, i.e., a seemingly small increase in price tends to produce a relatively large drop in demand for an IAC service;
- Small quantity of IAC service actually demanded (based on the size of the potential market for IAC services, the utilization of the service seems particularly small);
- Knowledgeable individuals who are informed about IAC services but who appear to underutilize the services;
- High "real" value of IAC services, in contrast to the low apparent willingness-to-pay and low utilization of IAC services.

IAC users typically are scientists, engineers, and technicians engaged in technical pursuits. Chapter 6 reviews the characteristics of IAC services which these users believe are important.

The characteristics of information and information channels judged to be important to the potential and actual IAC user include: cost, accuracy, currency, response time, ease of access, ease of use, technical quality, coverage of the topic, understandability, format, media, recall, and relevance. Currently available evidence is insufficient to define the relationships among these characteristics or to deduce the relative value IAC users place on these characteristics. It is recommended that further research be undertaken to establish the relative values of these characteristics, especially those characteristics which are uniquely associated with IAC services.

Optimum Service Levels

Chapter 5 develops a mathematical economic model that could be a prescriptive tool for policy and decision making. The model is a supply/demand model of an IAC which provides two services, handbooks and inquiry response. The basic model accounts for a number of diverse and apparently contradictory facts and observations about IAC's and shows these to be consistent with rational economic behavior.

The approach is a mathematical formulation of costs, revenues, demands, and benefits by IAC operations (using handbooks and inquiry response as example services). The Lagrangian multiplier technique is utilized to determine and compare implicit optimal values of the decision variables from the IAC managers' viewpoint and from society's viewpoint. Two optimal solutions are found: one from society's viewpoint and one from the managers' viewpoint. In general, these two solutions will not be identical, illustrating the potential incompatibility between incentives for the IAC manager and for socially ideal investment in IAC services. (These incompatibilities are discussed in further detail in Appendix C).

Implementation of the optimum decision demands considerable empirical research to specify the detailed functional forms and parameter values in the model. Numerical approximation techniques can then be used to solve the set of equations.

Impacts of Technology

Chapters 7 and 8 summarize the results of research effort which examined the impacts of technological trends and innovations on IAC's, their users, and the economics of their operation. Chapter 7 examines potential impacts of technology and technological innovations on IAC's and IAC users; and Chapter 8 postulates three alternative possible futures in the form of scenarios of the IAC and its environment for the year 1985 and compares these scenarios with the IAC's operation in 1975.

The general area of electronic communications technology is expected to have substantial impacts on IAC operations. The impacts are expected to be greatest in the time period 1980 to 1985. During this time period, four technological events were judged to be significant:

- A computer-linked network of IAC's could significantly affect the currency, technical quality, coverage of the topic, and recall capability. Such a network would also moderately affect response time and ease of use.
- The advent of the availability of natural English language inquiry and updating is seen as being moderately significant during this period. This capability would have a direct effect on the inquiry response service and would affect accuracy, ease of access, and ease of use.
- The use of lasers for facsimile transmission (at a speed of five million pages per second), particularly in conjunction with image input and storage, could have a substantial impact during this period. Such widespread use of highspeed transmission would affect the currency, technical quality, and topic coverage of IAC services.
- The final event which could substantially impact IAC operations is the common use of optical character recognition readers with multifont capability. Such a capability would have a moderately significant impact on accuracy and currency of IAC operations.

The three alternative scenarios for 1985 include a "base-line", or surprise-free, scenario, a scenario including a portable acceptable

microfiche reader (PAM), and a scenario including terminal-to-terminal conferencing. The cost benefit model was applied to these three scenarios and compared with the model results for 1975. Because the model more carefully accounts for cost, the 1985 scenarios exhibit more impacts on cost than they do on benefits. This indicates that the impact of technology on benefits will not be on the lower bound of benefits, but is likely to be further reaching, resulting in additional individuals having access to IAC services.

In general, the impacts of technology seem to be less on the distinguishing characteristics of an IAC (evaluation, data analysis, and synthesis) and on IAC management functions than on other functions. This suggests that IAC operations, although affected by technological change, will continue to have as their basis the key element of human judgment.

Summary of Recommendations

IAC Accounting Systems. It is recommended that IAC managers and administrators continue to review their accounting systems and to make the necessary changes to provide for meaningful, consistent allocation of major cost items, including professional staff time, to particular service or product outputs. (The DLA-administered IAC's have two common system oriented toward these objectives).

Additional Research Efforts. It is recommended that additional research effort be undertaken to develop an improved understanding of the perceived benefits of, and value attributed to, IAC services. The research should eventually include experiments that establish relationships between service prices and the demand for the service. However, intermediate research should establish (1) the relationships among information service characteristics and (2) the relative value IAC users place on the different clusters of characteristics. Such research, especially on the unique characteristics of IAC functions, will continue to be important, even with changing information technology and technological innovations.

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INTRODUCTION

Background

The National Science Foundation's Division of Science Information (formerly the Office of Science Information Service) emphasizes the development of concepts and data on the economics of scientific and technical information communication. The research effort described in this report originated from program solicitation NSF 74-38, Category 4, which was directed toward the "Economic Characteristics of Scientific and Technical Communication." The project focused on the economic characteristics of Information Analysis Centers (IAC's).

An IAC is a specialized information center. More specifically, it is

> "...a formally structured organizational unit specifically (but not necessarily exclusively) established for the purpose of acquiring, selecting, storing, retrieving, evaluating, analyzing, and synthesizing a body of information and/or data in a clearly defined specialized field or pertaining to a specific mission with the intent of compiling, digesting, repackaging, or otherwise organizing and presenting pertinent information and/or data in a form most authoritative, timely, and useful to a society of peers and management."[1]*

Additional discussion on the distinguishing characteristics of IAC's, IAC services, and IAC users is included in Chapter 2.

Many IAC's were developed in the 1960's when the prevailing concept was that of information as a free public commodity. Recently these centers, their users, and their sponsors have begun to face the increasing conviction that information is a commodity which should be paid for by the user. The Department of Defense, which originated and still sponsors many IAC's, instituted a policy in 1968 that called for centers to charge for their services and by 1972 to be recovering at least 50% of contract face value.[2] The implementation of this policy emphasized the need for an understanding of the economic impacts and implications of policy and decision options relating to the providing

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* Superscript numbers correspond to references listed at the end of each chapter. A bibliography is included in Appendix A.

and financing of IAC services. The research effort described in this report was intended to contribute to such an understanding.

Purpose and Objectives

The purpose of the research effort is to improve the economic information available for formulating policy and making decisions regarding IAC's and IAC services. The objectives are:

1. The development of a set of concepts and procedures which can be used to perform cost benefit studies of information service centers;
2. The application of these concepts and procedures to address crucial issues of mix, levels, and pricing of information services provided by IAC's; and
3. The determination of the sensitivity of the results of the applications to possible developments and innovations in communication technology.

The intent of the project is to develop usable tools for IAC managers and IAC policy formulators which are based on sound economic principles. The research effort includes the development of cost and benefit measures for information services and the application of these measures to issues of optimum levels, mix, and pricing of IAC services.

Report Overview

The remainder of this report is divided into 8 chapters and 5 appendixes. Chapter 2 examines IAC activities, provides a necessary background for analyzing IAC economics, and summarizes the observations about IAC operations and user behavior which the economic models should explain.

Chapter 3 establishes the conceptual framework for modeling the demand for IAC services. This framework provides a basic demand model that is consistent with the observations about the demand for IAC services.

Chapter 4 describes the practical procedures one can use to calculate IAC costs and a lower bound on IAC benefits. This chapter also demonstrates these calculation procedures and presents the results of an analysis of the sensitivity of the model to changes in parameter values.

Chapter 5 describes an IAC user decision model. This model complements the model described in Chapter 4, providing a probabilistic formulation of user behavior that is consistent with observations about IAC service demand and user behavior.

Chapter 6 addresses the question of how IAC users value the various characteristics or attributes (e.g., cost, timeliness, accuracy) of IAC services. This chapter summarizes relevant user studies and other information about the relative values of information service characteristics.

Chapter 7 summarizes an effort that identified which technological innovations and trends may impact on particular functions, IAC activities, and services. This analysis provided a basis for selecting particular innovations for additional study.

Chapter 8 examines the economic impacts of two innovations: extensive availability of terminals permitting terminal to terminal conferencing among researchers, and a new type of microfiche reader which would be widely accepted and utilized (a "cuddly" microfiche reader). The results of analyzing the impacts of these innovations indicate how sensitive calculation procedures are to changes in communication technology.

Chapter 9 summarizes the findings and conclusions of the research effort. This chapter also outlines needed and potentially fruitful research areas indicated by this project.

Appendix A is an overview of the relevant literature, including an annotated bibliography. Appendix B is a glossary of terms frequently used in economic analysis and cost benefit analysis. Appendix C is a background discussion on government funding of activities that otherwise might be left to private enterprise. Appendix D is an overall project narrative and provides a generally chronological account of the research process. Appendix E is a formulation for a method of pricing, or allocating costs, to joint products and services.

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for
Chapter 1

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INFORMATION ANALYSIS CENTERS AND THEIR USERS

Introduction and Highlights

The purpose of this chapter is to provide background information on Information Analysis Centers (IAC's) and their users. The intent of this chapter is to summarize information and concepts that will be useful in understanding the significance and limitations of the models described in subsequent chapters.

The information in this chapter represents a synthesis of background data known prior to the project. Comments and opinions provided by members of the Overview Committee during the project, and observations of the project team during and subsequent to the research effort. The chapter includes descriptions of IAC activities, functions, products, and services, and brief discussions of different IAC mission emphases. The chapter also includes a summary discussion on potential and actual IAC users.

Highlights include:

- The IAC concept, although not new, received considerable emphasis during the 1960's, with over sixty (of the approximately 108 federally sponsored) IAC's being formed during the period 1960 to 1969;
- IAC's currently are facing issues concerning roles, services, and financial support;
- IAC's, as distinguished from other information service centers, are characterized by analytic, evaluation, and synthesis functions and not just the screening, indexing, storage, retrieval, and repackaging of information;
- IAC utilization and benefits depend, among other factors, on the information needs of the user, the availability of other resources, and social factors;
- The demand for IAC services appears to exhibit a high price elasticity, and potential users seem to show a willingness-to-pay that is low compared with the actual value of IAC services.

Background

As defined by a panel of the Committee on Scientific and Technical Information (COSATI)[1], an Information Analysis Center provides information services that are characterized by evaluation, analysis, and synthesis by subject specialists. (Chapter 1 provides the complete definition of an IAC. The subjects range from brain information (the Brain Information Service at the UCLA School of Medicine) to x-ray attenuation coefficients (X-ray Attenuation Coefficient Information Center at the National Bureau of Standards).

The IAC concept is not new - as many as thirteen of what are now called IAC's were formed by the Federal Government before the beginning of this century.[2] However, 70% of the IAC's listed in the Directory of Federally Sponsored Information Analysis Centers [1] have been formed since 1960. During the 1960's, the IAC concept achieved considerable prominence; at least 62 IAC's were formed between 1960 and 1969[1]. The underlying motivation for establishing and continuing these Information Analysis Centers was the proposition that existing information systems were inadequate for users in other disciplines and frequently were inadequate even to meet the needs of users within the discipline. The publication of research and development results was leading to an explosion of data and concomitant difficulties of identifying which data were relevant to a particular problem and distinguishing between valid data and data of questionable validity. Another motivation to develop the specialized information collection and dissemination services which would be provided by IAC's was the increasing availability of automated equipment. The use of automated data handling equipment, it was believed, could lower the cost of meeting the user needs for accessibility of relevant information and assurance of the quality of the information. However, the total cost of such equipment was high and the "market" was disaggregated. Consequently, sponsors of IAC's (many of them federal agencies such as the Department of Defense) were necessary in order to establish the IAC's.

Recently, however, the rationale for establishing and maintaining IAC's with Federal funding has not been so clear. With the disbanding of COSATI and its

panel on Information Analysis Centers, there is no longer a central government-wide focus on IAC functions and problems. Consequently, the IAC's are facing several issues:

- What roles should the IAC's perform? Have these roles changed, particularly in view of the apparent international role of the Committee on Data for Science and Technology (CODATA) in performing the data evaluation function?
- What services should the IAC's be providing? Should they provide the current services or are there other services which would be more beneficial to the users?
- How should the IAC's be supported? Should there be user charges, and, if so, how should they be determined?

The research effort described in this report was intended to provide a framework for structuring economic data that could assist in resolving these issues. It should be noted, however, that economic data are only one consideration; the issues may involve inter alia, dimensions of national defense, and national policy.

IAC Functions, Products, and Services

IAC's may be quite diverse. Some are relatively small operations, having only one or two professional staff members who often are shared with a larger organization. Other IAC's, such as the National Environmental Satellite Service with 557 full time staff members, represent substantial organizational entities by themselves. However, all IAC's have the distinguishing characteristic of providing some degree of analysis and evaluation of the data they collect, store, and repackage. Consequently, all IAC's share some commonality in activities and functions.

IAC Functions. The primary IAC functions may be abstracted from the definition of an IAC (see Chapter 1) and from observing IAC activities. These primary functions, diagrammed in Figure 1, include:

- identifying and acquiring documents, data, and information;
- scanning and screening;
- evaluation of data and information;

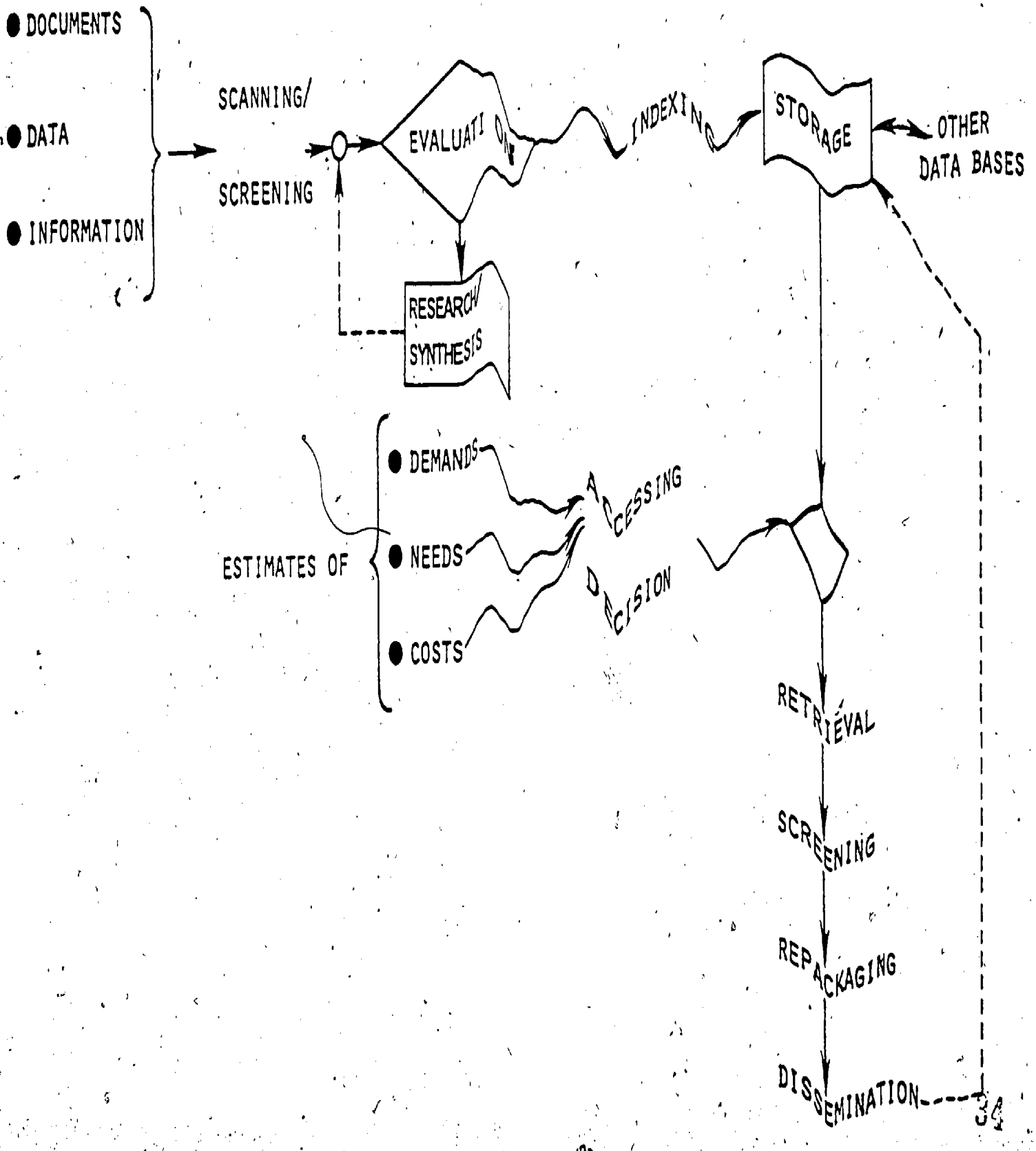

Figure 1. Diagram of IAC functions

- performing research to fill identified gaps in knowledge;
- indexing and storage;
- communication with other data bases;
- estimating the needs, demands, and costs of particular information dissemination opportunities; and
- the retrieval, screening, repackaging, and dissemination of the evaluated data.

The critical function of an IAC is the analysis, or evaluation, function. This evaluation/analysis aspect distinguishes an IAC from other information centers or libraries which may provide data collection, storage, retrieval, and repackaging services. Note that the feedback loop in Figure 1 indicates that an IAC may perform research to fill gaps in knowledge which may be identified by this critical evaluation function. The screening function is performed twice: once before the data or information is stored, again after retrieval but before the information is disseminated to the user.

IAC Products and Services. Table 1 lists eight basic categories of IAC products and services. This list includes both customized services (individualized for a particular group, organization, or person, such as a response to an inquiry) and products provided for a large number of users (aimed at a "mass market", such as a handbook or databook). Not every IAC offers each of the types of products/services, but most IAC's furnish several of the products/services shown in the table. Definitions of these products/services may vary, but the following paragraphs indicate generally accepted distinguishing characteristics.

Handbooks or databooks typically include data, which may be numerical, on physical constants, material properties, or techniques which have been established by research or practice. These books generally are intended to be used as reference books by a relatively wide audience.

Table 1. IAC Products and Services[3]

Handbooks/Databooks*
State of the Art Reviews
Critical Reviews and Technology Assessments
Bibliographies*
Responses to Inquiries
Current Awareness Services/Newsletters
Workshops/Seminars
Symposia Proceedings

* Also in magnetic tape form

State of the Art Reviews (SOARS) summarize the state of development of a particular technology or technical area. Like the handbook, SOARS typically are intended for a wide audience; they provide a snapshot of the limits of current knowledge in a particular field.

Critical Reviews and Technology Assessments are similar to state of the art reviews but may go beyond evaluation of the current status of a technology. These documents may include a critical assessment of the limiting factors in a research or technical area. The term "technology assessment", rather than referring to the identification and evaluation of social and second order effects, implies more an assessment of the status and potential future of the technology; it may include aspects of assessment similar to a technology forecast.

Bibliographies typically are annotated or include brief abstracts. A bibliography may be prepared in response to a request from an individual or it can be prepared by the IAC for distribution to a potentially large number of users before there is an actual demand for it.

Responses to Inquiries, or the "inquiry response" service, is, by definition, a customized service. The capability to provide a response to

a telephone or mail inquiry was a key factor in the rationale for establishing many Department of Defense (DoD) IAC's.

Current Awareness Services/Newsletters typically are aimed at groups of IAC users, though perhaps not at as broad an audience as the handbooks. In some instances, selective dissemination of information (SDI) services are provided to further screen the information that an IAC user receives regularly (e.g., a monthly list of new document acquisitions in the user's area of interest).

Workshops/Seminars sometimes are provided for IAC users and others to learn of new technical developments, to establish standards or achieve consensus on procedures or needs. An IAC may sponsor such workshops or seminars and may publish Symposia Proceedings of these and other meetings.

A study of IAC services must recognize the opportunity for, and likelihood of, interactions among the services. Consequently, analyses of IAC's must examine the services collectively rather than singly. An obvious example of service interactions is that of joint costs: an IAC, once it has established a data base, can respond to inquiries, produce bibliographies, and produce handbooks utilizing this data base. A more subtle example relates to the demand for services: an IAC which publishes and disseminates widely a comprehensive handbook may find a reduction in the number of inquiries it receives. Similarly, a poor handbook may have little impact on the number of inquiries and a comprehensive, well edited, handbook may have a significant impact.

Types of IAC's. Different IAC's may place different emphases on the various functions, and these different emphases may result from significant differences in objectives and types of users being served. Three different categories of IAC's may be distinguished: mission oriented, discipline oriented, and synoptic/census bureau.

A mission oriented IAC typically serves a particular set of users, addressing problems which may involve more than one technical discipline. For example, the Tactical Technology Center at Battelle focuses on technology related to tactical warfare; its subject areas include weapons, munitions, armor, mobility and logistics, operations analysis, surveillance, communications and electronics, socio-technical sciences, and ecological sciences.

A discipline oriented IAC emphasizes the review, analysis, assessment, and synthesis of information within a particular discipline and may serve diverse users. For example, the Thermophysical Properties Research Center at Purdue focuses on information such as thermal conductivity, thermal contact resistance, specific heat, viscosity, and reflectivity.

A synoptic IAC handles large quantities of data, often in raw form, in areas such as oceanography and atmospherics. For example, the Bathythermograph Data Processing and Analysis Facility at the Scripps Institute of Oceanography has over 675,000 bathythermograph temperature data readings in its holdings.

Each of these types of IAC's may choose to narrow its scope by selectively emphasizing particular functions or data sources. As examples, some IAC groups work primarily with formal published research literature; other IAC groups emphasize problem solving and utilize as inputs both the formal published literature and other sources such as government and industry reports; and still other IAC groups emphasize research on raw observations and empirical data. Another way of categorizing IAC's is according to the stage of development of the technical area being served, and this categorization may help characterize the role of the IAC. For example, an IAC serving a technical area which is just emerging as a well-defined focus of research may, in essence, act as a formalized clearinghouse for the "invisible college" of researchers performing work in that technical area. In a more established and less rapidly changing technical area, an IAC may serve as the archival repository for authoritative facts or observational data. Because the role may differ in the different stages of technological development, the benefits of an IAC may be substantially different within the different categories of IAC.

IAC Users

IAC users are at least as diverse as the IAC's they utilize, and therefore it is difficult to offer meaningful generalizations about "IAC Users". However, some concept of IAC service demand is necessary in order to develop useful economic models. Consequently, this section reviews what is known and perceived about IAC users through observations and relevant user studies, stipulating that the generalizations are not universally applicable and that many exceptions may exist.

User Studies. The user of scientific and technical information (the STI user) has been studied through numerous "user studies" over the past fifteen years. Chapter 6 reviews and synthesizes some of the ones relevant to IAC operation. One particular study warrants further mention in this chapter: a Defense Logistics Agency (DLA) study of DoD IAC users[4]. (DLA administers eight IAC's for DoD). DSA examined two aspects of IAC users: their level of satisfaction with IAC services and their STI needs.

For the first aspect, a survey established (1) 69% of the respondents were partially or completely unaware of the existence and services of the IAC's; of the remaining 31% of the respondents, (2) 95% were satisfied with the technical fields covered by the IAC's, and (3) 93% were satisfied with the products and services offered by the IAC's. (The first finding stimulated the initiation of new programs to increase the awareness of IAC's among DoD scientists and engineers).

Another survey aimed at identifying job related STI needs of DoD scientists and engineers. This survey established that almost three-fourths of the respondents experienced difficulty in locating, obtaining and using STI. The STI needs focussed on facts, data, constants, or other research findings rather than other types of STI. (This finding supported the recommendation that DLA increase the number of handbooks, databooks, and state-of-the-art reports).

Social Factors. There is at least superficial, face validity to several generalized propositions about social factors which influence potential IAC users. These social factors arise from the work environment of the potential user, particularly if there is a fee assessed for utilizing an IAC service.

A potential user, especially an engineer who was hired to be a specialist in a particular technical area, may be reluctant to "reveal his ignorance" by requesting information from an IAC. More precisely, he may be reluctant to reveal his ignorance by requesting funds (or an authorization for an expenditure) for an information service outside his own organization. By having to request funds, the engineer's need for assistance

becomes visible, and he no longer may be perceived as knowing everything he needs to know to perform his job.

Another factor related to the service charge is the possible resentment of IAC personnel to having to assess the fee for service. The concept of providing information as a free service persists, and IAC staff are not immune. Consequently, IAC personnel may be reluctant to promote or encourage the utilization of a service for which they must assess and collect a fee.

A third social factor is related to Tom Allen's concept of the information gatekeeper, who acts as a clearinghouse for STI information within an organization.[5] Because the gatekeeper is part of the informal organizational structure, he may not have the authority to purchase outside information services. (An exception would be the gatekeeper who also was the organization's librarian.) Consequently, the IAC might tend to be underutilized with the gatekeeper acting as an informal barrier to direct IAC utilization by the individual needing the information.

These three factors, to the extent that they operate within the potential IAC user's environment, all tend to reduce the utilization of IAC services. They tend to prevent information <u>needs</u> from being translated into actual <u>demands</u> for information services.

<u>User Typology.</u> Our understanding of (potential and actual) IAC users is inadequate to permit the design of a meaningful typology, but any such typology probably would include the following dimensions:

- Informational requirements/situational needs. Two cases may be distinguished. In one case, the user desires background information that has no immediate utility. Information such as that desired to maintain technical proficiency and current awareness has been termed "nutritional information"[6]. In the other case, the user is attempting to resolve an issue or to solve a problem; the utility of the information is determined by how well it helps solve the problem. The benefits of information services are likely to be measured, or at least perceived, differently in the two cases. For example, information used in solving a problem will have relatively well-defined requirements of timeliness (urgency), reliability/confidence, accuracy, and precision.

- Informational resources. Rather than examine potential users according to the size of the employing organization, it seems more relevant to consider the informational resources available other than the IAC. A potential user with an effective in-house information service, ceteris paribus, will be less likely to utilize IAC services than a potential user without the availability of such a service. Also included in this dimension is the nature of the information "market" in the technical area of need. If the IAC effectively is the only source for the needed information service, then the potential user faces a different situation than if there are several optional sources for the service.
- Financial resources and procedures. Assuming an IAC charges a fee for its services, a potential user who has no discretionary funds or who has to justify expenditures for outside information services is less likely to utilize an IAC service than a potential user who does not have these financial constraints.
- State of knowledge/awareness. A potential user who is technically up-to-date in the IAC's field of competence may be less likely to utilize an IAC service than one who has greater information needs. However, a potential user who is ignorant or unaware of the benefits of IAC services is not likely to become an actual user until he recognizes the benefits.
- User's perception regarding the nature of the expense. The expense of utilizing an IAC service may be perceived either as a problem-solving expense or as a capital expenditure. This perception might indicate the decision process that a potential user engages to decide whether or not to utilize the IAC service. (This dimension could be related, i.e., nonorthogonal, to the informational requirements dimension discussed above.)

Summary: Criteria for IAC User Models. Recalling the stipulation at the beginning of this section that many exceptions may exist to any generalizations about IAC users, the following observations ("stylized facts") summarize the facts that an economic model of IAC service demand should address. These criteria, although seemingly contradictory in some cases,

seem consistent with observations and the limited research findings on the demand for IAC services or for information services in general.

- Apparent low willingness-to-pay for IAC services by potential and actual IAC users. Subsequent to the initiation of fees for services after a period of free services, the number of requests for service drops substantially. (In some cases, the center experiences only a temporary drop in demand which later grows at approximately the same rate as before the initiation of fees. In other cases, the demand has remained low.) Similarly information center managers have reported that a significant number of requests for information are cancelled when the requestor is informed of the charging/fee policy.[7,8,9]
- Apparent high elasticity of demand. Similar to the above observation, a seemingly small increase in price tends to produce a relatively large drop in demand.
- Small quantities of IAC services actually demanded. This observation is a judgment based on the size of the potential market for IAC services. (It may reflect primarily a lack of awareness of the availability of the services.)
- Knowledgeable individuals who are informed about IAC services but who appear to underutilize these services. As opposed to someone who is unaware of an IAC, this observation concerns potential users who are well informed but do not utilize IAC's for other reasons, such as the social factor mentioned above, or the lack of appropriate financial resources or authorization.
- Apparent "real" value of IAC services. Anecdotal evidence[10,11] suggests that IAC services have high value to the user, in contrast to the low (apparent) willingness-to-pay and low utilization of IAC services.
- Interactions among service demands. This is a postulate that has face validity; examples include (1) the reduction of demand for an inquiry response service subsequent to the publication of a handbook, and (2) the stimulus for the publication of a state of the art review, handbook, or bibliography arising from a high number of inquiries regarding a particular subject or technical question.

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for

Chapter 2

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CONCEPTUAL FRAMEWORK: THE DEMAND FOR IAC SERVICES

Introduction and Highlights

This chapter presents the concepts necessary to establish the basis for cost benefit analyses of information analysis centers. The chapter includes a brief discussion of the model approach, criteria which the conceptual framework must meet, an outline of the economic model, and a discussion of the implications of the model.

Highlights of the chapter include:

- A conceptual framework which is consistent both with observations about the demand for IAC services and with fundamental economic principles;
- A potential user submodel which characterizes demand for IAC services as a residual (excess), risk-averse demand;
- Graphical descriptions of the potential user submodel and the economic model of the IAC; and
- Model implications which include epistemological, long-range, near term, and immediate considerations. Immediate implications include the basis for guidelines for calculating an estimated lower bound on IAC benefits.

The Model Approach

The conceptual approach adopted for this study is economic modeling of the IAC and the (potential and actual) IAC user. Similar to systems modeling in any research effort, modeling of the IAC-IAC user system accomplishes several objectives:

1. understanding - of the key elements and behavioral assumptions, of how these elements and assumptions interact in the system's operation;

2. measurement capability - by circumscribing and explaining system behavior, the model identifies items which require measurement and suggests methods of measuring these items;
3. requisite data - the model identifies what data are necessary and what data may be ignored for analyzing particular issues;
4. simulation capability - the model permits the evaluation of different policies by determining the outcome of alternative sets of assumptions and parameter values in a prescribed, consistent manner;
5. optimization possibility - the model parameter may be varied to determine an optimum operating point; if the model adequately represents reality, the results may be used to set optimum operating conditions for the actual system; and
6. new results/extensions - by integrating all the parts of the system, the model may suggest previously unrecognized results and policies which extend beyond the original scope of the model alone.

Model Criteria

In constructing models for specific systems, the approach is to work from a general framework, applicable to a wide class of phenomena, to a model which accounts for the observations on, and facts about, the particular system. The particular observations (or "stylized facts" as they are called in economic growth literature) for the IAC-IAC user system include those listed below. These are summarized from the project team's observations, from observations and comments from the members of the Overview Committee, and from comments and observations from IAC managers and staff members.

(Chapter 2 discusses the background from which these observations are distilled). The constructed model must, as a minimum, be consistent with these observations:

1. Low willingness-to-pay by actual and potential users of IAC services;
2. High elasticity of demand for IAC services;
3. Small quantities of IAC services demanded;
4. The existence of individuals who are knowledgeable and informed about IAC's but who are non-users or under-users of IAC services;
5. High "real" value of IAC services; and
6. Interaction among the demands for different services; in particular, reduced demand for other services with increased handbook sales.

Model Framework

The principal component of the IAC system model is the (potential) user sub-model. His demand for IAC services is modeled as a residual (or excess), risk-averse demand. It is a residual demand because each user can, to some extent, supply himself with information similar to that which an IAC supplies, and the demand for IAC services is thus the "residual", or "excess" demand. (Ironically, the individual's ability to supply himself, and thus avoid using the IAC, may depend on the quality of the IAC's handbook).

The model initially assumes that the potential user has several sources for information of equivalent quality and is motivated solely by economic efficiency. He thus makes the decision on the quantity of information he purchases and chooses his supplier (IAC or self) on an economic basis. (Note that "self" supply can represent all non-IAC alternatives, with no loss of generality).

Figure 2 illustrates a potential user's supply and demand curves for information. One supply curve (labeled "no Handbook") is a user's marginal cost of self-supply without an IAC handbook and the other supply curve (labeled "with Handbook") is that user's marginal cost

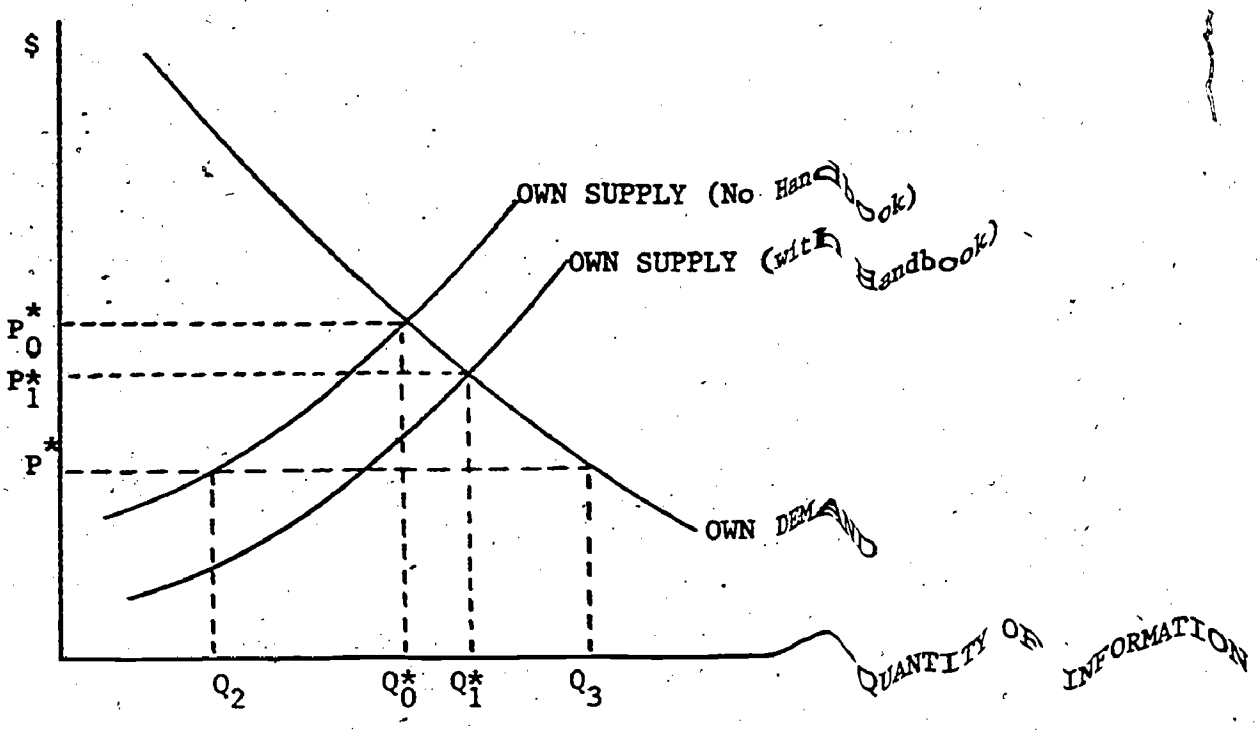

Figure 2. User's Demand And Own Supply Curves For Information

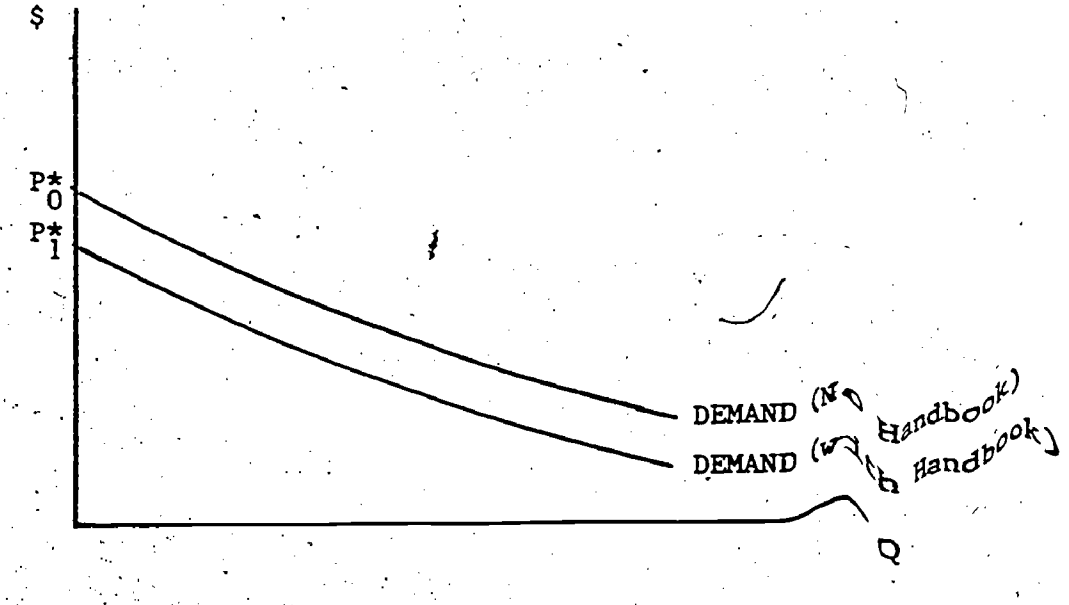

Figure 3. User's Demand For IAC Service

of self-supply with the IAC handbook. The latter is to the right of the former, indicating that possessing an IAC handbook reduces the cost of self-supply.

Now assume the user has no IAC handbook, and the IAC charges a price of P^* per unit of information service. Under these conditions, the user will supply Q_2 units himself (his supply curve is beneath the IAC price for $Q < Q_2$) and will purchase $Q_3 - Q_2$ units from the IAC. In general, the model indicates that the demand for IAC information services is the difference between a user's demand and supply curves below their intersection. Figure 3 illustrates the demands for IAC services corresponding to Figure 2. Note that the model, as described thus far, indicates the following:

- the highest price a user is willing to pay for IAC services is far more elastic than the demand for all information services;
- the user's possession of an IAC handbook reduces his demand for (other) IAC services. (This latter statement is not surprising, since a handbook may be, in a real sense, the product of experience in other services.)

The model as constructed above is a deterministic model with a rational, optimizing user, and it already accounts for several of the stylized facts for which it is intended. However, additional factors must be added if the model is to account for the remaining observations. This is accomplished by developing a probabilistic model, and the assumptions for such a model are summarized below.

First, assume that IAC services have a randomly distributed value, and assume the user periodically must "justify" his use of an IAC by demonstrating to an "auditor" that over the preceding period the benefits from using the IAC have exceeded the costs. Assume the user suffers a penalty (perhaps only psychic) if, at audit time, benefits do not exceed costs; and, moreover, he enjoys only a small reward if benefits do exceed costs. Under these circumstances, the user will be risk-averse. He may be willing to accept a probability of perhaps only 5% that at audit time benefits will not exceed costs. It can be easily shown that even if the expected value of IAC use is positive, the user may never find the risk

acceptable, particulary if audits occur at frequent intervals and the opportunities for IAC use are not frequent. This model illustrates the rationality of some potential users not to use an IAC, even though its expected long run value is positive. (This result stems from the institutional justification process which IAC use often entails).

Implications of the Model

The model summarized above accounts for all the "stylized facts" initially presented and thus serves as a convenient descriptive tool. It also offers a useful framework for economic analyses of IAC's. The utility as a framework seems to be evidenced at four distinct levels: epistemological, long run applications, short run applications, and immediate applications.

Epistemological. At this level, the model provides a rational, internally consistent systemization of the bits and pieces of knowledge of IAC economics. It provides a framework for additional speculation and suggests potentially revealing experiments which could lead to greater understanding of the demands for IAC services.

Long Run Applications. The model identifies concepts for which measurement techniques must be developed, especially if optimization is attempted. For example, an optimization model for IAC managers and policy makers seeks to set what might be called a "second best" price for IAC products and services. This "second best" price is a price which is socially optimum within a constraint, the constraint being that the IAC should break-even (revenues equal expenditures). Thus it is necessary to have measures of service benefits, costs, and break-even levels in order to determine the desired service price.

Short Run/Near Term Applications. The model focuses attention on variables for which data now do not exist but for which data should be collected in the near future, especially for complete cost benefit analyses. For example, historic data necessary to construct demand curves for IAC services are sparse, and careful records of the number of users at different price levels should be kept.

Immediate Applications. The immediate utility of the model is as a guide to a "first cut" cost benefit analysis, and later chapters of this report emphasize this application. Figure 4 illustrates the conceptual basis for a benefit model which provides a lower bound on benefits, and the following discussion is based on this figure.

The total net benefits of an IAC are represented by the region circumscribed by the points

A B C H J G F .

Similarly, the net benefits from a handbook are represented by the region outlined by

A B C D E F ,

and the marginal net benefits of other services are represented by the region

G E D H J .

If $Q_2 - Q_1$, the demand for IAC services, is small, then handbook use accounts for the greatest portion of IAC benefits. The value of handbook use is the area between the supply (marginal cost) curves, and the value can be calculated from the product

(cost savings per use)x(number of uses).

The next chapter describes in more detail procedures for calculating the benefits and costs of IAC services. These procedures, based on the above conceptual framework, permit the IAC manager or policy maker to estimate costs and benefits associated with an IAC service or with the entire IAC operation. These calculation procedures are designed to provide a well-defined method that requires only a hand calculator (preferably a programmable calculator) for efficient operation.

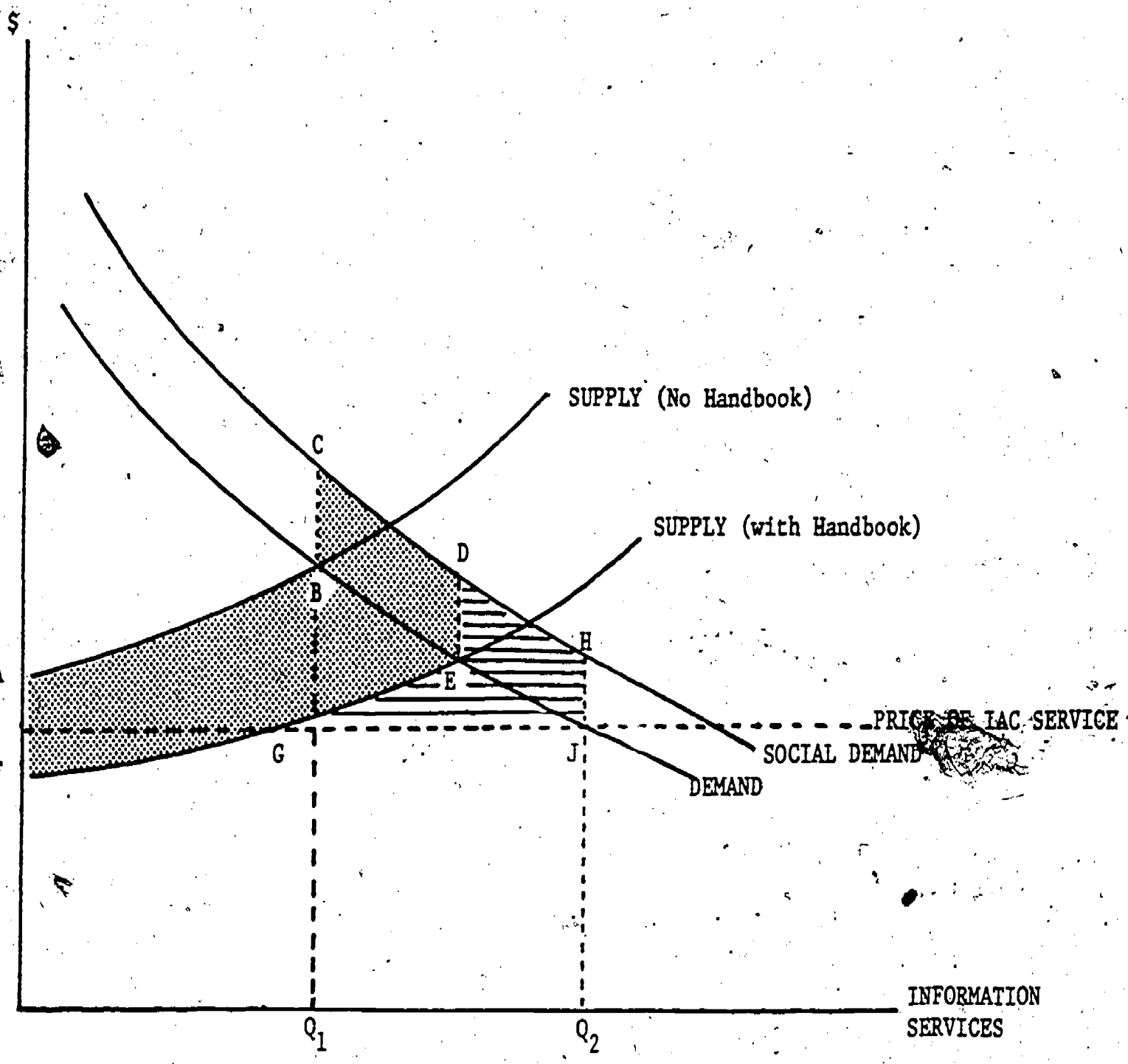

Figure 4. IAC Economic Model, Handbook Example

Introduction and Highlights

The establishment and operation of an IAC result in costs and benefits both to the direct users of the IAC and to society as well. The ideal model would account for all the significant costs and benefits, both private and social. The paucity of, and difficulty of obtaining reliable data, especially benefit data, or estimates from the existing data renders such a model currently impractical. The models described here quantify some of the benefits to the user of the IAC and the costs of providing IAC services. The models are intended to be useful for decision making by IAC managers. The following sections describe the objectives of the models, review the cost benefit approach, and describe the benefit and cost models, calculation procedures, and some preliminary results.

Chapter highlights include:

- Cost and benefit models that are consistent with fundamental economic principles and that are simple, easy to use (requiring only a hand calculator);
- A straightforward fixed-plus-variable cost calculation procedure based on cost component data that can be routinely collected by an IAC;
- A benefit calculation procedure based on estimates of the value of "user time saved"; this yields a lower bound on estimated benefits from IAC services;
- Example baseline calculations using the procedures indicate that benefits exceed costs even for conservative, lower bound estimates of benefits; and
- Sensitivity analyses indicate that (1) costs are moderately sensitive to the assumed time horizon, IAC professionals' salaries and time expended, and the allocation of fixed costs, and (2) benefits are moderately sensitive to the assumed

time horizon and number of users per year (handbook) and more sensitive to the (handbook) price charged by the IAC and to the annual benefit (time saved) postulated for the user.

Model Objectives

The objectives of the benefit model parallel those of the cost model. As such, each model is designed to answer four questions:

1. What is the total benefit from (cost of) providing a specified level of the particular services offered by the IAC?
2. What is the change in total benefits (costs) which results from a change in the level of a particular service?
3. What are the relationships among the benefits (costs) of providing the various services, that is, (1) given that the IAC offers a particular set of services at specified levels, what is the change in total benefits (costs) resulting from an increase or decrease in the level of one service, and (2) given that an IAC provides a particular set of services, what is the change in total benefits (costs) resulting from the addition or deletion of particular services from the set of offered services?
4. What are the impacts on total benefits (costs) of implementing particular innovations?

Review of the Cost Benefit Approach

Cost benefit analysis is a method for evaluating the relative worth, or value, of a particular decision, policy, or course of action compared with other decisions, policies, or actions. The evaluation is based on economic measures of the value of a project; these measures may include cost or the benefit cost ratio, the payback period, and net present value (NPV). For examining the economics of IAC's, NPV is an appropriate measure.

The NPV of a project is a single number representing the net benefits of all present and future resource flows, where future costs and benefits are discounted to account for the decreased value of a future

benefit or cost. (For example, it is evident that one would prefer having $100 now rather than receiving $100 a year from now; having the $100 now permits its investment and its being productive for a year. If one is indifferent to $100 now and $110 a year from now, then one's discount rate is .10, or 10%.)

A more precise formulation for the net present value (NPV) of a project having costs C and benefits B now and through H future time periods is

$$NPV = B_0 - C_0 + \frac{B_1 - C_1}{(1+d)} + \frac{B_2 - C_2}{(1+d)^2} + \ldots + \frac{B_H - C_H}{(1+d)^H}$$

$$= \sum_{t=0}^{H} \frac{B_t - C_t}{(1+d)^t} \text{ , where}$$

B_t = benefit (positive resource flow) in time period t,

C_t = cost (negative resource flow) in time period t,

d = discount rate, and

H = time horizon (generally taken as the economic lifetime of the project.)

Evaluation of two projects, or scenarios, can be accomplished by computing the NPV of the resource flows for each of the projects, and the additional net benefits of one over the other can be calculated by subtracting the NPV of one from the NPV of the other. However, because the difference between the sums of two series is identical to the sum of the differences between the series, the net benefits of one project over another can be calculated by finding the NPV of the differences in costs and benefits between the two projects. Similarly, one can also calculate the present value of the time stream of benefits and compare this with the present value of the time stream of costs; this is the approach illustrated in the following sections. (Appendix B is a glossary which includes terms used in cost benefit analyses.)

In performing the evaluation, two issues are important: costs and benefits accruing to whom, and the choice of discount rate. These considerations are discussed in the following paragraphs.

Determining Costs and Benefits. For a particular project and a particular decision context, two sets of individuals may be distinguished: a set, A, of individuals whose members will be affected by the project, and a set, B, for whom the project is being conducted. Normally, sets A and B will not be identical, and A will not be a subset of B. If this is the case, then externalities, impacts not included in an evaluation of the impacts on the set B for whom the project is intended, will exist. Externalities can be particularly evident when one analyzes a project (e.g., a manufacturing operation) from an investor's viewpoint: the actual cash flow enters into the analysis, but noncash costs (e.g., air and water pollution) and benefits (city prestige and pride resulting from the new industry) are not included.

For the models presented in the following sections, the viewpoint is U.S. society. Benefits and costs accruing to individuals and organizations outside the U.S. are not included. Similarly, as discussed in Appendix D the analysis quantifies only private/organizational benefits.

From Figure 5, for example, the benefits of the handbook can be calculated from the difference between the "users' supply curve (without the handbook)" and the IAC supply curve. Figure 5 can be interpreted as a "snapshot" view of the aggregated supply and demand curves or of the supply and demand curves which a particular individual might perceive at a given instant of time. Thus the benefits for a year would be estimated by accruing the benefits for each use over the number of uses during the year. For each use of the handbook, the benefit (the difference between the users' supply curve and the IAC supply curve) can be estimated to be the time saved (e.g., in hours) multiplied by the value per unit time (e.g., hourly salary rate of the IAC user times an overhead factor). The present value of the benefits from the handbook would then be the discounted stream of annual benefits summed over the life of the handbook.

Determining the Discount Rate. For an analysis from a societal viewpoint, the appropriate rate is the societal discount rate, representing the degree to which society as a whole is willing to give up present consumption for future consumption. Although considerable research and debate are evident, economists generally have concluded that calculating

the social discount rate is not amenable to economic analysis alone. Moreover, there is no widely accepted, "correct" rate to use in cost benefit analyses. Some analysts have argued for rates as low as 0%; others have used the government loan repayment interest rate (e.g., 8.5%). For this project, a rate of 6% is used as a baseline rate, but a sensitivity analysis indicates that the results are relatively insensitive to the assumed rate.

Benefit Model

Scope and Limitations. The benefit model, as presented in the following paragraphs, can be used to address the first and second of the questions listed under the above section, "Model Objectives." The model subsequently can be extended to address the third and fourth of those questions.

The model utilizes estimates of benefits based on the value of time saved as a result of using an IAC service, a private (or organizational) benefit. This estimate presumes that the alternative information supply ("self supply") would yield data or information having quality equivalent to that provided by the IAC. Because a key role of the IAC is to assure data quality (through the functions of analysis, evaluation, and synthesis), there is, prima facie, reason to believe that the IAC data would have greater intrinsic value (e.g., there would be less risk or uncertainty associated with using IAC data). Consequently, this method of estimating benefits is a lower bound on benefits, at best; there might be other approaches which would establish a higher lower bound. However, even with this limitation, this method at least establishes a quantitative estimate of benefits that is consistent with fundamental economic principles and with a conceptual framework that can be a basis for subsequent improvement.

Model Formulation. The total benefits in a given time period to users of an IAC can be expressed as:

$$B = \sum_{j=1}^{k} \left[\sum_{i=1}^{m_j} b_{ji} \right]$$

where

b_{ji} = the net benefit to the i^{th} user of the j^{th} service

m_j = number of users of the j^{th} service

k = number of services

Since it would be extremely difficult to determine the benefit to each user of each service, the approach to simplify the calculation of total benefits is to estimate the average benefit to each user and then multiply this benefit by the number of users of the service. Using this approach, the expression for total benefits in a given year is:

$$B = \bar{b}_1 m_1 + \bar{b}_2 m_2 + \ldots\ldots \bar{b}_k m_k$$

where

$\bar{b}_k$ = average net benefit to each user of the k^{th} service

m_k = number of users of the k^{th} service per time period

This approach results in the total benefits per time period. To determine the net present value (NPV) of future benefits, the benefits in future years must be discounted using an appropriate discount factor. The net present value of the stream of benefits can be represented as

$$NPV_B = \frac{B_1}{(1+r)^1} + \frac{B_2}{(1+r)^2} + \ldots\ldots \frac{B_h}{(1+r)^h}$$

where

B_h = benefits to users in year h

r = discount rate

Alternatively, the net present value of the benefits for each service can be determined and then summed to give NPV_B:

$$NPV_B = NPV_1 + NPV_2 + \ldots\ldots NPV_k$$

where

NPV_k = present value of the stream of net benefits for the k^{th} service

For the purposes of this model, the latter approach is used. The procedures for calculating the benefits of each service are outlined in the following sections.

Benefit Calculations. The quantitative measure of benefits used here is the time (and thus money) the user saves by utilizing an IAC service rather than obtaining the information by alternative methods. This approach results in a lower bound on the benefits of an IAC because it ignores the value of the information to the user and any benefits to society that result from the existence and operation of the IAC.

Two basic conditions arise in the consideration of the benefits of IAC services. In the first, the benefit to the user in terms of time saved occurs only at the time the service is provided (as does the cost of obtaining the service from the IAC). This is the case for inquiry response and bibliographic search services. In the second case, the benefits may continue to occur in later time periods even though the cost of obtaining the service only occurs once. This is the case for handbooks and to some extent for state of the art reports. In the first case, the IAC service will normally be used once in answering a specific question whereas in the second case the user may refer to a handbook on several occasions over a period of years to answer different questions.

For the first case, the benefits per time period can be calculated using the following procedure:

1. Estimate the time (in hours) the user saves by utilizing the IAC rather than obtaining the information by alternative means.
2. Estimate the per hour value of this time to the user (e.g., salary plus overhead).
3. Estimate the cost to the user of obtaining this information from the IAC.
4. Calculate the benefit to each user by multiplying the results of step (1) by the results of (2) and then subtracting the results of (3).
5. Estimate the number of users of the service during the time period of interest (normally one year).
6. Calculate the benefits (per time period) by multiplying the results of step (4) by the results of step (5).

The benefits for inquiry response services and bibliographic search services can be calculated for as many future years as desired. This stream of benefits can then be discounted using a suitable discount factor.

$$NPV_{B(IR)} = \frac{B_1}{(1+r)} + \frac{B_2}{(1+r)^2} + \cdots\cdots \frac{B_h}{(1+r)^h}$$

where

$NPV_{B(IR)}$ = net present value of benefits of inquiry response service

B_h = benefits in year h from inquiry response service

r = discount rate

For the second case, a slightly different procedure is used since benefits are assumed to continue for as many years as the handbook is useful, although the cost of purchasing the handbook occurs only once. The procedure to calculate benefits in any given year is as follows:

1. Estimate the cumulative sales of the handbook through the year of interest.
2. Estimate the average number of hours that the handbook saves each user each year.

3. Estimate the per hour value of this time to the user.
4. Multiply the results of step (1) by those of step (2) and (3) to obtain the gross benefit for the year of interest.
5. Estimate the sales of the handbook in the year of interest.
6. Estimate the purchase price of the handbook.
7. Multiply the results of step (5) by the results of step (6).
8. Subtract the result obtained in step (7) from the gross benefit - step (4) - to obtain the net benefits to all users for that year.

This procedure should be repeated for as many years as the handbook is considered to be useful. The resulting stream of benefits is then converted into the net present value of benefits using a suitable discount factor.

Preliminary Results. Applying the above procedures for a set of reasonable estimated values yields initial estimates of benefits, and a sensitivity analysis provides guidance on which estimates are most critical. Table 2 presents the name of each model parameter, an assumed baseline value for this parameter, a range of possible values, and the sensitivity of the result of the model (NPV) to changes in this parameter for an inquiry response service. This sensitivity measure is defined as

$$S_{P_1} = \frac{\Delta NPV}{NPV} \Big/ \frac{\Delta P_1}{P_1}$$

where

ΔP_1 = the change in parameter of interest

P_1 = the baseline value of the parameter of interest

ΔNPV = the change in NPV due to change in P_1

NPV = baseline value of NPV

The sensitivity is useful in assessing the changes in the output of the model to changes in parameter values. Thus, if the sensitivity of the model to a certain parameter is 1.9, then a 10% change in the value of that

Table 2. Benefit Model Parameters - Inquiry Response

Parameter	Baseline Value	Expected Range of Values	Sensitivity
Time Saved Per Use (Hrs)	5	0 - 16	-
Number of Uses Per Year	1	0 - 10	-
Value Per Hour ($)	15	5 - 30	-
Annual Benefit ($)	75	10 - 1000	3.0
Price Charged by IAC ($)	40	0 - 1000	-2.0
Number of Users Per Year	1000	100 - 3000	1.0
Discount Rate (%)	6	3 - 12	-0.3
Time Horizon (Yrs)	10	5 - 20	0.7

NPV_B (Using Baseline Values) = $257,603

parameter (from baseline value) will change the output of the model by 19% (from the baseline value).

Note that the first three parameters in the table -- hours saved per use, number of uses per year, and value of time saved per hour - are combined to obtain the annual benefit to each user and that the sensitivity is expressed in terms of this annual benefit rather than the three parameters separately. As the data in the table demonstrate, the results of the model (at the baseline) are very sensitive to estimated annual benefits and to cost to the user of inquiry services, while the results are relatively insensitive to choice of discount rate or to time horizon considered. Using the baseline values for all the parameters listed, the net present value (per user) of the inquiry response service is $258.

Similarily, Table 3 presents parameters, baseline parameter values, ranges of parameter values and sensitivities for the benefit model for handbooks produced and sold by an IAC. As with the inquiry response model, the handbook model is sensitive to the estimate of annual benefits to each user. It is most sensitive to the lifetime of the handbook. It is relatively insensitive to the cost of the handbook (sales of handbook held constant) and the discount rate used. Using the baseline values of the parameters listed, the net present value per handbook sold is $44.

Table 3. Benefit Model Parameters - Handbook

Parameter	Baseline Value	Expected Range of Values	Sensitivity
Time Saved Per Use (Hrs)	2	0 - 16	-
Number of Uses Per Year	1	0 - 10	-
Value Per Hour ($)	15	5 - 30	-
Annual Benefit for Each User ($)	30	10 - 1000	1.7
Cost of Handbook ($)	35	5 - 100	-0.7
Lifetime of Handbook (Yrs)	5	2 - 10	2.4
Total Number of Handbooks Sold	1000	100 - 20,000	1.0
Discount Rate (%)	6	3 - 12	-0.2
Percent of Total Sales by Years	1-15%;2-25%; 3-25%;4-20%; 5-15%	-	-

NPV_B (Using Baseline Values) = $44,359

Cost Model

Scope and Limitations. The cost model is intended to address the four questions listed under the above section, "Model Objectives". This allows the costs of operating an IAC at particular levels of service to be compared with the estimated benefits of the IAC at those levels of service to determine the level or mix of service that is economically optimum.

The emphasis of the model is on economic rather than accounting costs; the former is a measure of the total resources employed in an IAC and thus is the relevant variable for decision making. For clarity, the derivation and formulation of the model includes each significant cost item explicitly rather than using an overhead rate which aggregates the indirect cost elements. This formulation thus permits the model parameter values to be varied to correspond with the individual characteristics of a particular IAC.

Model Formulation. The first step in choosing an appropriate general form of the model is the listing of the relevant costs involved in the overall operation of an IAC. These cost categories, shown in Table 4, include all costs thought to be significant by the project team. These costs fall into one of two categories: fixed costs or variable costs. Fixed costs are those costs incurred that are independent of the level of output (at least over some fairly broad range of output) while variable costs vary directly with the output (level of services provided) of the IAC. Examples of fixed costs are rent, utilities, and subscriptions to journals and periodicals. Examples of variable costs are project salaries and reproduction and duplication. It appears obvious that some general cost categories have both a fixed and a variable cost component. Thus, some salaries conveniently may be considered fixed, such as the salary of the IAC manager, while others are variable costs such as the salary of persons working on responses to inquiries. This presents no particular difficulty as long as the cost can be reasonably separated into the fixed and variable components.

Based on the objectives of the cost model and the costs involved in an IAC operation, a fixed cost plus variable cost model appears to be the most appropriate general form for the model. Thus, at a given level of output, the total cost may be expressed as

Table 4. Components of IAC Costs

FIXED COSTS

- RENT
- TELEPHONE
- FURNITURE AND EQUIPMENT
- OFFICE SUPPLIES
- SUBSCRIPTIONS
- ADVERTISING AND MARKETING
- COPYING AND REPRODUCTION
- POSTAGE
- TRAVEL
- COMPUTER CHARGES
- SALARIES

VARIABLE COSTS

- SALARIES
- COMPUTER CHARGES
- REPRODUCTION AND PRINTING
- SUPPLIES

$$TC = FC_T + VC_T$$

where

TC = Total Cost ($)

FC_T = Total Fixed Costs (costs independent of output)

VC_T = Total Variable Costs (costs which vary with output)

This form assumes constant marginal costs for different levels of service. This assumption seems reasonable for a wide range of service levels, but it would not necessarily hold at very low (or perhaps very high) levels of services.

Since an IAC typically offers more than one service and since one of the objectives of the cost model is to predict changes in total cost as a function of the output of the different services, the general form of the model can be expressed as

$$TC = FC_1 + FC_2 + \ldots + FC_k + \overline{VC}_1 n_1 + \overline{VC}_2 n_2 + \ldots + \overline{VC}_k n_k$$

or

$$TC = \sum_{j=1}^{k} FC_j + \sum_{j=1}^{k} \overline{VC}_j n_j$$

where

FC_j = fixed cost attributable to service j,

$\overline{VC}_j$ = average variable per unit cost of service j,

n_j = number of units of output of service j, and

k = number of services offered.

This form of the model assumes that all costs can be uniquely associated with a particular service. In general this is not true. Examples are the salary of the IAC manager and the cost of maintaining a data base used by more than one of the IAC services. These costs, which belong to the general class of joint costs, are properly a part of the total cost of the IAC operation and as such should be reflected in the unit costs (cost of one unit of IAC service, e.g., one hour of bibliographic search) for the IAC services. For the most part these costs, however, would be incurred even if a service were eliminated by the IAC. For the purpose of

estimating total costs of the IAC, it is valid to collect all of these joint costs (which are also fixed costs) into a single unallocated fixed cost category. In this manner, an arbitrary allocation scheme is avoided and the model is still able to predict changes in total cost resulting from changes in the levels of services provided or from the deletion or addition of a service. In this case the model is expressed as

$$TC = FC_u + FC_1 + \ldots + FC_k + \overline{VC}_1 n_1 + \ldots + VC_k n_k$$

or

$$TC = FC_u + \sum_{j=1}^{k} FC_j + \sum_{J=1}^{k} \overline{VC}_j n_j$$

where

FC_u = unallocated fixed cost

Cost Calculations. The above equation allows computation of the total costs of operation of an IAC for given levels of each service, e.g., 1000 hours of bibliographic search. If a method is chosen for allocating the unallocated fixed costs, the above equation may also be used to calculate average unit costs and total costs for each particular service, and thus serve as a guide to pricing each service.

As envisioned in the cost model presented above, the costs are annual operating costs. The net present value (NPV) of the stream of future operating costs, either for total costs or for an individual service cost, is calculated from the following:

$$NPV = \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_h}{(1+r)^h}$$

where

C_h = cost in year h for complete IAC operation or for any individual service

h = time horizon

r = discount rate

Notice, however, that the above NPV calculation is not limited to evaluating operating IAC's. If a new IAC is envisioned, the calculation would simply include one or more years of start-up costs and then several (as many as desired) years of operating costs. The resulting calculation would yield the NPV of IAC costs for its lifetime, for the first ten years, or for some other specified period.

Preliminary Results. To demonstrate the nature and utility of the cost model as outlined above, a value for each cost item has been assumed. These values are then used to compute the total cost of providing 2000 hours of inquiry/response service over one year. This total ($73,551 in our example) is then used to compute the sensitivity of the model to changes in values of the various parameters. These sensitivities, calculated according to the methodology outlined below, allow one to focus on the critical cost parameters associated with IAC's and thus to concentrate on obtaining valid data or good estimates of values for these critical parameters as inputs to the calculations.

Carrying the calculation one step further and deriving a net present value for inquiry/response costs (for this example) yields a value of $246,935* for ten years. This compares to a net present value of benefits of $257,600 using the techniques described in the benefit section.

Table 5 shows the sensitivity of the model to each of the parameters of interest for inquiry/response service. For simplicity, 25% of the fixed costs have been allocated to inquiry/response. Then a 10% change in the cost of each item, e.g., rent, was assumed and the effect on total cost of inquiry/response measured according to the following:

$$\text{Sensitivity} = \frac{\Delta NPV_c}{NPV_c} \Big/ \frac{\Delta V}{V}$$

where

NPV_c = net present value of costs of inquiry/response service

ΔNPV_c = change in net present value of costs of inquiry/response service

* Using adjusted annual operating cost.

Table 5. Cost Model Parameters - Inquiry Response

Parameter	Baseline Value	Expected Range of Values	Sensitivity
Fixed Costs			
Rent	$ 2000	$ 1500 - $ 3000	.03
Telephone	750	600 - 1200	.01
Furniture, Equip.	900	600 - 1800	.01
Office Supplies	450	300 - 1200	.01
Subscriptions	1250	750 - 2500	.02
Advertising & Marketing	2500	1250 - 6500	.03
Copying & Reproduction	600	300 - 1200	.01
Postage	450	300 - 900	.01
Travel	1750	1500 - 6000	.02
Computer Time	1500	900 - 4500	.02
Computer Terminal	450	300 - 750	.01
Salaries	18375	12580 - 25000	.25
Manager 7500			
Clerical 4000			
Professional 6875			
Fringe Benefits	2756	1875 - 3750	.04
Allocation Factor for Fixed Costs	.25	.1 - .4	.46
Variable Costs (Per Hour of Professional Effort)			
Salaries	$14.91	$10 - 20	.41
Professional $13.67			
Clerical $1.24			
Computer Time & Supplies $5.00	$5.00	$4 - 8	.14
Number of Professional Hours Expended Per Year on Providing Inquiry Response Service	2000	500 - 10,000	.54
Discount Rate (%)	6	3 - 12	-0.3
Time Horizon (Yr)	10	5 - 20	0.7

Annual Operating Cost	$73,551
Annual Revenues (@ $20 per professional hour)	40,000
Adjusted Annual Operating Cost	$33,551

NPV_C of Adjusted Annual Operating Cost = $246,935

V = baseline value of a particular parameter of cost model, e.g., rent

ΔV = change in value of the particular parameter

This is a measure of how fast the total costs of a particular IAC service change when some individual component of the costs varies.

Examination of the table shows that the only parameters to which the model is very sensitive are labor related parameters (salary, fringe benefits, number of man hours expended) and fixed cost allocation parameters (what percentage of fixed costs are allocated to each service). This implies that the salary data collected for input to the model should be based on a cost accounting system that accurately allocates all personnel time among the different IAC activities. Also, the method chosen for allocating overhead among the various services should be based on an algorithm most appropriate to the IAC under study.

A similar table of sensitivities could be constructed for each of the other services. For state of the art reviews and bibliographic search services, the procedure would be essentially the same as for inquiry response. For handbooks the methodology is also similar except that most of the handbook production costs are incurred prior to publication and handbook revenues (and benefits) occur in succeeding years. Thus the NPV approach is the only way in which handbook costs could be calculated and reasonably compared to benefits.

Conclusions

The discussions presented in this chapter lead to the following conclusions:

1. These models provide a means by which IAC managers and decision makers can begin to quantitatively analyze the benefits and costs arising from the operation of an IAC or other information service center.
2. The difficulty of obtaining reliable data on the total benefits of an IAC (to users and to society) has led to the adoption of a benefit model which results in a lower bound of benefits. This lower bound, however, can be

significant as shown by the example calculations and is of the same magnitude as, but generally larger than, the costs derived from the cost model.

3. Because of the availability of good cost data, the cost model is much more comprehensive than the benefit model and represents a good approximation to the total costs of providing a particular service or of an IAC as a whole.
4. The results of both the benefit and cost models are highly sensitive to the estimates of some parameters and essentially independent of the estimates of other variables.

IAC POLICY AND DECISION MODEL

Introduction and Highlights

This chapter develops a mathematical economic model that is intended to offer a prescriptive tool for IAC policy and decision making. The chapter includes the development of a supply-demand model for two services, handbooks and inquiry responses, that assumes interactions between the two services. The chapter includes discussions of the prescriptive results of applying the model, simplifying assumptions which improve its utility, and current barriers to its practical application.

The evolving concept that information is not a public good but rather a quasi-public good or even a commodity, governed by the economic rules of supply and demand, requires the application of traditional economic concepts to information services. The model in this chapter applies standard economic theory to account for observations in the information services market, particularly observations about IAC's.

The approach is a mathematical formulation of costs, revenues, demand, and benefits of IAC operations, using handbooks and inquiry response as examples of services. The Lagrangian multiplier technique provides a means for determining and comparing implicit optimal values of the decision variables from the IAC manager's viewpoint and from society's viewpoint.

Highlights include:

- A basic model which mathematically accounts for a number of diverse and apparently contradictory facts and observations about IAC's and shows these to be consistent with rational economic behavior;
- Illustrations of the model's relevance to issues of IAC service levels, mix, pricing, and government support;
- Illustration of how a societal optimum solution to the model may differ from an IAC manager's optimal solution to the model; and
- Discussion of barriers to implementation.

Basic Model

The following mathematical model addresses the issues of level, mix, pricing, and government support of IAC services. We assume the IAC produces two goods, a handbook and inquiry response. The variables within the model are:

H	the number of copies of the IAC handbook produced and sold.
I	the number of units of inquiries serviced by the IAC (a unit is one man-hour of service).
P_H	the price of a handbook.
P_I	the price of a unit of inquiry response.
R_H	the revenue earned from handbook sales.
R_I	the revenue earned from inquiry responses.
C_H	the total cost of handbook provision.
C_I	the total cost of inquiry response services.
TR	the total revenue earned by the IAC.
TC	the total costs incurred by the IAC.
Π	the net revenue (or profit) of the IAC.
B_H	the total social benefit derived from the IAC handbooks.
B_I	the total social benefit derived from the inquiry response service.
B	the total social benefit from the IAC.

The behavioral relations within the model are the demand for handbook,

$$H = f^H(P_H, P_I) \quad , \quad \frac{\partial H}{\partial P_H} < 0 \quad , \quad \frac{\partial H}{\partial P_I} > 0 \qquad (1)$$

and the demand for inquiry response

$$I = f^I(P_I, P_H) \quad , \quad \frac{\partial I}{\partial P_I} < 0 \quad , \quad \frac{\partial I}{\partial P_H} > 0 \qquad (2)$$

These demand equations reflect the possible substitution between handbooks and inquiries. The first equation indicates that a lower price for inquiry response will decrease the demand for handbooks. The second

equation indicates that a lower price for handbooks will decrease the demand for inquiry response.

The revenue expressions are

$$R_H = P_H \cdot H \tag{3}$$

$$R_I = P_I \cdot I \tag{4}$$

$$TR = R_H + R_I \tag{5}$$

The cost relations may be written as

$$C_H = g^H(H, Z_I) \quad , \quad \frac{\partial C_H}{\partial H} > 0 \tag{6}$$

and

$$C_I = g^I(I, Z_H) \quad , \quad \frac{\partial C_I}{\partial I} > 0 \tag{7}$$

Z_I and Z_H are 0-1 variables.

$Z_I = 1$ if $I > 0$.

$= 0$ otherwise

$Z_H = 1$ if $H > 0$

$= 0$ otherwise

These 0-1 variables reflect the common data base which a handbook and inquiry response share. Thus, the cost of providing inquiry response depends on whether a data base is already available (as would be the case if a handbook were produced). If so, a large fixed cost is avoided. Likewise, the cost of providing a handbook depends on whether inquiry response is provided. If so, the necessary data base exists, and cost is avoided.

The total cost of the IAC is

$$TC = C_H + C_I \tag{8}$$

and the net revenue is

$$\Pi = TR - TC. \tag{9}$$

We express the benefits to society of an IAC's handbook as

$$B_H = B^H(H) \quad , \quad \frac{\partial B_H}{\partial H} > 0 \quad , \quad \frac{\partial}{\partial H}\left(\frac{\partial B_H}{\partial H}\right) < 0 \tag{10}$$

These benefits represent the difference between the users' own information supply curve with and without a handbook.

The benefits of inquiry response are given by the area under the social demand curve for that service. Of course, the social demand curve shifts higher or lower depending on the existence of a handbook. Thus

$$B_I = \int_0^I SD(I, Z_H)dI \tag{11}$$

$$= B^I(I)$$

We assume the private costs of (6) and (7) also represent the social costs of an IAC. That is, there are no external diseconomies in running an IAC. For example, the social demand equation may be

$$SD(I, Z_H) = a_0 - a_1 Z_H - a_2 I \tag{12}$$

So that,

$$B_I = a_0 I - a_1 Z_H I - (a_2 I^2)/2 \tag{13}$$

Equations 1-10 and 11 or 13 comprise the elements of the IAC decision model. Note that two distinct points of view may be adopted in IAC decision making. One viewpoint is that of the IAC manager, and the other is that of society. While it is reasonable to postulate that society is interested in maximizing net benefits to its members, the motivation of the IAC manager is not quite so apparent. The manager does not own the operation, nor does he report to anyone who does (assuming we remain in the realm of public IAC's). Of the several possible alternatives, we choose constrained revenue (or sales) maximization as the motivation to ascribe to IAC managers. This criterion captures the desire of IAC management to expand the operation as much as financially feasible. Since IAC's are subsidized by the government, the manager's sales expansion is limited by the level of subsidy available.

The approach in the following analysis is to characterize the outcome of management's policies and compare these outcomes with socially optimal outcomes. When differences exist, the reason for the difference is explored and corrective policies discussed. The interdependent issues of interest are the level, mix, pricing, and subsidy of the IAC services.

IAC Management Perspective. The constraint faced by IAC management is that its losses must not exceed its subsidy, or

$$-\Pi = TC - TR \leq S \tag{14}$$

where S is the amount of subsidy. Subject to (14), the expression to maximize is

$$TR = R_H + R_I \tag{5}$$

For convenience, inequality (14) may be changed to

$$TC - TR = S \tag{15}$$

since it is known a priori that any subsidy will be fully utilized to expand sales. The relevant Lagrangian expression is

$$L = R_H + R_I + \lambda(S - TC + TR)$$

or

$$L = P_H \cdot H + P_I \cdot I + \lambda[S - g^H(H,Z_I) - g^I(I,Z_H) + P_H \cdot H + P_I \cdot I]$$

Since, for IAC management, prices are control variables, we should further substitute to obtain

$$\left.\begin{aligned} L = {} & P_H \cdot f^H(P_H,P_I) + P_I \cdot f^I(P_I,P_H) + \lambda[S - \\ & g^H(f^H(P_H,P_I),Z_I) - g^I(f^I(P_I,P_H),Z_H) \\ & + P_H \cdot f^H(P_H,P_I) + P_I \cdot f^I(P_I,P_H)] \end{aligned}\right\} \tag{16}$$

First order conditions are

$$\frac{\partial L}{\partial P_H} = P_H \frac{\partial f^H}{\partial P_H} + f^H(P_H,P_I) + P_I \frac{\partial f^I}{\partial P_H}$$

$$+ \lambda \left[- \frac{\partial g^H}{\partial f^H} \frac{\partial f^H}{\partial P_H} - \frac{\partial g^I}{\partial f^I} \frac{\partial f^I}{\partial P_H} \right.$$

$$\left. + P_H \frac{\partial f^H}{\partial P_H} + f^H(P_H,P_I) + P_I \frac{\partial f^I}{\partial P_H} \right] \qquad (17)$$

$$= 0$$

$$\frac{\partial L}{\partial P_I} = P_H \frac{\partial f^H}{\partial P_I} + P_I \frac{\partial f^I}{\partial P_I} + f^I(P_I,P_H)$$

$$+ \lambda \left[- \frac{\partial g^H}{\partial f^H} \frac{\partial f^H}{\partial P_I} - \frac{\partial g^I}{\partial f^I} \frac{\partial f^I}{\partial P_I} \right.$$

$$\left. + P_H \frac{\partial f^H}{\partial P_I} + P_I \frac{\partial f^I}{\partial P_I} + f^I(P_I,P_H) \right] \qquad (18)$$

$$= 0$$

$$\frac{\partial L}{\partial \lambda} = S - g^H(f^H(P_H,P_I),Z_I) - g^I(f^I(P_I,P_H),Z_H)$$

$$+ P_H \cdot f^H(P_H,P_I) + P_I \cdot f^I(P_I,P_H) \qquad (19)$$

$$= 0$$

Societal Perspective. By way of contrast, the social objective is to maximize Net Social Benefits,

$$NSB = B - TC$$

or

$$NSB = B_H + B_I - (C_H + C_I)$$

or

$$NSB = B^H(H) + B^I(I) - g^H(H,Z_I) - g^I(I,Z_H)$$

or

$$NSB = B^H(f^H(P_H,P_I)) + B^I(f^I(P_I,P_H)) - g^H(f^H(P_H,P_I),Z_I) - g^I(f^I(P_I,P_H),Z_H) \quad (20)$$

First order conditions are

$$\frac{\partial NSB}{\partial P_H} = \frac{\partial B^H}{\partial f^H}\frac{\partial f^H}{\partial P_H} + \frac{\partial B^I}{\partial f^I}\frac{\partial f^I}{\partial P_H} - \frac{\partial g^H}{\partial f^H}\frac{\partial f^H}{\partial P_H} - \frac{\partial g^I}{\partial f^I}\frac{\partial f^I}{\partial P_H} = 0 \quad (21)$$

$$\frac{\partial NSB}{\partial P_I} = \frac{\partial B^H}{\partial f^H}\frac{\partial f^H}{\partial P_I} + \frac{\partial B^I}{\partial f^I}\frac{\partial f^I}{\partial P_I} - \frac{\partial g^H}{\partial f^H}\frac{\partial f^H}{\partial P_I} - \frac{\partial g^I}{\partial f^I}\frac{\partial f^I}{\partial P_I} = 0 \quad (22)$$

In general, the solution $(\hat{P}_H,\hat{P}_I)$ to (17), (18), and (19) is different from the solution (P_H^*,P_I^*) to (20) and (21).

Implications of Different Optimal Solutions. If explicit functions were available for all basic equations, then (with a possibly good deal of effort) explicit solutions could be found to the two systems. This would certainly facilitate comparisons between management's desired outcome and the socially desired outcome. If substantial differences exist, a government tax-subsidy policy could be used to establish agreement. Taxes or subsidies on the individual goods offered for sale by the IAC could produce the proper ratio of one good to another, and a lump sum tax or subsidy could effect the overall proper level of production.

The foregoing remarks implicitly assumed positive levels of outputs for both handbooks and inquiry response. Of course, this need not be the case. Indeed, the possibility of one or the other set at zero output is permitted by the 0-1 Z variables. In order to properly consider the determination of whether a particular good is offered by an IAC, equations (17), (18), and (19) must be solved under three conditions.

I: $Z_H = 1, Z_I = 0$

II: $Z_H = 0, Z_I = 1$

III: $Z_H = 1, Z_I = 1$

Likewise, equations (20) and (21) must be solved under the same three conditions.

Practical conclusions from the above discussion include:

1. Pricing, mix, level, and government support of IAC services should be simultaneously determined.
2. This determination requires a great deal of unavailable information -- namely the forms and parameter values for the model's basic equations.
3. Given the adequacy of the model as a descriptive tool, government tax-subsidy policies are sufficient to induce optimal resource allocation within an IAC.

Analytic Extension with Simplifying Assumptions. The analysis can be carried a step further if one is willing to make some simplifying assumptions about the form of the equations underlying (17) - (21). In particular, assume most equations are linear, the demand for handbooks is negligibly dependent on the price of inquiry response, and both handbooks and inquiry response are provided. The modified equations now become

$$H = b_0 - b_1 P_H \qquad (1)'$$

$$I = b_2 - b_3 P_I + b_4 P_H \qquad (2)'$$

$$C_H = c_0 + c_1 H \qquad (6)'$$

$$C_I = c_2 + c_3 I \qquad (7)'$$

$$B_H = B^H(H) \ , \ \frac{\partial B_H}{\partial H} > 0 \ , \ \frac{\partial}{\partial H}\left(\frac{\partial B_H}{\partial H}\right) < 0 \qquad (10)$$

$$B_I = B^I(I) \quad \frac{\partial B_I}{\partial I} > 0 \ , \ \frac{\partial}{\partial I}\left(\frac{\partial B_I}{\partial I}\right) < 0 \qquad (11)$$

Equations (10) and (11) are still expressed implicitly but they capture the presumed existence of diminishing marginal benefits from both H and I. Note that (2)' has not sacrificed the cross elasticity between I and H. The modified conditions necessary for sales maximizing prices are

$$- P_H + H + P_I b_4 + \lambda(+ c_1 b_1 - c_3 b_4 - P_H b_1 + H + P_I b_4) = 0 \qquad (17)'$$

$$- P_I b_3 + I + \lambda(+ c_3 b_3 - P_I b_3 + I) = 0 \qquad (18)'$$

$$S - (c_0 + c_1 H) - (c_2 + c_3 I) + P_H \cdot H + P_I \cdot I = 0 \qquad (19)'$$

(1)' and (2)' can be substituted into (19)', which can then be solved for P_H as a function of P_I:

$$P_H = h^1(P_I) \qquad (23)'$$

(17)' and (18)' can each be solved for λ, equated, and solved for P_H:

$$P_H = h^2(P_I) \tag{24}$$

The RHS's of (23) and (24) can be equated to produce a solution, $\hat{P}_I$; i.e.

$$h^1(\hat{P}_I) = h^2(\hat{P}_I) \tag{25}$$

Finally, using (23),

$$\hat{P}_H = h^1(\hat{P}_I) \tag{26}$$

$\hat{P}_I$ and $\hat{P}_H$ are the prices which are optimal from the IAC's management's point of view. Turning now to the social perspective, the first order conditions are

$$-\frac{\partial B^H}{\partial H} b_1 + \frac{\partial B^I}{\partial I} b_4 + c_1 b_1 - c_3 b_4 = 0 \tag{21}'$$

$$-\frac{\partial B^I}{\partial I} b_3 + c_3 b_3 = 0 \tag{22}'$$

With (10) and (11) explicitly stated in terms of H and I, and substituting from (1)' and (2)', socially optimal prices (P_H^*, P_I^*) could be determined.

Only by chance would $(P_H^*, P_I^*) = (\hat{P}_H, \hat{P}_I)$, so that in general IAC management's behavior would need to be modified. This could be accomplished by a tax/subsidy scheme in which the revenues received by the IAC are appropriately modified by taxes/subsidies on the goods sold to induce management to produce at the (P_H^*, P_I^*) level.

Discussion and Conclusion

The above approach assumed it is feasible to determine the unconstrained socially optimal level of IAC outputs and then to achieve that level via appropriate financial incentives (taxes and subsidies) to IAC management. A somewhat more realistic point of view would be to assume a maximum amount of subsidy is available to an IAC, where that maximum is less than would be necessary to achieve the overall social optimal. This is a "second best" problem, since the first best

is now ruled out as unfeasible. The problem is to maximize (20), constrained by (15). The solution may be characterized by a set of first order conditions (as above), and a tax/subsidy scheme constructed to induce management to attempt to achieve those "second best" levels.

There are two hurdles which must be overcome in order to implement a model of the type discussed here. The first hurdle is the specification of the functional forms and parameters. That is, the demand, cost, and benefit functions must be known. The second hurdle is a reasonably efficient method for solving the characterizing equations to find optimal prices and/or levels of outputs. Of these hurdles, the first is by far the more difficult, demanding a great deal of empirical research. The second hurdle can be overcome by numerical approximation techniques implemented on a computer.

USER VALUES OF INFORMATION SERVICE CHARACTERISTICS

Introduction and Highlights

This chapter is intended to be a summary and synthesis of relevant literature and data on how IAC users perceive the characteristics of IAC services and how they value these characteristics. Primary inputs to this chapter include the Defense Logistics Agency (DLA) study[1] on IAC user needs, the Defense Documentation Center ten year requirements and planning study[2], a study by Forecasting International, Ltd., on a forecast of technology for the scientific and technical information communities[3], and an unpublished report by Tom Allen[4].

Chapter highlights include:

- IAC user characteristics, particularly how users perceive the value of different characteristics of information and service channels, require additional study as a necessary step toward improved data for economic analyses;
- IAC users typically are engaged in technical work (as opposed to management of a technical area) and utilize facts, data, and constants;
- The usage and awareness of IAC's both are low compared to the size of the potential user audience; and
- Characteristics of information and channels of technical information judged to be important to the potential and actual IAC users include: cost, accuracy, currency, response time, ease of access, ease of use, technical quality, coverage of topic, understandability, format, media, recall, and relevance. Research is needed to further define the relationships among these characteristics and to deduce the relative value of each characteristic to the IAC users.

User Characteristics of DLA

Two specific user need studies have been performed on the group of IAC's sponsored by the Department of Defense and administered by the Defense Logistics Agency (DLA). The findings of these two studies can be summarized and applied to the question of how users perceive the value of IAC services.

According to the first [illegible] directly applicable study, the Defense Logistics Agency effo[illegible] the primary mission of the DLA-administered IAC's is "to collect, review, and select from the world's literature scientific and technical information of interest to the Defense Community (DoD and DoD contractors) and to evaluate, synthesize, and disseminate this information in formats most useful to Defense scientists, engineers and technicians."[1]

From the information in this study, the users of MCIC, MDC, and other DoD IAC's can be described as scientists, engineers and technicians employed by either DoD activities or DoD contractors who are working within the IAC's areas of technology. These personnel manage technical work, and perform technical tasks and a variety of miscellaneous duties. The respondents to the survey carried out these activities in the following ratios: 31% of tasks consist of managing technical work, approximately 53% in performing tasks (design and development engineering 13.2%, test and evaluation 15.7%, and research and experimentation 24%). The remainder is divided among miscellaneous tasks.

The respondents generally need more facts, data, findings, or [illegible] other types of information. In other words, respondents prefer and need the type of information typically contained in data books and handbooks above that contained in other types of IAC products and services. Respondents also expressed problems in locating, obtaining and using scientific and technical information and spend a significant amount of their time in these activities. Respondents obtain the greatest amounts of scientific and technical information from their local technical libraries, from their own collections and from colleagues.

One finding of the survey was that only 31% of all DoD scientists and engineers are aware of the existence of IAC's. This finding explains to a great degree the observation that IAC's are underutilized.

These findings are supported by those of the second report, the Defense Documentation Center (DDC) 10 year requirements and planning study.[2] The user survey conducted as part of this study was more general than the DLA study, covering users and nonusers of all DDC services, not just IAC's. Many detailed cross-linked statistical tables which would have been useful in describing IAC users are not included in the report. However, several of the report's observations do deal directly with IAC's. Table 6 shows the percentages of DDC users who have used various IAC's. These percentages show the use of IAC's by support personnel to be low overall, the average being 14.4%. Even so, the percentages for support personnel are much larger than the percentages for bench and management IAC users.

From these two reports we can draw a general picture of the user community for the DLA-administered IAC's and of their information seeking behavior, and can relate it in a general fashion to those characteristics of an information delivery system that a user values.

Perceived Value of IAC Delivery Channel Characteristics

Economic analyses of services related to information often slide into a morass of issues related to the value of "data" or "information" rather than the value of the service which furnishes the data or provides access to the data or information. The DDC study put it this way:

> No value measures of information have been developed which would be useful in making economic decisions. Information has subjective and pragmatic value to its users, but this value has been difficult, if not impossible, to measure to date ...

Chapter 3 discusses the importance of making the distinction between the value of the service and the value of the information. Only in the case that an IAC provides totally unique information could the value of the IAC be measured by the value of the information. Consequently, it is necessary from both a practical and conceptual viewpoint that the value of an IAC be studied with an approach that examines the value of the IAC service. This is consistent with a marketing approach, adopting

Table 6. Percentages of DDC Users Who Have Used Various Information Analysis Centers*

INFORMATION ANALYSIS CENTER	SUPPORT	BENCH	MANAGEMENT
Infrared Information and Analysis Center	42.0%	7.9%	7.9%
Metals and Ceramics Information Center	39.7%	3.4%	6.8%
Shock and Vibration Information Center	37.5%	2.3%	3.2%
Chemical Propulsion Information Agency	36.4%	1.7%	6.8%
Reliability Analysis Center	31.8%	.6%	5.0%
Nondestructive Testing Data Support Center	27.3%	.6%	4.3%
Thermophysical and Electronic Properties Information Analysis Center	26.1%	3.4%	3.6%
Plastics Technical Evaluation Center	25.0%	.6%	3.2%
DoD Nuclear Information and Analysis Center	19.3%	5.1%	4.6%
Mechanical Properties Data Center	18.2%	3.4%	4.3%
Electronic Properties Information Center	17.0%	0.0%	3.9%
Tactical Technology Center	13.6%	0.0%	2.9%
Machinability Data Center	10.2%	.6%	2.5%
Radiation Shielding Information Center	9.1%	0.0%	.7%
Physical Data Group, Lawrence Livermore Laboratory	7.9%	2.3%	1.8%
USAF Environmental Technical Applications Center	6.8%	0.0%	.4%
Environmental Information Division (Air Force)	6.8%	1.1%	2.9%
Strategic Technology Office Data Base	5.7%	0.0%	1.1%
Soil Mechanics Information Analysis Center	5.7%	.6%	1.4%
Coastal Engineering Information Analysis Center	3.4%	0.0%	0.0%
Concrete Technology Information Center	3.4%	0.0%	1.4%
Hydraulic Engineering Information Analysis Center	2.3%	.6%	.3%
Pavements and Soil Trafficability Information Analysis Center	2.3%	0.0%	1.1%
Chemical Kinetics Information Center	2.3%	1.1%	1.4%
Data Collection and Processing Group, Scripps Institution of Oceanography	2.3%	.6%	2.5%
X-Ray Attenuation Coefficient Information Center	1.1%	.6%	0.0%
Institute of Polar Studies	1.1%	.6%	2.5%
Bathythermograph Data Processing and Analysis Facility	0.0%	0.0%	.4%

*N = 544

Source: Auerbach Associates, Inc., DDC 10 Year Requirements and Planning Study, Volume II: Technical Discussion, Bibliography, and Glossary, June 13, 1976, 27.

the viewpoint that the IAC is an information delivery system, utilizing handbooks, responses to inquiries, etc., as channels for delivering the information.

The following paragraphs summarize literature relevant to this approach. Forecasting International (FI) conducted a study whose results are pertinent[3]; the DSA and DDC studies are directly related; and Tom Allen's work[4,6] provides useful general information.

FI conducted a survey of members of five scientific and technical information (STI) communities to determine their ideas of the relative importance of seven information (delivery) system characteristics. The five communities were the health community, industry, the library community, the academic community and the financial community. The systems characteristics studied were:

- accuracy
- browsability
- security
- availability of hard copy
- convenience
- cost
- timeliness (currency of information)

Table 7 summarizes the results of the survey for each community and the entire group.

The DLA and DDC studies contributed very little specific data concerning delivery system characteristics valued by the user. The DLA study did provide some information on the types of delivery systems valued and types of information needed by IAC users. The survey found that IAC users felt that the most important products that can be produced or offered by IAC's are handbooks and databooks. The study also concluded that DoD scientists and engineers have a great need for summary-type information. More specific findings indicated that DLA-administered IAC's are underutilized because their potential users in the DoD laboratories and contractor organizations are unaware of their existence. In evaluating current IAC services, users noted their greatest dissatisfaction was with the timeliness (response time) of the IAC inquiry service. This would indicate that response time is one characteristic to which users attach importance.

The DLA report presented an interesting sidelight which could be of interest in future work in determining benefit measures. One of the

Table 7. Relative Importance of Information Delivery System Characteristics to Five STI Communities

Characteristics (Rank-ordered by Group Aggregate)	Measure of Importance to: Entire Group	Health Community	Industry	Library Community	Academic Community	Financial Community
Accuracy	34	8	8	2	8	8
Browsability	24	4	2	8	2	8
Security	22	8	4	4	2	4
Availability of Hard Copy	20	4	2	8	2	4
Convenience	18	4	2	2	8	2
Cost	18	2	2	4	8	2
Timeliness	16	2	8	2	2	2

8 (High) 2 (Low)

4 (Medium) 1 (Negligible)

primary goals of the IAC's is to free defense scientists, engineers and technicians from the time-consuming and nonproductive task of locating, analyzing and extracting information in their work. This goal indicates that time and dollars saved are appropriate measures of benefit. Time costs could be measured by asking respondents to list the information which they spend the greatest amount of time locating, analyzing, condensing, extracting and applying to their work. Dollars could be measured by asking the respondent to estimate the total savings to himself if information were readily available in an easy-to-use format.

The DLA report implies the following characteristics as being important to the user:

Cost
Timeliness (response time)
Availability
Format
Relevance

The DDC study just touched on user values of information delivery system characteristics. The user survey found that users would not pay unless the quality of service was substantially improved and targeted toward their precise needs. The survey also found that increases beyond the current level of response time would be unacceptable. From survey results, the researchers implied the need for improved access to IAC services by bench level personnel. Major problem areas were found in information quantity received, quality, response time, and currency. Minor problems appeared to be in format and media. The following characteristics are distilled from the DDC report:

Cost
Relevance
Quality of service
Response time
Accessibility
Quantity of information received
Quality of information received
Currency of information received
Format
Media

An interesting note on cost: the DDC researchers found that users are unaware of cost of information. They stated that: "In many cases,

the overwhelming majority of user organizations attach no contingencies to the amount of money users spend on information services".[2] This finding tends to discount cost as a valid measure of importance to the user or, at least, calls for careful scrutiny of all cost-related conclusions.

Tom Allen, at MIT, has done extensive work in measuring information needs among engineers and scientists. His work highlights three characteristics of information channels of importance to the user:

Accessibility
Ease of use
Technical quality or reliability

Allen found that accessibility of the information channel almost exclusively determines frequency of use and that perceived technical quality influences the decision to only a minor extent. An engineer will choose the channel which minimizes his loss in terms of the physical or psychological effort which must be expended to gain access to the channel.[6]

Victor Rosenberg's findings support Allen's (although Rosenberg includes ease of use as part of accessibility). Rosenberg notes that: "Relative priority of the most frequently used channels has been established by almost all studies, and in almost every case the analysis has shown that one of the most significant factors in determining the priority is the availability of the source."[7]

From his findings, Rosenberg draws the conclusion, important to the IAC's, that users' preference rankings are more closely related to their evaluations of information source accessibility then to estimation of the amount of information expected. The information gathering behavior of users is governed by the facilities available and changes to reflect a change in the availability of facilities.

The research highlighted in the preceding discussion and subsequent deliberations permitted the synthesis of a list of those characteristics appropriate for analysis of IAC delivery system channels. These synthesized characteristics are:

Cost
Accuracy
Currency
Response time
Ease of access
Ease of use
Technical quality
Coverage of topic
Understandability
Format
Media
Recall
Relevance

The definitions of these characteristics are shown in Table 8. Table 9 presents a survey of the characteristics cited by each background document discussed above and the resulting synthesis.

As a test of the appropriateness of the synthesized characteristics and as a transition step in relating user values to the IAC/user system, the study team related characteristics of importance to users to the various IAC delivery channels. The result is shown in Table 10. Cost, ease of access, and media type were judged important in every case. Conversely, recall and relevance are appropriate measures only in those channels requiring complete search of a master file, query response, abstracting and indexing, and literature search.

Table 8. Definitions of Synthesized Characteristics of Importance to IAC User.

Cost	Dollar cost of using the delivery channel
Accuracy	Whether data is input and output without error
Currency	The up-to-dateness of information delivered
Response time	Elapsed time between a person's request for information and the arrival of the requested information
Ease of Access	Availability of access when and where required
Ease of Use	Ease of operating system/channel
Technical quality	Subjective evaluation by user of expected performance of delivery channel
Coverage of topic	Comprehensiveness of information delivered
Understandability	Ease of comprehending information delivered
Format	Physical arrangement in which information delivered
Media	Way in which the information appears (e.g., hardcopy/CRT display/microfiche)
Recall	Percentage of appropriate information in a file that is retrieved by system
Relevance	Percentage of information retrieved that is appropriate to user needs.

Table 9. Survey of Delivery System/Channel Characteristics of Importance to User

FI/STI Study	DLA Study	DDC Study	Allen	Synthesis
Cost	Cost	Cost	Accessibility	Cost
Convenience	Availability	Accessibility	Ease of Use	Accuracy
Accuracy	Relevances	Relevance	Technical Quality or Reliability	Currency
Timeliness (Currency of Information)	Timeliness (Response Time)	Response Time		Response Time
Security	Format	Format		Ease of Access
Hard Copy Availability		Quality of Service		Ease of Use
Browsability		Quality of Information		Technical Quality
		Quantity of Information		Coverage of Topic
		Currency of Information		Understandability
		Media		Format
				Media
				Recall
				Relevance

Table 10. Delivery Channel Characteristics of Importance to User Related to IAC Delivery Channels

IAC SERVICES/PRODUCTS	CHARACTERISTICS OF IMPORTANCE TO USER												
	Cost	Accuracy	Currency	Response Time	Ease of Access	Ease of Use	Technical Quality	Coverage of Topic	Understandability	Format	Media	Recall	Relevance
Handbook	x	x	x	x	x	x	x	x	x	x	x		
Query Response	x	x	x	x	x	x	x	x	x	x	x	x	x
State-of-the-Art Reports	x	x	x	x	x	x	x	x	x	x	x		
Bibliographies	x	x	x		x		x	x	x	x	x		
Abstracting and Indexing	x	x	x	x	x	x	x		x	x	x	x	x
Reproduction	x	x		x	x	x					x		
Seminars	x	x	x		x		x	x	x		x		
Loan Service	x		x	x	x	x					x		
Referrals	x	x	x	x	x	x					x		
On-site Use of Collection	x	x	x	x	x	x	x	x			x		
Consulting	x	x	x	x	x	x	x	x	x	x	x		
Literature Search	x	x	x	x	x	x	x	x		x	x	x	x

Summary and Conclusions

This investigation of user values suggests three conclusions:

1. There is a need for detailed studies of IAC users, their characteristics, and their perceptions of the channels by which IAC's deliver information. The DLA and DDC studies indicate that such information can be obtained through surveys of users, particularly groups of IAC's which deal with specific disciplines or manageable multidisciplinary areas.
2. Users of DLA-administered DoD IAC's primarily are scientists, engineers, and technicians employed either by DoD activities or by DoD contractors working within the IAC's areas of technology. They manage technical work, perform technical tasks, and are responsible for a variety of miscellaneous duties. Generally, the users need facts, data, findings, or constants rather than other types of information. Users have problems locating, obtaining, and using scientific and technical information. They obtain the greatest amounts of scientific and technical information from their local technical libraries, from their own collections and from colleagues. Both usage and awareness of the IAC's are low within the possible user universe. Support personnel use the IAC's much more than bench and management personnel. However, even among support personnel, usage is low. Less than a third of all DoD scientists and engineers are aware of the existence of IAC's.
3. IAC users consider the following channel characteristics important: cost, accuracy, currency, response time, ease of access, ease of use, technical quality, coverage of topic, understandability, format, media, recall, and relevance. Current information is inadequate to determine the relationships among these characteristics or to determine the relative values users assign to these characteristics.

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Chapter 6

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IMPACTS OF TECHNOLOGIES ON IAC'S AND IAC USERS

Introduction and Highlights

The purpose of this chapter is to examine potential impacts of technology and technological innovation on IAC's and IAC users. The chapter, based on effort that is described in detail in four project working papers[1,2,3,4], provides a background for Chapter 9, which examines the impacts of two particular innovations on IAC costs and benefits. The time period examined extends to 2000 in three periods: 1975-1980, 1981-1985, and 1986-2000.

The next section summarizes impacts on the IAC itself, evaluating the effects of selected technological trends and events on IAC inputs, IAC outputs, and internal activities. The third section examines the impacts of technological trends and events on IAC product and service characteristics. The chapter concludes with a brief summary and conclusions.

Chapter highlights include:

- The time period 1980-1985 is judged to be the time of greatest technological impact on IAC's and their operations.
- The development of a portable, acceptable microfiche reader could have a substantial impact on the handbook service.
- Electronic communications technology is a general area that is judged to have substantial impacts on IAC operations, especially on the inquiry response service.
- Technological trends and events appear to have significantly less impact on the distinguishing functions of an IAC (evaluation and research) and on IAC management than on other information center functions.

Impacts on IAC Functions

Figure 1 (Chapter 2) illustrates the functions and activities of IAC's, and this diagram may be a useful reference for the discussions which follow. Technological trends and events which can affect IAC functions are examined in three segments: events and trends which can affect IAC inputs, events and trends which can affect internal activities of the IAC, and events and trends which can affect the outputs of the IAC's.

Table 11 shows those trends and those events in each time period that significantly impact the input activities of the IAC. Overall, the technological trends and events examined primarily affect the entry of documents and information into the IAC system. However, among the high impact trends and events, impacts tend to cluster by input type within time frames. The strongest cluster of impacting events falls in the 1980-85 time period. The greatest single impact will be caused by the advent of automatic OCR multifont readers in common use. Information no longer being created predominantly in document form (i.e., hard copy, microfiche, etc.) will have the second greatest effect. Note also that documents are the type of inputs likely to be affected most by this set of technological trends and events.

Table 12 presents the technological trends and events which have the greatest potential impact on the internal activities of the IAC. These trends and events primarily affect the activities of indexing, storage, and communications with other data bases. Here, as in the case of input activities, the time period of greatest impact activity will be 1980-85. The event of greatest single impact, the use of the laser for facsimile transmission at a speed of 5 million pages per second in conjunction with image input and storage, falls in this time frame along with second ranked image storage. The advent of a computer-linked network of IAC's and the use of natural English language file inquiry-updating are also seen as being significant during this time frame. The time period 1975-80 contains one very significant event, the advent of cheap, automatic indexing of natural language text. 1985-90 contains two, the use of one integrated master thesaurus for all S&T data bases and the adoption of associative or content-addressing based upon the availability of cheap, large memories. Among the trends, the decrease in cost of a typical on-line search in a large domestic S&T data base (using an interactive terminal and standard telephone lines) is judged to have the greatest potential for impact on internal activities of the IAC's.

As evidenced by the column sums, certain of the internal IAC activities appear to be affected significantly more than others by the set of technological trends and events. In particular, the evaluation function, research to fill gaps, the accessing decision, and the final screening (before repackaging and dissemination) were functions judged to be less affected by the technology than other functions. Note that these are

Table 11. Technological Trends and Events Affecting IAC Inputs

	Document	Data	Information	Query	Σ
TRENDS					
Percent of S&T Information Generators/Users with Access to a Remote Interactive Terminal Increases	1	1	2	4	8
Cumulative Number of Facsimile Transceivers Installed Increases	4	1	4	1	10
Cost of Cross Country (Daytime) Long Distance Telephone Line Decreases	2	2	1	2	7
1975-80 EVENTS					
Cheap, automatic indexing of natural language text	4	1	4	1	10
International technical data system accessed by company library via electronic I/O	2	2	2	4	10
Ratio of non-print:print published materials is 2:1	4	2	2	1	9
1980-1985 EVENTS					
Natural English language file inquiry-updating	4	1	4	4	13
50% of all data entered captured in MR form at point of origin	4	4	4	1	13
Automatic OCR multifont readers in common use	8	4	8	1	21
Laser used for facsimile transmiss: million pages per second (In conjunc[illegible] with image input and storage)	4	4	4	1	13
Information no longer created predominantly in document form	8	4	4	1	17
1985-1990 EVENTS					
Video phone conferencing	1	1	1	4	7
Extensive 2-way CATV	1	1	1	4	7
Instant network conferencing available to 90% of S&T personnel	1	1	1	4	7
Video personal communication with facsimile transceiving	4	1	4	1	10
Cable TV or similar permits home/office storage of text images at competitive costs to hard copy versions	1	1	1	4	7
Σ	53	31	47	38	

Table 12. Technological Trends and Events Affecting Internal IAC Activities

	Scanning/screening	Evaluation	Research to fill gaps	Indexing	Storage	Communication with other data bases	Accessing decision	Retrieval	Screening	Repackaging	Σ
TRENDS											
Cumulative Number of Facsimile Transceivers Installed Increases	1	1	1	1	2	1	2	2		4	16
Cost of Typical On-Line Search in a Large Domestic S&T Data Base Using an Interactive Terminal and Standard Telephone Lines Decreases	4	2	4	1	2	4	1	1	1	1	21
Bandwidth Commonly Employed for S&T Access to Remote Time-Shared Computer Systems Increases	1	1	1	1	2	4	2	2	1	2	17
Average Access Time for Magnetic Tape Decreases	2	1	1	2	2	1	2	2	1	1	15
1975-80 EVENTS											
Source "locator"	4	2	4	4	2	4	2	1	1	1	25
Cheap, automatic indexing of natural language text	2	1	1	8	4	2	2	4	4	4	32
Ratio of non-print:print published materials is 2:1	4	1	1	4	4	1	2	2	1	4	24
1980-85 EVENTS											
Image input and storage	4	1	2	4	8	4	4	4	1	4	36
Communications so cheap that large memories can be shared between geographically dispersed computers	1	1	1	4	4	4	4	4	1	1	25
Natural English language file inquiry-updating	2	1	1	8	4	2	2	4	4	4	32
Computer-linked network of LAC's	1	4	4	2	4	8	4	2	4	1	34
50% of all S&T personnel have personal automated data base	4	4	4	1	1	1	1	1	1	4	22
Laser used for facsimile transmission-5 million pages per second (In conjunction with image input and storage)	8	8	1	1	8	4	1	4	4	8	47
1985-90 EVENTS											
Associative or content-addressed memories (cheap and large)	1	1	1	8	8	1	1	8	1	1	31
Remote graphic terminals with I/O capability-cost $100	2	1	1	4	4	1	1	4	1	4	23
One integrated master thesaurus for all S&T data bases	2	1	4	8	2	8	2	2	1	4	34
Cable TV or similar permits home/office storage of text images at competitive costs to hard copy versions	4	4	4	1	1	1	1	1	1	4	22
Σ	47	36	36	62	62	51	34	48	29	52	

the management function (accessing decision), functions unique to an IAC (evaluation and research), and the final judgment of data relevancy. In short, these functions judged least likely to be affected by technological change, are judged to require human judgment that cannot easily be replaced by technology.

The technological trends and events with the greatest effects on the output activities of the IAC's are shown in Table 13. Again 1980-1985 appears to be the period of greatest activity with two of the technological events with the strongest potential for impact falling in this timespan. The greatest potential for impact is attached to the attainment of a level of 50% of all scientific and technical personnel having their own personal automated data base. The effects of this event will be felt through the competition that these personal automated data bases will offer IAC services, particularly handbooks. The use of the laser for facsimile transmission at 5 million pages per second in conjunction with image input and storage, the event which was judged so significant to IAC internal activities, is also seen as being of great potential impact to output activities. In the time frame 1985-1990 only one event was assessed as being very significant to output activities. However, that event, cable TV or similar permitting home/office storage of text images at competitive costs to hard copy versions, was judged to have very significant potential for impact on output functions. The trends and events affecting output functions appear to affect handbook production more than the inquiry response service.

Table 14 summarizes the trends and events of greatest potential impact, classified by time period and by functional area (IAC inputs, outputs, and internal activities). Technology appears to impact IAC internal activities more than either input or output functions, and 1980-1985 appears to be the period of greatest technological impact.

Impacts on IAC Product and Service Characteristics

Two information delivery channels, handbooks and inquiry response, were assumed in order to estimate the impacts of trends and events on the service characteristics judged to be important to the IAC user. (These service characteristics are discussed in Chapter 6.) Tables 15 and 16 present the results of an assessment of the impacts on the handbook

Table 13. Technological Trends and Events Affecting IAC Outputs

	Handbooks/Data Books	Query Response	Σ
TRENDS			
Percent of S&T Information Generators/Users with Access to a Remote Interactive Terminal Increases	1	4	5
Cumulative Number of Facsimile Transceivers Installed Increases	2	4	6
Bandwidth Commonly Employed for S&T Access to Remote Time-Shared Computer Systems Increases	1	4	5
High Speed Printer Print Speed Increases	4	2	6
1975-80 EVENTS			
Portable/acceptable microfiche reader	4	2	6
Ratio of non-print:print published materials is 2:1	4	4	8
1980-85 EVENTS			
Image Storage	4	4	8
50% of all S&T personnel have personal automated data base	8	4	12
Laser used for facsimile transmission-5 million pages per second (In conjunction with image input and storage)	8	2	10
1985-90 EVENTS			
Cable TV or similar permits home/office storage of text images at competitive costs to hard copy versions	8	4	12
Σ	44	34	

Table 14. Summary: Technological Trends and Events of Greatest Potential Impact on IAC Inputs, Internal Activities, and Outputs

	FUNCTIONAL AREA		
TIME PERIOD	INPUT ACTIVITIES	INTERNAL ACTIVITIES	OUTPUT ACTIVITIES
TREND	-	Cost of a typical on-line search in a large domestic S&T data base using an interactive terminal and standard telephone lines decreases	-
1975-1980	-	Cheap automatic indexing of natural language text	-
1980-1985	Automatic OCR multifont readers in common use Information no longer created predominantly in document form	Laser used for facsimile transmission-5 million pages per second (In conjunction with image input and storage) Image input and storage Computer-linked network of IAC's Natural English language file inquiry-updating	50% of all S&T personnel have personal automated data base Laser used for facsimile transmission-5 million pages per second (In conjunction with image input and storage
1985-1990	-	One integrated master thesaurus for all S&T data bases Associative or content-addressed memories (cheap and large)	Cable TV or similar permits home/office storage of text images at competitive costs to hard copy versions

Table 15. Relative Impacts of Technological Trends and Events on Handbook Service Characteristics

	Characteristics of Importance to User											
	Cost	Accuracy	Currency	Response Time	Ease of Access	Ease of Use	Technical Quality	Coverage of Topic	Understandability	Format	Media	Σ
Trends of Greatest Potential Impact												
Cumulative number of facsimile transceivers installed increases	1	1	1	1	1	1	1	1	1	1	1	11
Cost of typical on-line search in large S&T data base using interactive terminal and standard telephone line decreases	1	1	1	1	1	1	2	2	1	1	1	13
Percent of users with access to remote interactive terminal increases	1	1	1	1	1	1	1	1	1	1	1	11
Bandwidth commonly employed for S&T access to remote time-shared computer systems increases	1	1	1	1	1	1	1	1	1	1	1	11
Most Significant Events Through 1990												
Laser facsimile transmission (up to 5 million pages/second)	1	1	1	1	1	1	1	1	1	1	1	11
Image input to storage and image storage	1	2	1	1	1	1	1	1	1	2	1	13
Natural English language file inquiry and updating available	1	1	1	1	1	1	1	1	1	1	1	11
Cheap, automatic machine indexing of natural language text	2	1	1	1	1	1	2	1	1	4	1	16
A computer-linked network of LAC's will be available to S&T users	1	1	1	1	1	1	2	2	1	1	1	13
At least 50% of all S&T personnel have almost completely automated personal data bases	1	1	1	1	1	1	1	1	1	1	1	11
Ratio of non-print published S&T materials to printed products is 2:1	1	1	1	1	1	1	1	1	1	2	4	15
Cable TV or other electronic methods permit home/office storage of textual images cost-competitive with hard copy versions	2	1	2	1	1	1	1	1	1	2	4	17
One integrated master thesaurus exists for all S&T data bases	1	1	1	1	1	1	2	2	1	1	1	13
Associative or content-addressed memories possible due to use of large, inexpensive memory units	1	1	1	1	1	1	1	1	1	1	1	11
Remote graphic terminals with input and output capability available for $100	1	1	1	1	1	1	1	1	1	1	1	11
Information no longer created predominantly in document form	1	1	1	1	1	1	1	1	1	1	1	11
Source locator (directory of LAC's plus thesaurus)	1	1	1	2	4	1	1	1	1	1	1	15
Automatic OCR multi-font readers in common use	2	1	1	1	1	1	1	1	1	2	1	13
Σ	21	19	19	19	21	18	22	21	18	25	24	

Table 16. Relative Impacts of Technological Trends and Events on Inquiry Response Service Characteristics

	Characteristics of Importance to User													
	Cost	Accuracy	Currency	Response Time	Ease of Access	Ease of Use	Technical Quality	Coverage of Topic	Understandability	Format	Media	Recall	Relevance	N
Trends of Greatest Potential Impact														
Cumulative number of facsimile transceivers installed increases	1	2	1	4	2	2	1	1	1	1	4	1	1	22
Cost of typical on-line search in large S&T data base using interactive terminal and standard telephone line decreases	4	1	2	2	1	1	2	2	1	1	1	1	1	20
Percent of users with access to remote interactive terminal increases	1	1	1	4	4	4	1	1	2	4	4	1	1	29
Bandwidth commonly employed for S&T access to remote time-shared computer systems increases	1	1	1	1	1	1	2	1	1	2	2	1	1	16
Most Significant Events Through 1990														
Laser facsimile transmission (up to 5 million pages/second)	1	1	4	1	1	1	4	4	1	1	1	1	1	22
Image input to storage and image storage	1	2	1	1	1	1	1	1	1	2	1	1	1	15
Natural English-language file inquiry and updating available	1	4	2	1	1	1	2	1	1	1	1	1	1	18
Cheap, automatic machine indexing of natural language text	1	4	2	1	1	1	4	4	1	1	1	4	4	29
A computer-linked network of IAC's will be available to S&T users	1	1	4	2	1	2	4	4	1	1	1	4	1	27
At least 50% of all S&T personnel have almost completely automated personal data bases	1	1	1	1	1	1	1	1	1	1	1	1	1	13
Ratio of non-print published S&T materials to printed products is 2:1	1	1	1	1	1	1	1	1	1	2	2	1	1	15
Cable TV or other electronic methods permit home/office storage of textual images cost-competitive with hard copy versions	1	1	1	1	1	1	1	1	1	1	1	1	1	13
One integrated master thesaurus exists for all S&T data bases	1	2	1	1	1	1	4	4	1	1	1	4	4	26
Associative or content-addressed memories possible due to use of large, inexpensive memory units	1	1	1	1	1	1	4	1	1	1	1	4	4	22
Remote graphic terminals with input and output capability available for $100-	2	2	1	4	4	4	1	1	2	8	4	1	1	35
Information no longer created predominantly in document form	1	1	1	1	1	1	1	1	1	1	1	1	1	13
Source locator (directory of IAC's plus thesaurus)	1	1	1	4	4	2	1	1	1	1	1	1	1	20
Automatic OCR multi-font readers in common use	1	4	4	1	1	1	1	1	1	1	1	1	1	19
Σ	22	31	30	32	28	27	36	31	20	31	29	30	27	

and inquiry response services.

Table 17 summarizes the most significant events and trends by service and by time period. Note that none of the trends and few of the events appear to have much potential for affecting the characteristics of the handbook service. Because there may have been inadvertent screening of significant events and trends, the original cross-relevance matrices[1] were utilized again, this time with more user emphasis rather than a technology emphasis. The results of this second assessment are shown in Tables 18 and 19; these results are summarized by service delivery mode (handbook or inquiry response) and time period in Table 20.

The two analyses were then merged to form one combined set of trends and events judged to be significant for each delivery channel. The results of this merged analysis are shown in Tables 21 and 22. Within each table and each time period, events are listed in decreasing order of importance.

As shown in Table 21, none of the technological trends considered was judged to have a significant potential for impacting the handbook. However, technological events were found in each time frame with the potential of such an impact. In 1975-1980, the handbook may be significantly affected by the advent of a portable/acceptable microfiche reader. Such a reader would particularly affect format and media characteristics. The cheap, automatic indexing of natural language text will affect cost, ease of use, and format at a very moderate level.

In the 1980-1985 time frame, the use of mathematical models on computers as direct input for numerical control systems will significantly impact the handbook. Effects will be felt in cost, accuracy, technical quality, format and media, making this the event with the broadest impact on characteristics of the handbook.

Both analyses showed that in 1980-1985, cable TV or other electronic methods permitting home/office storage of textual images which is cost-competitive with hard-copy versions will moderately affect the handbook through slight impacts on cost, currency and format, and a moderate affect in media.

Table 22 presents the merged analysis of trends and events with significant impact on query input and response. A large number of trends and events were judged to have a potentially significant impact on this delivery channel.

Table 17. Summary: Technological Trends and Events of Greatest Potential Impact on Handbook and Inquiry Response Service Characteristics

HANDBOOK

1975-1980 EVENTS

Cheap, automatic machine indexing of natural language text

1985-1990 EVENTS

Cable TV or other electronic methods permit home/office storage of textual images cost-competitive with hard copy versions

QUERY RESPONSE

Trend

Percent of users with access to remote interactive terminal increases

Cumulative number of facsimile transceivers installed increases

Cost of typical on-line search in large S&T data base using interactive terminal and standard telephone line decreases

1975-1980 EVENTS

Cheap, automatic machine indexing of natural language text

Source locator (directory of IAC's plus thesaurus)

1980-1985 EVENTS

A computer-linked network of IAC's will be available to S&T users

Laser used for facsimile transmission-5 million pages per second (in conjunction with image input and storage)

Automatic OCR multi-font readers in common use

Natural English-language file inquiry and updating available

1985-1990 EVENTS

Remote graphic terminals with input and output capability available for $100

One integrated master thesaurus exists for all S&T data bases

Associative or content-addressed memories possible due to use of large, inexpensive memory units

Table 18. Trends and Events Affecting Handbook Related to Characteristics Important to User

	Characteristics of Importance to User											
	Cost	Accuracy	Currency	Response Time	Ease of Access	Ease of Use	Technical Quality	Coverage of Topic	Understandability	Format	Media	Σ
High Impact												
1980-85												
Laser used for facsimile transmission-5 million pages per second (In conjunction with image input and storage)	1	1	1	1	1	1	1	1	1	1	1	11
1985-90												
50% of all S&T personnel have personal automated data base	1	1	1	1	1	1	1	1	1	1	1	11
Cable TV or similar permits home/office storage of text images at competitive costs to hard copy	2	1	2	1	1	1	1	1	1	2	4	17
Moderate Impact												
Trend												
High speed printer print speed increases	1	1	1	1	1	1	1	1	1	1	1	11
1975-80												
Portable/acceptable microfiche reader	2	1	2	1	1	1	1	1	1	4	8	23
Integrated editorial processing system provides process control for computerized type-setting	4	2	1	1	1	1	1	1	1	2	1	16
1980-85												
Image input to storage and image storage	1	2	1	1	1	1	1	1	1	2	1	13
Mathematical models on computers as direct input for numerical control systems	2	4	1	1	1	1	4	1	1	4	4	24
Electronic or microimage composition used by subscription information services	4	1	1	1	1	1	1	1	1	2	1	15
Information no longer created predominantly in document form	1	1	1	1	1	1	1	1	1	1	1	11
Σ	19	15	12	10	10	10	13	10	10	20	23	

Table 19. Trends and Events Affecting Inquiry Response Related to Characteristics Important to User

	Characteristics of Importance to User													
	Cost	Accuracy	Currency	Response Time	Ease of Access	Ease of Use	Technical Quality	Coverage of Topic	Understandability	Format	Media	Recall	Relevance	Σ
Moderate Impact														
Trend														
Percentage of S&T information generators/users with access to a remote interactive terminal increases	1	1	1	4	4	4	1	1	2	4	4	1	1	29
1975–80														
Terminal-terminal conferencing	4	1	4	4	4	2	1	1	1	4	4	1	4	35
Low-cost mini links between IAC's and smart terminal in home/office	2	2	4	4	4	4	1	1	1	4	4	4	4	39
International technical data system accessed by company library via electronic I/O	1	1	1	1	1	1	1	1	1	1	1	1	1	13
1980–85														
Natural English language file inquiry-updating	1	4	1	1	4	4	2	1	1	1	1	1	1	23
50% of all S&T personnel have personal automated data base	1	1	1	1	1	1	1	1	1	1	1	1	1	13
1985–90														
Video phone conferencing	1	2	1	1	1	2	1	1	1	1	1	1	1	15
Extensive 2-way CATV	4	1	4	4	4	2	1	1	1	4	4	1	4	35
Instant network conferencing available to 90% of S&T personnel	2	4	4	1	4	2	4	2	1	4	4	2	2	36
Cable TV or similar permits home/office storage of text images at competitive costs to hard copy versions	1	1	1	1	1	1	1	1	1	1	1	1	1	13
Σ	18	18	22	22	28	23	14	11	11	25	25	14	20	

Table 20. Summary: Trends and Events Which Significantly Affect Characteristics Important to User

HANDBOOK

1975-1980 EVENTS

Portable/acceptable microfiche reader

1980-1985 EVENTS

Mathematical models on computers as direct input for numerical control systems

1985-1990 EVENTS

Cable TV or other electronic methods permit home/office storage of textual images cost-competitive with hard-copy versions

QUERY. INPUT

Trend

Percent of S&T information generators/users with access to a remote interactive terminal increases

1975-1980 EVENTS

Low-cost mini links between IAC's and smart terminal in home

Terminal-terminal conferencing

1980-1985 EVENTS

Natural English language file inquiry-updating

1985-1990 EVENTS

Instant network conferencing available to 90% of S&T personnel

Extensive 2-way CATV

QUERY RESPONSE

Trend

Percent of S&T information generators/users with access to a remote interactive terminal increases

1975-1980 EVENTS

Low-cost mini links between IAC's and smart terminal in home

Terminal-terminal conferencing

1985-1990 EVENTS

Instant network conferencing available to 90% of S&T personnel

Remote graphic terminals with I/O capability cost $100

Video personal communication with facsimile transceiving

Table 21. Merged Analyses Summary: Trends and Events Affecting Users of Handbooks

Trends: None

1975-1980 Events

Portable/acceptable microfiche reader

Cheap, automatic indexing of natural language text

1980-1985 Events

Mathematical models on computers as direct input for numerical control systems

1985-1990 Events

Cable TV or other electronic methods permit home/office storage of textual images cost-competitive with hard copy versions

Table 22. Merged Analyses Summary: Trends and Events Affecting Users of Inquiry Response Service

Trends

Percent of S&T information generators/users with access to remote interactive terminal increases

Cumulative number of facsimile transceivers installed increases

Cost of a typical on-line search in a large domestic S&T data base using an interactive terminal and standard telephone lines decreases

1975-1980 Events

Low-cost mini links between IAC's and smart terminals in home/office

Terminal/terminal conferencing

Cheap, automatic indexing of natural language text

Source locator

1980-1985 Events

Computer-linked network of IAC's

Natural English language file inquiry-updating

Laser used for facsimile trasmission-5 million pages per second (in conjunction with image input and storage)

Automatic OCR multifont readers in common use

1985-1990 Events

Instant network conferencing available to 90% of S&T personnel

Remote graphic terminals with I/O capability cost $100

Extensive 2-way CATV.

Video personal communication with facsimile transceiving

One integrated master thesaurus for all S&T data bases

Associative or content-addressed memories (cheap and large)

In both analyses, one trend stood out as having a potentially powerful impact on user valued characteristics of the query delivery channel. The increase in the percentage of scientific and technical information generators and users having access to remote interactive terminals will significantly impact response time, ease of access, ease of use, format, and media. It will moderately affect understandability.

Two other trends are of significant potential impact based on data from the analysis of trends and events of greatest potential overall impact. The increase in the number of facsimile transceivers installed will significantly affect response time and media and will moderately impact ease of access and ease of use. A trend of decreasing cost of typical on-line search in a large domestic scientific and technical data base (using an interactive terminal and standard telephone lines) will have a significant impact on cost and moderate impacts on currency, response time, technical quality and coverage to topic.

In the time frame 1975-1980, low-cost mini computer links between IAC's and smart terminals in the home or office will have a very significant impact, affecting currency, response time, ease of access, ease of use, format, media, recall and relevance significantly, and cost and accuracy moderately. Terminal-to-terminal conferencing will also have a significant impact through its strong effects on cost, currency, response time, ease of access, format, media and relevance, and its moderate effects on ease of use. Cheap, automatic indexing of natural language text will significantly impact accuracy, technical quality, coverage of topic, recall and relevance, and moderately impact currency. The "source locator" will significantly affect response time and ease of access, and moderately affect ease of use.

From 1980-1985, four technological events were judged significant. The availability of a computer-linked network of IAC's will significantly affect currency, technical quality, coverage of the topic, and recall. It will moderately affect response time and ease of use. The advent of availability of natural English language file inquiry-updating was seen as being moderately significant during its analysis as one of the overall potentially significant events. Its significance was upgraded in the second analysis because of its direct effects on query input. It was seen

to affect accuracy, ease of access and ease of use significantly, and to impact technical quality moderately. The use of the laser for facsimile transmission at a speed of 5 million pages per second (in conjunction with image input and storage) would significantly affect currency, technical quality and coverage of the topic. The common use of OCR multifont readers would have a moderate significance through its strong affects on accuracy and currency.

The time frame 1985-1990 presents the greatest number of significant events. The availability of instant network conferencing to 90% of scientific and technical personnel will have widespread significant impacts on query input, strongly affecting accuracy, currency, ease of access, technical quality, format and media. It will moderately affect cost, ease of use, coverage of topic, recall and relevance. The availability of remote graphics terminals with input/output capability at a cost of $100 will have a major impact on query response. These low cost terminals will have a major impact on format, significant impacts on response time, ease of access, ease of use and media, and moderate impacts on cost, accuracy and understandability. Extensive 2-way CATV will affect query input, significantly impacting cost, currency, response time, ease of access, format, media, and relevance, and moderately impacting ease of use. Video personal communication with facsimile transceiving will significantly affect the cost, ease of access, and media of query response, while moderately affecting its accuracy, currency, response time, ease of use, understandability, and format. The existence of one integrated master thesaurus for all scientific and technical data bases will significantly impact technical quality, coverage of topic, recall and relevance of the query, and will moderately affect its accuracy. Finally, the possibility of associative or content-addressed memories due to the use of large, inexpensive memory units will affect the technical quality, recall and relevance of queries significantly.

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for

Chapter 7

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SENSITIVITY OF COSTS AND BENEFITS TO TWO TECHNOLOGICAL INNOVATIONS

Introduction and Highlights

The analytical models developed in this study have a major application as tools for assessing the impacts which changes in communications technology will have upon the anticipated costs and benefits of IAC products and services. This chapter describes the utilization of the models for this purpose and provides a test of their applicability as tools for IAC management.

Highlights include:

- Model parameters with sufficient detail to permit projections of IAC service costs to 1985.
- Three alternative scenarios for 1985: a "baseline", or surprise-free scenario, a scenario including a portable acceptable microfiche (PAM) reader, and a scenario including terminal-to-terminal conferencing.
- Model benefits (lower bound) are relatively insensitive to the changes presumed by the 1985 scenarios. However, costs are better incorporated into the model and consequently the 1985 scenarios exhibit higher costs, particularly higher salaries for the evaluation/research functions.

Rationale for Selection of Innovations

In this chapter we postulate three alternative possible futures in the form of "scenarios" of the IAC and its environment in the year 1985 and, based on available data, compare these with the IAC as it was in 1975. This comparison permits examination of the related changes which will most probably occur in the various model parameters thereby affecting anticipated costs and benefits.

The first of the scenarios is the "surprise-free" baseline against which we can assess the impact of two technological innovations which appear likely to have significant effects upon IAC's and their users. The innovative events examined are the introduction and widespread adoption of a portable, acceptable microfiche reader, (PAM - often

referred to as a "cuddly microfiche reader") and the development within the S&T community of a substantial network permitting terminal-to-terminal conferencing. Detailed discussions of the precise form which we are stipulating for these developments and the explicit assumptions which are made to generate the requisite level of detail for application of the models are included in subsequent sections of this chapter. This section explains the reasons for the selection of these particular innovations for consideration.

Chapters 6 and 7 describe analyses which compared selected technological trends and events explored in earlier studies,[3,7] in terms of their relative impacts upon IAC functions and upon the characteristics of IAC products and services which are valued by IAC users insofar as these have been identified. Also, in the early stages of this project, the members of the Overview Committee were presented with a list of some potential innovations and asked for their opinion of those in three given time frames which would have significant impacts on IAC's and their users. The Overview Committee's responses and the relevance analysis were used to produce a "short list" of potentially significant innovations. Use of data from one of the early studies, specifically a series of probability estimates for the occurrence of such innovations by a specified year which was provided by experts in relevant fields, enabled the selection of events which have been estimated to have a 90% likelihood of happening by 1985.

The ultimate selection of the two innovations to be applied was based on the judgment of the study team. The chosen innovations are considered representative of a much wider class of potential changes which will probably affect the specific IAC services of inquiry response and handbooks.

Definition of "Baseline" (Surprise-Free) Scenario

This scenario is based upon the assumption that no radical changes occur which are likely to affect IAC operations between the present (1975 in this case) and the "snapshot" date of 1985. Thus, extrapolation of present trends will define the parameters of concern, extrapolation being defined in this context as basically judgmental and rationally defensible rather than purely mathematical. Due to the inherent variation and uncertainty in the 1975 data, it did not seem either valuable or justifiable to apply sophisticated mathematical curve-fitting and extrapolation techniques.

To conceptualize the impacts of the innovations on cost and benefits of IAC services, the project team utilized the conceptual "supply/demand" model described in Chapter 3 as a framework for analysis. Figure 4 in Chapter 3 illustrates the supply and demand model graphically. It would seem that in the absence of "surprise", i.e., if only current growth patterns need be considered, these curves will remain an adequate description of the relation of the IAC to its potential user environment. Qualitative variation may occur in both supply of and demand for information services. The cost can also be expected to change, but the positional and topological curve shifts will not affect the basic contention that the potential market for IAC services or for a particular channel for delivery of an IAC service will be defined as that area bounded by the supply and demand curves below their intersection; by the cross-over line where self-supply is cheaper than IAC supply; and by the boundary where the service becomes more costly than its perceived value as measured by user's willingness-to-pay.

Granting, therefore, that this same diagramatic representation remains valid, we do not attempt to apply dimensions to relate the 1985 and 1975 versions. Rather, in considering the changes due to innovations, we relate the shifts in the curves due to one or another of the innovations to the 1985 "surprise-free" configuration without attempting to define that configuration precisely.

The quantitative cost-benefit models, on the other hand, are applied under this assumption of "no radical change" by projecting current data in accordance with established historic trends, by analogy with other parameters whose anticipated behavior can be predicted with an acceptable degree of probability, by subjective "informed judgment" based on explicitly formulated assumptions, and where no other data are available, by stipulating a value and observing the results of applying the model in each specific case.

Table 23 summarizes the predicted parameter changes that affect the models:

- Benefit model, inquiry response
- Benefit model, handbook
- Cost model, inquiry response
- Cost model, handbook

Table 23. Baseline Scenario for 1985: Variation of Model Parameters Over a Decade

Parameter	1985:1975 Value	Data Source Reference
Benefit Model: Inquiry Response		
Time saved per use	1	
Number of uses per year (by one client)	1	
Value/hour of user time	12.5:8.9 = 1.40	
Price charged by IAC	6% p.a. = 1.79	1
Number of users per year	1	
Benefit Model: Handbook		
Time saved per use	1	
Number of uses per year	1	
Value/hour of user time	12.5:8.9 = 1.40	
Cost of handbook	26.6:18.6 = 1.43	2
Lifetime of handbook	1	
Number of handbooks sold/year	1	
IAC Cost Model: Inquiry Response and Handbook		
Fixed: Rent	6.5:5.4 = 1.20	2
Telephone	5:17 = .29	3
Furniture & equipment	6% p.a. = 1.79	
Office supplies	28.2:21 = 1.34	2
Subscriptions: #	490:462 = 1.06	2
@	250:166 = 1.51	
Total	= 1.60	

Table 23. (Continued) Baseline Scenario for 1985: Variation of Model Parameters Over a Decade.

Parameter		1985:1975 Value	Data Source Reference
IAC Cost Model (Continued)			
Fixed:	Advertising & marketing	1.9:1.35 = 1.41	4
	Copying & reproduction	.48:.37 = 1.30	2
	Postage	24:13 = 1.85	5
	Travel	.086:.076 = 1.13	4
	Computer time	3:11 = .27	6
	Computer terminal	.21:2.7 = .08	7
	Salaries:		
	Manager #	1	
	@	22.5:15.5 = 1.45	4
	Total	= 1.45	
	Clerical #	51.7:51 = 1.01	2
	@	9.5:7 = 1.36	3
	Total	= 1.37	
	Professional #	67.5:51 = 1.32	2
	@	18:12.7 = 1.42	4
	Total	= 1.87	
	Total	= 1.59	
	Fringe benefits	25% '85 salaries: 15% '75 salaries = 2.65	
	Allocation factor	1	
Variable:	Salaries:		
	Professional	1.87	As above
	Clerical	1.37	As above
	Computer time & supplies	3:11 = .27	6
	Professional hours	67.5:51 = 1.32	
	Discount rate	1	
	Time horizon	1	

for this 1985 baseline case. The table lists the defined parameters, the ratio of their projected 1985:1975 values, and the data sources employed in deriving these estimates. All dollar amounts are measured in current, not constant dollars. The following paragraphs discuss predicted variations in the individual parameters. Data sources in both text and table are given as a number referring to an entry in the list of references at the end of this chapter.

In each instance for which a parameter is predicted to change from its 1975 value, the change will be noted in the text in the following form. The first decimal figure represents the multiplicative factor for computing the 1985 value, given the 1975 value. The numbers in parentheses are expressed as a ratio indicating how this factor was derived. For example, where the 1975 salary for a technical engineer is $8,900 and the 1985 predicted value is $12,500, the multiplicative factor is 1.4 (12.5/8.9).

Benefit Model for the Inquiry Response Service. In the case of inquiry response, time saved per use is defined as the time which would be chargeable to locating the desired information rather than the elapsed time between making the request and receiving the response. As such, it appears reasonable to assume that this parameter does not change during the decade of interest.

The number of uses per year is defined as the number of times a specific user avails himself of this service during one year. This number will certainly vary during the year. However, we believe this variation is dominated by the extent and nature of the user's experience with the IAC, his position and length of service in his own organization, and similar factors, rather than by whether the year is 1975 or 1985. For the average user of the average IAC, the number of uses per year may increase due to the fact that he has become more familiar and, thus, comfortable with the use of IAC services. However, this effect does not appear to be predictable. Hence, we have assumed this factor remains constant.

Lacking information as to the precise identity of the user population in terms of those whose time is saved by use of this service, we make the

assumption that the rate of increase of the value per hour of user time is the same as that of the median salary of the male technical engineer[1]. This assumption gives a ratio of 1.40 (12.5:8.9) in current dollars.

The price charged by the IAC is a dependent rather than an independent variable and is a function of outside funding through subsidies. We assume a 6% inflation rate.

As was the case for the number of uses of the service by a single user, one would intuitively expect the number of users per year to increase with the age of the particular IAC. However, based on the data available, we have assumed the number will remain constant for the average IAC. The largest span of historical data available to us is 8 years, for the Machinability Data Center, and this appears to have roughly stabilized over the last 5 years.

Benefit Model for the Handbook. The analysis of the parameters of time saved per use, number of users per year and value per hour of user time follows the same rationale as for the inquiry response service.

We do not have adequate data on historic variation in handbook cost to project this parameter far ahead. Fortunately, the model is relatively insensitive to this variable. We have based the estimated price increase of 1.43 (26.6:18.6) on the average price for scientific and technical books published in the U. S. since 1960.[2]

We have assumed the lifetime of the handbook will remain constant during the period of interest. This parameter is probably governed by the time sensitivity of the contents and, therefore, can be expected to vary according to the maturity of the technological field.

Based on the data available, the number of handbooks sold per annum is projected to stabilize a few years after introduction of the handbook. Therefore, we have assumed a constant value as the typical case.

Cost Model for Inquiry Response. Looking first at fixed costs, rent is clearly both time and location dependent. Therefore, for analysis purposes, we have taken the national average value per square foot for the information industry in general and have assumed no increase in area occupied. These assumptions yield a ratio[2] of 1.20 (6.5:5.4).

Fixed cost for the telephone is a function of the number of hours spent on the telephone, as well as the average cost per hour. We have assumed that the former will be constant and have projected the 1985 average cost per hour to be lower by a factor of .29 (5:17) on the basis of the findings of a previous study.[3] Respondents in that study indicated that by 1985 such communication costs would probably be independent of distance.

We make the assumption that the fixed costs of furniture and equipment include both purchase/rental costs and upkeep. In the baseline scenario, it is implicit that no radical change in the type of equipment needed will occur. The projected increase of 1.79 is based on a 6% inflation rate.

We assume that the fixed cost of office supplies will be dominated by paper costs which have risen dramatically and are projected to double in the twenty years from 1960 to 1980. In the decade of interest to this study, the ratio would be[2] 1.34 (28.2:21).

Fixed costs of subscriptions are governed by two factors here, the number of publications to which the IAC subscribes and the cost of an individual subscription. Both of these will depend on the particular orientation of the IAC itself. We have combined the fields of physical science, mathematics, computer sciences engineering, and engineering, and have assumed that the number of subscriptions will grow at the same rate, 1.06 (490:462), as the national journal output in these fields.[2] The cost per subscription is based on this same combination of disciplines, assumes that the IAC has an institutional subscription rate, and is projected to increase by 1.51 (250:166) in the ten year period.[2]

Fixed costs for advertising and marketing is a judgmental figure based on 2% of the gross annual income of the IAC's. The 2% was based on a review from a variety of sources covering service industries in general.

The parameter of fixed costs for copying and reproduction is a function of two factors: the number of pages copied and the cost per page. The estimated figures here are based on increases in photocopying costs. We assume a constant number of pages, and assess the total cost increase rate, 1.30 (48:37), as that of a page of photocopy.[2]

Since first-class mail can be assumed to be the predominant mode used for all office mail, the projection of the fixed costs of postage, 1.85 (24:13), is based on the projected per ounce costs of this service.[5]

Based on current practice for the IAC's included in our survey, fixed costs for travel are assumed to increase at the rate of air travel per mile, with no significant change in the number of miles traveled. Due to inflation and the oil crisis, the trend in this parameter has changed radically over the past four years. Two separate projections were made, representing the extreme boundaries of a probability sector, and the factor of 1.13 (86:76) is an average of these extremes.[4]

The figure for fixed costs of computer time measures IAC expenditures on computer operations not related to the inquiry response service. This is best represented in terms of an indicator such as connect-time charges which would apply if the computation were performed using time-shared facilities. Since charges are predicted[6] to drop by a factor of .27 (3:11) between 1975 and 1985, we have employed that modifier for this parameter.

Fixed costs for use of computer terminals will vary considerably according to the type of terminal. Present trends indicate an increasing tendency towards using the "intelligent" or "smart" terminal, and the cost estimate given here, .08 (.21:2.7), reflects this trend but assumes no radical breakthrough in equipment capabilities or costs. We also assume that rental costs will follow the same curve as purchase costs.[7]

Fixed costs for salaries are considered in three categories: managerial, clerical and professional. The salary figures for managers are based on the assumption that the manager is male or, at least, is paid at the same rate as a male. The corresponding multiplicative factor over the decade is then 1.45 (22.5:15.5). Similarly, clerical help is assumed to be female, giving a value of 1.36 (9.5:7), and professional salaries are averaged over male and female trends since 1962 giving a factor of 1.42 (18:12.7).

In computing a total salary figure, it is assumed in accordance with Chapter 4, that the IAC staff involved with inquiry response consists of:

1 manager (1/4 time)
2 clerks (each 1/4 time)
1 professional (1/4 time)

We have allowed for the fact that staffing requirements and individual salaries will increase over the decade. We assume that the number of professionals will increase at roughly 1.32 (67.5:51), the rate of increase of relevant journal articles[22] in the fields previously defined; that the number of clerical personnel will increase at the rate of 1 for every 10 professionals; and that the number of managers will remain constant over the decade.

Fringe benefit costs are very difficult to predict because of the lack of a clear definition of what constitutes such benefits, the uncertainty of their "real cost" even after they have been defined, and the need to predict changes in either the nature or extent of benefits over the decade of concern. The 1975 "fringe benefits" figure in practice has been quoted as between 15% and 20% of total salaries. Social trends such as the decreasing work-week, more paid sick leave, and negotiation of generally more "labor-favorable" contracts have led to an increasing ratio. Therefore, we estimate an increase to 25% of total salaries by 1985.

The multiplicative factor in this case is the ratio of 25% of the total salaries of 1 manager and 1.32 professionals, for 1/4 time, and 1.01 clerks half-time; to 15% of the total salaries of 1 manager and 1 professional 1/4 time, and 1 clerk half-time. This gives a value of 2.65 (7302.8:2756.3) using the salary figures previously computed.

Despite the changing rationale for the establishment of an allocation factor for fixed costs, empirical observations have shown that this factor tends to remain fairly constant over long periods of time. Accordingly, in this base-line scenario, we assume no change in the factor through 1985.

Turning to variable costs, salaries on a per hour basis will change at the same rate predicted for the salaries included in fixed costs.

Variable costs for computer time and supplies are assessed in so many different ways that it is difficult to give a generalized figure

for this parameter. We therefore assume that if a professional spends the same proportion of his time in computer operations as he does now, the computer charges in current dollars per professional hour will be likely to decrease at the same rate as connect-time, .27 (i.e., 3:11 by 1985).[6]

The number of professional hours expended per year on providing inquiry response service is likely to go up as the data-base increases, even if, as we are assuming, the number of inquiries processed remains the same. Relating this to the number of relevant articles,[2] we have an increase factor of 1.32 (67.5:51) by 1985.

We assume that the discount rate and the time horizon remain unchanged.

Cost Model for Handbooks. The cost model for handbooks has the same total fixed operating costs as the inquiry response service (one-fourth of total fixed operating expenses). The changes in the individual cost components are presented in the discussion of the cost model for the inquiry response service.

The preparation costs (writing, editing, typesetting, proofing) for a handbook are almost exclusively salary costs. Thus, the change in the costs from 1975 to 1985 should be the same as that for other IAC salaries. Using the overall composite ratio (managerial, professional, clerical) yields a factor of 1.59 for the change in salaries between 1975 and 1985.

Printing costs are assumed to change in approximately the same ratio as copying and reproduction costs, or .48:.37 = 1.30. Thus printing costs of $5 in 1975 become $6.50 in 1985.

The selling price of the handbook, as discussed under the Benefit Model, will rise by a factor of 1.43 over the decade of 1975 to 1985. This is based on the trend in the prices for scientific and technical books published in the U. S. since 1960.

The lifetime of the handbook and the discount rate are predicted to remain the same.

Effects of Innovation 1: Portable, Acceptable Microfiche Reader (PAM)

This discussion presumes the development of a simply constructed, highly acceptable portable fiche-reading unit which could be used by an individual at home or in the office. By utilizing new technology such as "fish-eye" micro-imagery, the poor read quality now widely encountered would be radically improved with consequent increase in user acceptance. On the basis of information from manufacturers now working on the development of such a product, the estimated future price is around $100 per unit.

As described in Chapter 7, the study team performed a relevance analysis on the impact of the PAM on the IAC products and functions, and on product characteristics perceived as important by the user. The conclusions of this analysis were that the PAM would:

- have a minimal effect on query response.
- have a moderate effect on handbooks in general. This impact would be expressed mainly in a change of medium and some accompanying change in format. There would also be some minor impact upon the cost and currency of the information produced.
- slightly affect storage, retrieval and repackaging requirements internal to the IAC itself.

The baseline scenario developed above permits a more detailed and specific analysis. Consider first, however, different ways in which the PAM could affect the IAC and the IAC's potential and actual market.

The wider acceptance of microform which a PAM would achieve would result in reduced storage requirements for a fixed amount of data. Because microform is cheaper to produce, more and more information would be produced in this form once acceptance was certain. If present trends continue, by 1985 the price differential will be about 8.5 (17:2) between a paper and a fiche copy of the same report.[2] A probable result of this would be an increased tendency for individuals and companies to store more data themselves, thereby decreasing their need for outside information services.

We do not believe that these changes would greatly affect the demand for the type of service provided by either inquiry response or handbook. However, introduction of the PAM could lower the cost of alternative (i.e., non-IAC) sources of inquiry response if the use of microform increases the relative speed of consulting such alternative sources, thereby lowering their cost as measured in time expended.

In our analysis, we assume that, if the IAC handbook is produced as microfiche, a policy will be adopted calling for a complete reissue of the handbook every year and frequent updates of appropriate segments during the year. Frequency of update would depend on the subject matter, i.e., on the maturity of the technology as reflected by its probable rate-of-change. We have chosen a quarterly update in this case, which might consist of only a single microfiche representing 96 pages of textual material. The savings to the IAC of producing fiche rather than hard copy would probably be offset by the more frequent updating. One intangible benefit of this policy to the user would be the increased currency of the information.

Table 24 summarizes our analysis of the changes from the 1985 baseline to be anticipated as a result of the PAM innovation. The specific changes are discussed in subsequent paragraphs. Those parameters which are unaffected are not mentioned except where they are of special interest. Any parameter shifting less than 5% is considered unaffected.

The number of uses per year of the inquiry response service by a single client decreases 10% to reflect the probability that the client will store more data of his own or will use someone else who does so as a source. For the same reason, the number of users may also fall, but by the less than significant amount of 5%.

With regard to the handbook benefit model, we calculated a more moderate reduction in cost of handbook than that used in the surprise-free scenario, which was based on a projection of prices charged by NTIS for their reports in fiche and hard copy. This difference in cost reflects the facts that there will certainly be a "switch-over" penalty in changing from paper production to microform equipment, and that "cost" is defined as price charged for a unique product and, as such, is not likely to drop so radically. A price reduction from $35 to $10 is postulated. The lifetime of the handbook has been assumed to drop from the present 5 years to one year based on our time estimate for issue of a new handbook. For purposes of this analysis, we have defined "life-time" as the time period from one issue to the next. The number of handbooks sold per year is assumed to increase by 10% as a consequence of decreased price combined with increased currency.

Table 24. Alternative Scenario No. 1 for 1985: Variations Due to the Portable, Acceptable Microfiche Reader (PAM)

Parameter	BASELINE 1985:1975 Value	INNOVATION 1. (PAM) 1985:1975 Value
Benefit Model: Inquiry Response		
Time saved per use	1	
Number of uses per year (by one client)	1	.9
Value/hour of user time	12.5:8.9 = 1.40	
Price charged by IAC	6% p.a. = 1.79	
Number of users per year	1	.95
Benefit Model: Handbook		
Time saved per use	1	
Number of uses per year	1	
Value/hour of user time	12.5:8.9 = 1.40	
Cost of handbook	26.6:18.6 = 1.43	10:35 = .29
Lifetime of handbook	1	.2
Number of handbooks sold/year	1	1.1
IAC Cost Model: Inquiry Response and Handbook		
Fixed: Rent	6.5:5.4 = 1.20	
Telephone	5:17 = .29	
Furniture & equipment	6% p.a. = 1.79	
Office supplies	28.2:21 = 1.34	
Subscriptions: #	490:462 = 1.06	
@	250:166 = 1.51	
Total	= 1.60	$\frac{1.60}{2}(1 + \frac{2}{17}) = .89$

Table 24. (Continued) Alternative Scenario No. 1 for 1985: Variations Due to the Portable, Acceptable Microfiche Reader (PAM)

Parameter		BASELINE 1985:1975 Value	INNOVATION 1 (PAM) 1985:1975 Value
IAC Cost Model (Continued)			
Fixed:	Advertising & marketing	1.9:1.35 = 1.41	
	Copying & reproduction	.48:.37 = 1.30	1.17
	Postage	24:13 = 1.85	1.10
	Travel	.086:.076 = 1.13	
	Computer time	3:11 = .27	
	Computer terminal	.21:2.7 = .08	
	Salaries:		
	Manager #	1	
	@	22.5:15.5 = 1.45	
	Total	= 1.45	
	Clerical #	51.7:51 = 1.01	
	@	9.5:7 = 1.36	
	Total	= 1.37	
	Professional #	67.5:51 = 1.32	
	@	18:12.7 = 1.42	
	Total	= 1.87	
	Total	= 1.59	
	Fringe benefits	25% '85 salary: 15% '75 salary = 2.65	
	Allocation Factor	1	
Variable:	Salaries:		
	Professional	1.87	
	Clerical	1.37	
	Computer time & supplies	3:11 = .27	
	Professional hours	67.5:51 = 1.32	
	Discount rate	1	
	Time horizon	1	

In considering components of the cost model for inquiry response, specifically, increased investment and maintenance costs for furniture and equipment, we find no significant change from the baseline case. With only one professional researcher assumed for this model, only one r[redacted], at most, two need be considered. In order to be truly ac[redacted], the cost of the PAM reader will be of the order of $100, which when amortized over 5 years can be disregarded. The cost of purchasing microfiche production equipment would presumably be ascribed to the handbook service.

Office supplies will include microfiche as well as paper, but without knowing the proportionate usage by different services there is no rational basis for modifying the baseline estimate. Microfiche is not very likely to be used for inquiry response. If it is used for the handbook, the more frequent updating and publication of new editions will probably offset the inherent cost advantage of fiche over paper.

The estimate for subscriptions will change because of the general shift toward microfiche. We calculate that the number of subscriptions will remain the same as for the baseline but that the cost of those received in fiche will be down to .12 (2:17) of the paper cost. Based on our earlier study[3], fifty percent of S&T professional literature dissemination will be in microform by 1984. Accordingly, we estimate that half the subscriptions will be at the reduced price. The adjusted subscription total ratio of 1985:1975 values with PAM therefore becomes .89.

Copying and reproduction costs undoubtedly will also reflect the shift towards microfiche, but it is difficult to quantify the variation. If handbook production is counted as a "fixed cost" relative to inquiry response, this parameter will be dominated by the greatly reduced cost of microfiche versus paper dissemination, somewhat modified by the increased frequency of update and republication, and the increased sales. If this parameter is considered to be invariant with regard to all specific services, it will still be affected by the assumption that 50% of incoming material will be in microform, so that reproduction of fiche-to-fiche or fiche-to-hard-copy will be involved. The former is much cheaper (2:17 by 1985) than paper-to-paper. The latter is currently about twice as costly per page as photocopying, but likely to become much cheaper as demand in-

creases. Accordingly, we have assumed that reproduction costs will drop by 10% in current dollars in this scenario.

A similar consideration has to be applied to postage. Microfiche weighs much less than paper (about 1:64 by information content). We assume that the microfiche makes up 50% of the total pages disseminated and is sent fourth class, while the other 50% goes by first class mail. Based on projected changes in postage rates, the multiplicative factor is 1.10.

The only other quantity that seems likely to change in this scenario is the number of professional and clerical hours. As a consequence of the more frequent handbook updating, there should be some reflection in terms of increased hours. However, the variable in this model refers to inquiry response, whereas the increase will show up in connection with the handbook. This may result in increased staffing requirements which in turn would affect the fixed salary costs.

The parameters for the cost model for the handbook change in several ways to reflect this scenario. First, since the handbook will be published once a year and updated on a quarterly basis, the costs of handbook preparation will occur every year, rather than in just the first year of the five year cycle. It is likely, however, that a larger share of these costs will be incurred in the first year since the following years will involve an update process, rather than preparation of an entirely new handbook. Therefore, the total handbook preparation costs, which are assumed equal to the one-time preparation costs in the surprise-free scenario, are distributed as follows: 33% in the first year and 16.7% each year after the first.

The printing cost of the handbook will fall significantly since it will be published in fiche rather than on paper. As discussed previously, the price differential between a paper copy and a fiche copy of the same report in 1985 should be approximately 8.5:1. Thus, if the printing cost of the hard copy is $6.50 in 1985, the "printing" cost of the fiche version should be about $.76.

The price of the handbook will fall from $35 to $10 because of the drop in the lifetime of the handbook and because of the lower cost of printing due to conversion to fiche.

Although the lifetime of the handbook is reduced from five years to one year, the time horizon for considering costs and benefits is maintained at five years to provide a comparison between this and the other scenarios. This is consistent with the assumption that the annual publications of the handbook after the first year are more like updates than like entirely new handbooks. The discount rate remains the same.

Sales of the handbook are predicted to increase by 10%. This means that instead of 1000 handbooks sold over a period of five years, 1100 handbooks will be sold every year for five years.

Effects of Innovation 2: Terminal-to-Terminal Conferencing (TTC)

Terminal-to-terminal conferencing allows the user to connect his terminal with the terminal(s) of one or more others so that direct communication can take place. This innovation represents a phase of communications technology midway between the telephone conferencing capability that exists today and the cable television (CATV) and video phone conferencing of the future. Its widespread adoption will affect the IAC in various ways, both supportively and competitively. Supportively, it will primarily affect the inquiry response service by raising the benefits provided by that service. The user, sitting at his terminal, can directly communicate with the analyst at the IAC as the analyst works with the computer. This gives the user much surer control over the form of his request and enables him to receive almost instantly the output from the computer. He can then review the output and discuss changes with the analyst. He will keep his paper copy of the terminal/terminal conference as the official response of the IAC.

Terminal-to-terminal conferencing also allows the analyst at one IAC to call upon the data banks of other IAC's by "ringing up" his counterpart on the terminal. The user then has access to the combined knowledge of several IAC's.

On the other hand, terminal-to-terminal conferencing will make it both easier and cheaper for a potential user to consult non-IAC suppliers once their identity or location is known to him. In terms of the conceptual model, the total demand for inquiry response services from all sources will rise since a new type of information, that of information source location, has now entered the system. A new or expanded invisible

college will emerge based upon TTC which may have the effect of reducing the total demand for handbook-type information. From the IAC's point of view, therefore, the handbook will be unaffected or else will be less in demand. The inquiry response service will be subjected to opposing trends: a decrease due to users employment of TTC to access alternative sources, an increase because of referrals through the invisible college and the creation of a demand for different types of information.

Table 25 summarizes the specific impacts of TTC in terms of the cost and benefit model parameters. Again, we consider changes less than 5% insignificant and we will discuss in the text only those parameters significantly affected or of special interest.

The inquiry response benefits, as already mentioned, will be intangible in many instances since they consist of improved user interaction and participation in the response activity, hence, increased user satisfaction. The number of uses per year by one client may drop as he becomes aware of alternate sources so we have estimated a 10% decrease. However, considering all of the trends discussed above, we have estimated a 10% increase in the number of users.

Where the handbook is concerned, the time saved per use may decrease, not because of decreased effectiveness of the handbook, but because this measure is relative to alternative sources which may now be more effective. We have shown this as a 5% decrease. Because we feel that the handbook may be referred to during TTC transactions within the S&T community, we also show a 5% increase in number of handbooks sold per year as a consequence of increased awareness.

Applying the inquiry response cost model, the expenditures for furniture and equipment may increase as much as 10% due to the need for purchase and maintenance of terminals. This estimate may be high since terminal costs are predicted to decrease radically by 1985. However, we allow the figure to stand since the decrease in price will probably be offset by the introduction of ancillary equipment or more sophisticated terminals. Although the nature and balance of office supplies may change, the total cost is still likely to be dominated by paper costs and will remain as reflected in the baseline scenario.

Table 25. Alternative Scenario No. 2 for 1985: Variations Due to Terminal-to-Terminal Conferencing

Parameter	BASELINE 1985:1975 Value	INNOVATION 2: TTC 1985:1975 Value
Benefit Model: Inquiry Response		
Time saved per use	1	
Number of uses per year (by one client)	1	.90
Value/hour of user time	12.5:8.9 = 1.40	
Price charged by IAC	6% p.a. = 1.79	
Number of users per year	1	1.1
Benefit Model: Handbook		
Time saved per use	1	.95
Number of uses per year	1	
Value/hour of user time	12.5:8.9 = 1.40	
Cost of handbook	26.6:18.6 = 1.43	
Lifetime of handbook	1	
Number of handbooks sold/year	1	1.05
IAC Cost Model: Inquiry Response and Handbook		
Fixed: Rent	6.5:5.4 = 1.20	
Telephone	5:17 = .29	
Furniture & equipment	6% p.a. = 1.79	1.97
Office supplies	28.2:21 = 1.34	
Subscriptions #	490:462 = 1.06	
@	250:166 = 1.51	
Total	= 1.60	
Advertising & marketing	1.9:1.35 = 1.41	
Copying & reproduction	.48:.37 = 1.30	
Postage	24:13 = 1.85	

Table 25. (Continued) Alternative Scenario No. 2 for 1985: Variations Due to Terminal-to-Terminal Conferencing

Parameter		BASELINE 1985:1975 Value	INNOVATION 2: TTC 1985:1975 Value
IAC Cost Model (Continued)			
Fixed:	Travel	.076:.086 = 1.13	
	Computer time	3:11 = .27	
	Computer terminal	.21:2.7 = .08	.12
	Salaries:		
	Manager #	1	
	@	22.5:15.5 = 1.45	
	Total	= 1.45	
	Clerical #	51.7:51 = 1.01	
	@	9.5:7 = 1.36	
	Total	= 1.37	
	Professional #	67.5:51 = 1.32	
	@	18:12.7 = 1.42	
	Total	= 1.87	
	Total	= 1.59	
	Fringe benefits	25% '85 salary 15% '75 salary = 2.65	
	Allocation factor	1	
Variable:	Salaries:		
	Professional	1.87	
	Clerical	1.37	
	Computer time & supplies	3:11 = .27	
	Professional hours	67.5:51 = 1.32	
	Discount rate	1	
	Time horizon	1	

Copying and reproduction and postage may be affected, but probably not significantly. Because telecommunication is more expensive than postage, the bulk of responses will probably still be mailed out except where speed is a factor.

The impact of this innovation upon computer time and computer terminal charges depends very much on how these charges are assessed. According to our interpretation, computer time is concerned mostly with accessing large data bases and would probably not be significantly affected by the introduction of TTC. However, terminal usage would certainly increase in connection with functions involving research to fill gaps and in interaction with the inquirer. The figure of .12 quoted here represents a 50% increase over the baseline scenario. This is the minimum to be expected: it may easily go as high as 100% (.16), however, we elected to use the more conservative estimate.

We have assumed no impact on salaries. Although the increased interaction capability would put a greater load on the professional staff, and, hence, increase the number of personnel, this increase would be counterbalanced by a decreased load on the clerical staff where material was transmitted directly via the terminal.

Finally, the variable factor of computer time and supplies directly chargeable to the inquiry response service has been shown in the table as unchanged on the basis that increased usage and decreased cost will balance each other. The wide community increase in terminal usage should result in a terminal purchase/rental cost decrease even more significant than that postulated for the baseline scenario.

The impacts on the cost model for the handbook are relatively minor. The changes in the allocated share of the IAC fixed operating costs are presented in the discussion of the inquiry response cost model. The handbook preparation costs, handbook printing costs, and selling price are the same as the 1985 Surprise-Free Scenario. Sales are predicted to increase by 5% with respect to the 1985 scenario so that a total of 1050 handbooks will be sold over the five year period rather than 1000. The time horizon and discount rate remain the same.

Application of Cost and Benefit Models to Scenarios

Applying the cost and benefit models to the inquiry response service and handbook service for this scenario (1985 surprise-free or 1985 SF) produces the results shown in Tables 25 and 26. The net present value (NPV) of the "operating" costs for the inquiry response service rises from $246,939 (1975 scenario) to $383,473. This is primarily a result of the significant increases in salaries predicted for the 1985 surprise-free scenario. On the other hand, benefits to users change slightly, dropping from a net present value of $257,603 (1975) to $245,827 (1985 SF). This is a change of slightly less than 5% and is not considered significant. The overall effect is, thus, to change from a positive net benefit (benefits to users minus IAC operating costs) to a negative one because of the significant increase in operating costs without a corresponding increase in benefits to user. The breakeven point (net costs to IAC equal to net benefits to users) for the 1985 surprise-free scenario is 3270 hours per year (number of hours customers are charged for) compared to 1918 hours for the 1975 scenario. This 70% increase, as pointed out above, results primarily from salary increases.

For handbook service, the net present value of the "operating" costs changes from $201,662 (1975) to $301,142 (1985 SF), again primarily due to the significantly higher salaries predicted for 1985. The net present value of the benefits to users rises from $44,359 (1975) to $61,216 (1985 SF). Thus the overall net benefit changes from $-157,303 (1975) to $-239,926 (1985 SF). The breakeven point for handbooks (benefits to users equal operating costs), for the 1985 surprise-free scenario is 3448 copies over the five year life of the handbook (average annual sales of 690) as compared to 3257 (average annual sales of 651) for the 1975 scenario. This is a 6% increase in the breakeven point and is barely significant.

The results of applying the cost and benefit models to the 1985 PAM Scenario are presented in Tables 26 and 27. For the inquiry response service, the net present value of the net costs of IAC operation is $369,159 and the net present value of net benefits to users is $160,119. This gives an excess of costs over benefits of $209,040, which is 52% greater than for the 1985 surprise-free scenario. The breakeven point for this scenario is 4936 hours, 157% higher than the 1975 scenario and 51% higher than the 1985 surprise-free scenario. The higher breakeven

Table 26. Summary of Costs, Benefits and Breakeven Points for Inquiry Response

SCENARIO	NPV COSTS($)	NPV BENEFITS($)	NPV B-C($)	BREAKEVEN POINT(HRS)
1975	246,939	257,604	10,665	1918
1985 Surprise Free	383,473	245,827	-137,646	3270
1985 PAM	369,159	160,119	-209,040	4936
1985 Terminal	384,460	185,401	-199,059	5100

Table 27. Summary of Costs, Benefits, and Breakeven Points for Handbook Service

SCENARIO	NPV COSTS($)	NPV BENEFITS($)	NPV B-C($)	BREAKEVEN POINT(VOLUMES)
1975	201,662	44,359	-157,303	3257
1985 Surprise Free	301,142	61,216	-239,926	3448
1985 PAM	274,869	148,273	-126,596	1829
1985 Terminal	300,033	58,857	-241,176	3648

point results from both higher operating costs and a lower level of benefit to each user.

For the handbook, the NPV of IAC operating costs are $274,869 and the NPV of benefits to users are $148,273, giving an excess of $126,596 of costs over benefits. This is a lower deficit than for either the 1975 or the 1985 surprise-free scenario. The breakeven point, however, is 1829 copies per year. Direct comparison of sales volume between this and the other scenarios is difficult because the method of publishing is different as is the lifetime of the handbook (one year instead of five years). Thus the 1829 sales might (and probably would) be to the same purchasers each year while for the other scenarios, the sales are assumed to be to different purchasers each year.

Application of the cost and benefit models to the 1985 Terminal-to-Terminal Conferencing yields the results presented in Tables 26 and 27. For the inquiry response service, the NPV of the net costs of IAC operation is $384,460 and the NPV of benefits to users is $185,401, yielding an excess of $199,059 of costs over benefits. As with the other scenarios, this deficit is primarily a result of higher salaries and within the limits of the model, no major increase in the level of service or of benefits to users. The breakeven point is 5100 hours charged to users. This is the highest of any of the scenarios and is 166% higher than the 1975 scenario value.

For the handbook, the NPV of net operating costs is $300,033 and the NPV of benefits to users is $58,857, giving an excess of $211,176 of costs over benefits. The breakeven point is 3648 over the five year life of the handbook (average annual sales of 730) which is 12% higher than the 1975 scenario. This demonstrates the sensitivity of costs and benefits to sales volume. Since most of the handbook costs are fixed (associated with handbook preparation), total costs go up very slowly as a function of sales. The marginal cost of printing is the only significant variable cost. Benefits are, however, linear with respect to sales volume. Thus, a doubling of sales increases costs by only a small percentage while benefits are doubled.

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for

Chapter 8

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CONCLUSIONS AND RECOMMENDATIONS

Highlights

The research effort described in this final report has yielded improved knowledge about IAC's and IAC economics. This improved knowledge should benefit policy formulation and decision making on the levels, mix, and pricing of IAC services. Highlights of the research effort and the results include the following points:

- An IAC performs evaluation and research functions which make an IAC and its services and activities distinct and unique among information centers and other information services.
- The research effort developed models for performing cost benefit analyses of IAC's; the models are consistent with observations about IAC's and with economic principles.
- Data to permit calculations of costs and benefits are lacking; particularly lacking are benefit data.
- Potentially incompatible incentives exist between federal funding policies (guidelines for IAC managers) and economic efficiency considerations.
- Technological changes can affect IAC operations, particularly during the 1980-1985 time period. However, the impacts of technology are likely to be less on the unique IAC functions than on other information center functions.
- IAC cost accounting systems should include the identification and allocation of major cost items in a useful, consistent manner. The system should provide for detailed allocation of personnel time.
- Additional research is needed to estimate the benefits of the IAC services which utilize evaluation, analysis, and synthesis.

Uniqueness of IAC Functions

An IAC performs many functions that other information centers perform, and an IAC's activities include many that are common to most information center operations. These functions and activities include the collecting and screening of data and documents, the indexing and storage of information and documents, the accessing of stored information and the communication with other data bases, and the repackaging of information to meet the particular needs of the users.

However, an IAC also performs functions that are unique and that make an IAC distinct from other information centers. The unique function of an IAC is evaluation. Not only does the IAC screen data and documents for relevancy to the subject area, but the IAC evaluates the data and information. This evaluation activity examines the quality of the information and compares the content of the documents with related information in the subject field. When the results of these evaluations indicate a knowledge gap, the IAC may undertake research to fill the gap. The evaluation and synthesis, generally performed by subject specialists, set an IAC apart from other centers which provide information services.

Cost Benefit Models

The research effort produced models of costs and benefits associated with IAC services. These models have several characteristics:

1. The models treat multiple services and illustrate interactions between services;
2. The models are consistent with observations about the demand for IAC services and with fundamental economic principles; and
3. The benefit model permits the calculation of a lower bound on benefits to the IAC users.

However, the benefit model does not permit an estimation of the social benefits, and there is some indication that the lower bound estimation of benefits is too low. Using the models to develop only quantitative estimates of benefits does not reveal sufficiently detailed information on the impacts of technology, which is judged to produce

impacts on the expected value of benefits and the potential for benefits (rather than changing substantially the lower bound on benefits).

Perhaps the most important aspect of the models is that they provide a consistent framework for examining the economics of IAC's. The models incorporate known observations about IAC's and furnish a framework for formulating hypotheses and making future observations about the supply and demand for IAC services.

Data Availability

There are insufficient data on the demand for IAC services to permit meaningful studies using the benefit model. The cost model provides a framework for utilizing normal cost accounting data, and thus the availability of cost data exceeds the availability of benefit data.

Future studies are needed to improve the information available for calculating benefits. It is recommended that additional research effort be undertaken to develop information in two categories.

The first category is that of private (or organizational) benefits. Information should be developed which would permit more meaningful estimates of the benefits of IAC services to the user. In particular, the relative values of the different characteristics of the IAC services (e.g., timeliness, cost, accuracy, precision) need to be examined.

The second category is that of social (or societal) benefits. The indirect and societal benefits of IAC operation, such as the benefits resulting from the codification of knowledge, should be examined. These benefits may greatly exceed the private/organizational benefits of an IAC, but currently there are not data to permit an estimate or a calculation of the magnitude of these benefits.

Potentially Incompatible Incentives

Currently, managers of many federally sponsored IAC's operate under the guideline of recovering about 50% of the face value of the federal support contract by charging user fees. This guideline assures feedback on the utility of IAC services, since it is unlikely that a user will continue to pay a fee for a service which is not useful. However, there is no assurance that this guideline leads to the socially optimum level

or mix of services. Additional studies on the values of the IAC services are needed to determine whether, and to what extent, service charges can be used to establish valid indicators of the socially optimum level for an IAC service.

Technological Changes

The cost benefit models, while inadequate tools to determine quantitatively the impact of technological change, do indicate substantial impacts on IAC operations by technological trends and events. These impacts can affect all phases of IAC activity, but the effects on the unique IAC functions (evaluation and research) are judged to be less than on functions common to many types of information centers. It appears that the evaluative and research functions, because they involve mental judgment and the utilization of mental resources, are less affected by technology than some of the other information service functions. However, there can be considerable changes in how the evaluative and research functions are performed. For example, the widespread implementation of terminal-to-terminal conferencing can affect how research is performed by improving the efficiency of communication among members of an "invisible college".

Cost Accounting Systems

Cost accounting systems which collect and report the costs of providing IAC services are feasible and should be utilized by all IAC's. The implementation of such systems will permit more knowledgeable decisions and policies regarding the level, mix, and pricing of IAC services. The systems should include provision for consistent accounting for major cost items. Personnel time, in particular, should be allocated to major service outputs in a meaningful, consistent manner.

Value of IAC Functions

The "value added" by the unique IAC functions of evaluation and research needs to be examined. This value added, resulting in higher quality data and information, is relatively expensive, since it arises

from the application of resource specialists' efforts. There needs to be a careful examination of how valuable such quality appears to be to the IAC user. As a minimum, there needs to be some estimate of the relative value of "data quality" compared with other service characteristics such as responsiveness, ease of access, cost, etc. This study of the value of the IAC function is the single most important next step in developing cost benefit information for IAC services.

APPENDIX A

IAC BENEFITS AND COSTS: A LITERATURE OVERVIEW AND ANNOTATED LIST OF REFERENCES

CONTENTS

INTRODUCTION

This appendix reviews the literature relevant to a cost-benefit study of information analysis centers (IAC's). It is intended to review the ideas from the literature which were judged most salient and relevant to the research effort.

This literature review is divided into eight general subject areas. Although there is considerable overlap between some of the papers reviewed here, they are categorized by their primary emphasis. The eight areas are: (1) General Reference and Background, (2) Economic Analyses of Information, (3) Financing of IAC's, (4) Cost Accounting for IAC's, (5) Cost Recovery and User Charges, (6) Marketing of IAC Products and Services, (7) User Appraisal of IAC Performances and User Needs Studies and (8) Descriptions of IAC's.

The results of the literature survey indicate considerable interest in the problems of information dissemination such as user needs, cost accounting, and financing of information centers and IAC's. However, much of the literature is qualitative and that which is quantitative is usually case specific.

GENERAL REFERENCE AND BACKGROUND

An excellent reference and background source on information centers is Information Systems, Services, and Centers (Weisman, 1972). The book is concerned with several aspects of information such as the properties of information systems and services, mechanisms of information transfer, design considerations for information systems, technical details of documentation, administration of information centers and services, and the financial support for and concept of the worth of information services.

The last three chapters of the book are devoted to an examination of the information analysis center concept. The background, functions, and definition of IAC's are reviewed with emphasis on the distinguishing characteristic of an IAC, critical evaluation. In addition, several typical IAC's are examined to illustrate the environment of IAC's and the impacts that these IAC's have on science. The last chapter contains an analysis of the characteristics of federally supported IAC's in terms of age, professional fields, host organization, service and products, sponsors, and size of the IAC. Qualitative criteria for establishing and disestablishing IAC's are presented to provide some guidelines for decision and policy makers. The status and prospectus of IAC's are also reviewed.

"Information Analysis Center: The Challenge of Being Needed" (Branscomb, 1972) provides a good overview of some of the basic needs for information analysis centers in the dissemination of scientific and technical information, the traditional undervaluing of information, the factors limiting the prices for products of an IAC, the importance of critically evaluated data in research, and the role of automatic data processing in IAC operation. In addition, a basic methodology for measuring the success of IAC's is presented in terms of questions that should be asked of the users of IAC's, of the IAC itself, and of the R&D policy makers in government and industry. The author suggests five necessary and sufficient requirements for the success of an IAC:

competence, continuity, completeness, conscience, and cash. The concluding remark is a quotation of a recommendation from a report to the Secretary General of the OECD that governments should increase their support of the information interchange mechanism and ...."that policies and strategies for scientific and technical information should be developed as an integral part of design of policy as a whole and R&D policy in particular..."

ECONOMIC ANALYSES OF INFORMATION

The most interesting, and innovative, research to come to light in our literature search and review is a 1971 MATHEMATICA report to the National Science Foundation entitled "A Cost-Benefit Approach to Evaluation of Alternative Information Provision Procedure (sic)" (Baumol, 1971). The research was directed by an eminent economist, Dr. William S. Baumol. The report is actually a compendium of four distinct research projects, each investigating a salient aspect of the economics of information. Interestingly enough, insofar as cost-benefit analysis is a fairly well defined approach to economic viability, and the title of the MATHEMATICA report notwithstanding, none of the four separate research efforts deals with cost-benefit analysis. In particular, with the exception of the one macro-econometric study, there is little in the way of benefit estimation, a sine qua non of cost-benefit analysis.

The first of four separate research studies is the just mentioned macro-econometric approach. Building on some well-recognized work of Griliches, Mansfield, and Menasian in explaining gross national product over time as a function of, inter alia, a variable measuring disembodied technological change; this study introduces a flexible distributed lag formulation of R&D expenditures. The model was estimated using various specific lag formulations. While the approach showed promise, there were sufficient discrepancies between the MATHEMATICA results and those of other studies regarding economics of scale that the results were judged questionable.

The second research study is a microeconomic analysis of efficiency conditions in information dissemination. Insofar as the analysis posits a fixed amount of government subsidy available for all dissemination channels, the research does not aid in finding the benefits of such dissemination. The results of the analysis are expressed as the usual economic "marginal" characterization of optimality. A number of theoretically interesting cases are analyzed and discussed.

The third study follows the lines pioneered by Lancaster in his "A New Approach to Consumer Theory" (Lancaster, 1966) in which commodities are characterized by a vector of characteristics. While the approach is spelled out clearly, the empirical problems of demand estimation remain. The model appears applicable to the design of new information channels, but adds little to the resolution of benefit estimation problems.

The final study deals with the economics of two sector unbalanced growth. It is shown that the nontechnologically progressive service sector will demand ever increasing labor supplies in the coming years. Such results are shown to be applicable to cost forecasting for information services. The model is seen as providing input data for use in the potential application of the second and third studies.

A.D.J. Flowerdew and C.M.E. Whitehead provide a critical survey of economists' forays into the information science field in "Cost-Effectiveness, and Cost-Benefit Analysis in Information Sciences" (Flowerdew, 1974). For our purposes, the most interesting conclusion was as follows: "Despite much interesting work, no really satisfactory cost-benefit study has yet been carried out...no investigations have really faced up to the problem of assessing the value of extra information to a firm or to society...."

Flowerdew and Whitehead provide a fairly complete discussion of the principles, applications, and problems of cost-effectiveness and cost-benefit analyses in information science. As economists, they are critical of improper costing techniques which pervade the information literature. They take care to point out the important classes of problems economists can fruitfully attack, and outline the approaches and data relevant to each problem.

The "Report of the Panel on Economics of the Science Information Council" (Danilov, 1973) is a relatively nontechnical overview of the principles, problems, and approaches of economic analysis (particularly cost-benefit and cost-effectiveness) as applied to the information science field. For our purposes, their main conclusion is: "Though it may in rare instances be possible to get objective measures of bene-

fits, or lower bounds to them, in most cases the ultimate judgment of value will have to come from the multitude of users or purchasers of the services: these will usually have more expert and firsthand knowledge of the benefits delivered than anyone else...." The authors feel the most useful sources of quantitative information on benefit values are "market responses" and "investment of time by individual users."

There are many more general references to the economics of information. These were discussed in the proposal under the classifieations: risk analysis, search behavior, market signals, advertising, research and development, demand analysis, pricing policy, and cost analysis. The discussion will not be repeated here; however, specific references to these topics are included in the bibliography for completeness.

FINANCING OF IAC'S

One of the fundamental questions concerning IAC's is whether they should be completely publicly supported, i.e., subsidized by public funds, or completely privately funded. Two informative papers on this subject which present somewhat different viewpoints were reviewed.

The first paper, "Fundamental Aspects of the Financing of Information Centers" (Schwuchow, 1973), provides a concise statement of the basic question and offers some answers to these problems. Five questions are presented with a short discussion of each. Briefly, these questions are (1) should public or private funds be used to finance information centers, (2) can centers be operated on a profit making basis, (3) should centers be financed from general tax revenue or from user fees, (4) should fees be based on costs, and (5) what practical forms should fees take. In answering these questions the author feels that these centers will by their nature be primarily publicly financed (but that private financial resources should be used wherever possible), that in certain information sectors the market place mechanism is useful and desirable, and that user fees (with some limitations and exceptions) are appropriate. However, he considers the level of fees to be quite controversial and so presents the pro and con arguments for cost recovery through user fees. In addition, he outlines the principles to be used in formulating a fee policy. Some of the possible forms of user charges for the different services provided by an information center are presented.

A paper which offers a different perspective is "IAC's and the Private Sector" (Norton, 1972). Because of the slow response of the private sector to expanding information needs during and after WW II, the federal government became involved in funding of information programs. However, in the author's opinion, the private sector has made much progress in recent years in this area and now has real contributions to make in the field of information. This presentation brings out some of the issues facing the private sector in deciding on the

feasibility of an IAC-type information service, whether with or without government support. These issues are presented in the form of seven questions with discussion of the pertinent aspects of each question. The author concludes that the private sector is qualified to work with IAC's in the development of cost-effective and widely useful information services and that the private sector is probably in a unique position with regard to answering the seven questions presented in the paper. These areas are estimating market size, evaluating the need for customer education, estimating all probable start-up and ongoing expenses, obtaining and applying user feedback, identifying and making risk investments in development and publications of useful byproducts, applying cost reduction techniques, and developing maximum penetration of the market given that protection from unfair competition is provided.

COST ACCOUNTING FOR IAC'S

Since operating costs must be well defined before realistic cost recovery systems can be implemented, the literature was reviewed for papers concerning cost accounting systems for information services. A good overview paper in this area is "The Practice of Charging Users for Information Services: A State-of-the-Art Report" (Penner, 1970). The author performed an extensive review of the literature to identify actual operating cost accounting systems that charge users for services, the attitudes of users toward being charged for information services, and the degree of concern about cost-accounting for information centers. In these areas there was a scarcity of articles on actual operating systems (although their desirability was frequently mentioned), a general resistance to paying for information, and a scarcity of information on cost accounting for information services. Some data on costs of unit operations were collected and are presented, but the author feels that arriving at realistic cost figures is risky because of the "unique" aspects of each system described, and the lack of standardized definitions of terms such as "input costs", "searching", and "abstracting".

The conclusions drawn concerning the lack of information on the practice of charging users for information services were that (1) paying for information was not commonly accepted by society, (2) charges must be based on realistic costs and the methods for arriving at these costs were still primitive and (3) if centers did cost-account and did charge, they didn't write about it. The author perceived that the evasive attitude toward costs was changing, at least in large operating systems.

A paper which goes into some detail to explain an approach to determining the costs of an information center is "Real Costs for Information Managers" (Price, 1973). The operational system described, a building block cost analysis, is based on the premises that (1) the most effective display of information systems costs is in terms of unit

costs and (2) unit costs are only meaningful in a framework which includes all costs of the system.

The basic approach to building block cost analysis is to identify the activities of the information system such as general costs, ad hoc efforts, inputs, outputs, and collateral services. For each of these activities the classes of charges are itemized (e.g., direct labor, fringe, computer usage, other direct costs) to determine the total direct costs. For these costs which cannot be directly associated with production, some realistic method of allocation is used. The result is a detailed breakdown by activities and function of the unit costs for each operation in the information system, which provides the decision maker meaningful information concerning control and reduction of costs and possible service charges for users.

The problems of obtaining cost information in a technical information center are addressed in "Managerial Cost Accounting for a Technical Information Center" (Helmkamp, 1968). This Ph.D. thesis is concerned specifically with a NASA Regional Dissemination Center. This center which provided two basic services, retrospective search and selective dissemination, had the objective to operate as a self-supporting entity. Thus the need for relevant cost information was as vital as in any business firm.

The approach to the problem of providing cost information consisted of two steps. First, a formal managerial cost accounting system was designed expressly for the two information services. This system was then implemented for a trial period to test its effectiveness. The data developed from this system can then be used in the statistical cost control model developed as the second step in providing reliable and relevant cost information. The statistical cost system is founded on the theory of statistical quality control and permits management by exception. A random sample of five searches is selected each month for each service and the direct costs associated with each search are recorded. The mean and range of each sample are then compared with representative values to test the null hypothesis that the direct unit search costs are in control.

The major conclusions of this study are that "objective managerial cost accounting practices such as those developed in the preceding chapters are both possible and essential in the operation of a technical information center."

COST RECOVERY AND USER CHARGES FOR IAC'S

Several interesting papers were reviewed in the area of cost recovery and user service charges. This is an area of considerable interest, especially for IAC managers, because of the concern over discouraging information transfer through the imposition of user service charges.

The first article, "Information Analysis Centers - DoD Policy on Cost Recovery" (Christensen, 1972), reviews the DoD policy regarding service charges for IAC products and the concern which prompted this policy, i.e., that the benefits from some DoD IAC's were not commensurate with the cost of the IAC. The benefits of IAC's have been difficult to measure and because these benefits must be established if viable information activities are to be maintained, service charges were selected as a mechanism of demonstrating these benefits to policy makers for resource decisions. The possibility of adverse effects on DoD R&D programs is recognized and therefore the effects of service charges on IAC's are being closely monitored. In addition, the author points out that service charges are a means of which more DoD IAC's can be opened for use by the general public.

Another presentation in this area, "DoD Policy on Cost Recovery as Viewed from an Information Analysis Center" (Veazie, 1972), is an overview of the problem faced by DoD IAC's in implementing the DoD policy on cost recovery. Some of the objections to this policy are the effect on relationships between the IAC and its users (especially those beneficial to the IAC), the reduced utilization of an IAC after institution of service charges, and the induced time lag between compilation of data and its availability to users (presumably due to more paperwork and procedures). The efforts made by EPIC (Electronic Properties Information Center) to recover costs through user charges are presented.

The main purpose of the article, however, is to present a plan by which IAC's can make DoD's cost recovery policy work and still maintain the IAC as a national resource. The basic premise of the plan is that

a marketing group be included as an integral part of the DoD-IAC network. This marketing organization would have responsibility for "market research." The author feels that the implementation of such a plan can "...retain the IAC network and publish products that sell because they are beneficial to the customer."

A pragmatic approach to the problem of determining what users should be charged for information services is taken in "Costing Information Services" (Lutz, 1971). In his opinion, basing user charges on estimates of user benefits is not profitable and therefore, user charges should be based on costs of services provided, since charges based on costs would be easier to develop, understand, and evaluate. Starting with this assumption, the author then examines four different types of user charge systems, discussing the advantages and disadvantages of each. For any user charge system selected, the decision of what costs are to be recovered must also be made. Four levels of cost recovery, from the full cost pricing to minimum value pricing, are outlined with an example of each, using cost figures for an operational information center. Finally, the author presents eight steps for implementing the cost analysis and user charge system.

MARKETING OF IAC PRODUCTS AND SERVICES

Because of the requirement for some federally supported IAC's to recover a significant portion of their operating costs, the marketing aspects of the products and services of IAC's have received increased attention. In the paper, "Marketing the Products and Services of Information Analysis Centers" (Roch, 1972), the problems of production, publication, technology and marketing are explored. William Roch identifies the marketing challenge for IAC's as being..."to identify and reach the group of potential users even where this group is of a narrow scientific or technical discipline." Other problems are created by the acceptability criteria of economy, timeliness and quality. His conclusion concerning the market value of evaluated data compilations is that the information is valued by users at only slightly above the distribution cost level. He also identifies examples of user oriented data products, their characteristics, and traditional publishers of these data products.

Another paper in the same area, "The Marketing of Information Analysis Center Products and Services" (Veazie, 1971), examines the need for national guidelines on IAC service charges and the factors that determine what products and services are saleable and what could be charged for them. He outlines four different objectives of IAC's; the advantages of using an IAC; the variables that affect IAC operation; the objectives, advantages, and disadvantages of service charges; variables affecting guidelines for marketing; factors influencing demand for IAC products and services; distribution channels for these products and services, and the problems involved in the measurement of benefits. Two case studies of IAC's which have implemented service charges are presented. In addition, a survey of federally sponsored IAC's concerning attitudes of their managers to marketing products and services was performed. The results indicate that most managers feel that service charges would interfere with or reduce the effectiveness of their service.

A third paper in the area of marketing is "PLASTEC Reports Selling Through National Technical Information Service " (Pebly, 1972). This paper reviews the sale of reports of an IAC through NTIS over a two year period. The sale of publications by the Plastic Technical Evaluation Center (PLASTEC) was first considered when it was recognized that DoD was moving in the direction of cost recovery. The development of the arrangement with NTIS and the results of sales on several reports are reviewed. Although sales of PLASTEC reports have been generally good, the total distribution of PLASTEC reports was appreciably less than before free distribution was stopped. This article provides some good insight into the type of problems encountered in marketing the products of IAC's.

USER APPRAISAL OF IAC PERFORMANCE AND USER NEEDS STUDIES

The report, "User Appraisal and Cost Analysis of the Aerospace Materials Information Center" (Scheffler, 1970), is an evaluative study of the performance of the AMIC document retrieval system in terms of its ability to meet the information needs of the users and the variations in operating costs over a period of time. The degree of user satisfaction was estimated using an evaluation questionnaire mailed to over 340 past users of AMIC (twenty-nine telephone contacts were made initially to check out the questionnaire). This special questionnaire, different from the search evaluation form routinely sent with each reply to an inquiry, was designed to identify user characteristics (organization, type of work, subject area of work), satisfaction with information obtained from AMIC (speed, pertinence), other sources of information used, and suggestions for improvement of AMIC service. There was no attempt to determine perceived benefits on the part of the users. There is some quantitative attempt at benefit estimation on the search evaluation form sent out with each reply to an inquiry, but the responses to this particular question are of limited value in the opinion of the authors.

Because of the difficulty of quantifying benefits to users, the only economic data presented are historical operating cost data which relate to the efficiency of systems operation.

Although this report does not attempt to estimate benefits of users, it is useful in terms of identifying user characteristics and user satisfaction with the products and services of an IAC, and providing some cost data on operating a typical DoD IAC.

A Ph.D. thesis which examines the degree of use of IAC's is "Use of Federally Supported Information Analysis Centers by Special Libraries in Large Companies" (Sternberg, 1971). The objectives of the study were to determine the extent of use of IAC's and to establish the percentage of user and nonuser libraries, the profile of user and nonuser libraries, the reasons for using or not using the centers, the ratings

of the services of each center, and the effect on the libraries as a result of using the centers.

The study was conducted using a lengthy questionnaire sent to the libraries in the top 100 companies in the "Fortune Directory of the Largest Industrial Corporations." The total number of libraries surveyed was 548, of which 386 responded. Of these 386 respondents, 94 used IAC's and 29 of the 94 felt that the use of the IAC's saved their library money. Other results of the survey were that many librarians (46%) encourage their patrons to use IAC's, that the great majority (80%) consider IAC's another resource tool and that the reason given most often for using an IAC was the availability of supplementary services. A significant number of libraries were not aware of the existence of IAC's, an indication that IAC's need to do a better job of advertising their services.

As a result of this study, the author makes several recommendations (both to libraries and IAC's) including (1) more librarians in special libraries in large companies should use IAC's, (2) both small and large special libraries should take advantage of IAC services, (3) IAC's should advertise to reach libraries that are not aware of IAC's, (4) IAC's should adopt programs to educate these libraries that do know about IAC's but don't use them, (5) IAC's should continue to provide state-of-the-art reviews and other unique publications, (6) IAC's should improve their services so their users will be better satisfied, (7) a liaison should be provided between IAC's and special libraries, and (8) a set of guidelines to foster use of IAC's should be adopted by both librarians and IAC's.

A recently completed study which examines the utilization of IAC's is "Scientific and Technical Information Needs of Users or Potential Users of the DSA Administered, DoD Information Analysis Centers" (Corridore, 1976). The Defense Supply Agency (DSA) serves as administrative manager for eight DoD-sponsored IAC's and is responsible for providing program guidance to these IAC's. To insure that this program guidance is effective, DSA obtained feedback from Defense scientists and engineers by the use of two separate but related surveys. The first as-

sessed the users' level of satisfaction while the second determined users' scientific and technical information needs. This report describes the results of both these surveys.

The survey to determine the level of user satisfaction was distributed to 27 of the leading DoD/RDT&E laboratories/activities engaged in R&D effort within the IAC's areas of technology. Of the 19 laboratories that responded, 95% were satisfied with the technical fields covered by IAC's, 93% were satisfied with the products and services offered by the IAC's, but a significant percentage (69%) were either completely unaware or only partially aware of the existence of IAC's. As a result of this last finding, several actions have been taken to increase the awareness of IAC's among DoD scientists and engineers. These include briefings to selected laboratories, distribution of a User Guide for IAC's to approximately 30,000 Defense scientists and engineers, announcements in DDC's Technical Abstract Bulletin, promotional mailings to selected individuals/organizations, and identification of and contact with potential IAC users.

The User Needs Survey was conducted among 949 personnel at 51 major DoD R&D activities to identify specific, job-related scientific and technical information needs of Defense scientists and engineers. Of the 51 activities addressed, 47 responded with 703 questionnaires. Some of the principal findings were that (1) 72% of all respondents experience difficulty in locating, obtaining and using scientific and technical information, (2) 24% of the respondent's time is spent in locating, obtaining and using this information, and (3) respondents generally need more facts, data, findings or constants than other types of information. Based on the findings of this survey, the following conclusions and recommendations are presented:

(1) DSA should increase the scopes of IAC's and direct them to produce handbooks, databooks, and state-of-the-art reports,

(2) the most important products or services that can be offered by IAC's are handbooks and databooks,

(3) DoD scientists and engineers have a great need for summary type scientific and technical information,

(4) by increasing their scopes, DSA IAC's can satisfy approximately 40% of the information needs identified in the study and,

(5) IAC's collectively appear to be underutilized which apparently stems from a lack of awareness of the existence of IAC's.

Another study which examines the information needs of scientists and engineers is "User Survey Report" (Maddock, 1976). This study was performed for the Defense Documentation Center (DDC) by Auerbach Associates to (1) identify and document the scientific and technical information (S&TI) needs and management information needs for the DoD Research, Development, Test, and Evaluation community, and (2) to identify user problems associated with the acquisition of S&TI/RDT&E management information provided by DDC or other government or nongovernment sources.

A total of 100 organizations were surveyed (25 in each of four categories) with twenty staff members selected randomly from each organization. A total of 698 interviews were successfully completed.

The principal findings of this study are (1) local libraries are the primary formal source of information while "distant" libraries are preferred by a very small minority, (2) technical reports are preferred to other formats for information presentation, (3) printed media are preferred to computer printouts and microforms, (4) users will not pay for information services unless the quality of service is substantially improved and targeted toward their precise needs, (5) increases beyond the current level of response time are unacceptable, and (6) support personnel reported a significantly higher rate of IAC utilization than bench level or management personnel but total IAC usage is low.

As a result of this study, two of the conclusions and recommendations presented are: (1) DDC should move from a position of providing only bibliographic, document-oriented service to the provision of fact and information service as well, and (2) improved access to IAC's by bench level personnel is required.

DESCRIPTION OF IAC'S

A paper which describes the organization and operation of a group of IAC's is "The Information Center Complex at Oak Ridge National Laboratory Bibliographic Information Services for ERDA Activities" (Ulrikson, 1975). The ICC, established in 1971, provides ORNL, ERDA, and other government agencies with information in several areas including energy, human health, environmental impact, radiation, trace contaminants, land use and planning, and ecosystems remodeling and analysis.

The major types of services supplied by ICC are bibliographic references, directories of researchers, inventories of current research projects, factual information, numerical data, organization of collected material, and assessment of information. The paper provides a description of each of these services including the types of information included and the ways in which these services can be utilized. In addition, the organization components of the ICC are described in terms of their areas of expertise, and the specific services and products offered. Of the thirteen components of ICC, five are identified as IAC's in the 1974 Directory of Federally Supported Information Analysis Centers.

Another paper which provides a description of the organization and operation of an IAC is "Data Availability and the Role of the EROS Data Center" (Watson, 1975). The Earth Resources (EROS) Data Center was established in 1972 to serve as a prime dissemination source of LANDSAT and other remotely sensed data and information.

The center provides data, both in the form of photographic images and in the form of digital data on computer compatible tables (CCT's), and services in the form of domestic and international training, preparation of education aids, the conduct and documentation of applications demonstration projects, and application assistance in the use of specialized analysis equipment.

This paper describes the history of the EROS Data Center, some of the specific products and services available, the types of customers utilizing the center, and the volume and trends of sales over the past several years. In addition, the procedure for obtaining data from the center is outlined.

CONCLUSIONS

As is evident from this literature review, little of the available literature is concerned with quantification of benefits of IAC's and their services. Although the benefits are perceived as significant, the progress toward realistic estimation of these benefits has been minimal. In general, the available literature tends to concentrate on the services provided by IAC's and the costs of providing these services. The literature which does discuss use of IAC services is case specific and thus does not offer much useful data for the development or testing of a cost-benefit methodology for IAC's.

Another conclusion which seems apparent from this literature survey is that a low level of awareness among potential IAC users is a continuing problem, at least for DoD IAC's and likely for other IAC's as well. Thus, the potential benefits could be much larger than current benefits simply because so many potential IAC users are not aware of IAC products and services. For those users who are aware of IAC products and services, the overwhelming majority of those surveyed are satisfied with the available services.

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APPENDIX B

GLOSSARY OF TERMS

GLOSSARY OF TERMS

This glossary defines major terms frequently employed in cost analysis, in cost-benefit analysis and in connection with information analysis centers as they will be used in this study.

ALTERNATIVE COST: See "opportunity cost".

COMPETITIVE MODEL: An abstract model of a market economy which satisfies certain well-defined assumptions. It is the basic model of economic analysis. Economists have shown that an actual economy patterned after the competitive model will make the most efficient use of resources and make society as well off as possible (according to the Pareto criterion*). If certain assumptions are made in addition to those characterizing the competitive model, it can be shown that observable market prices equal the shadow prices* of the economy's goods and services.

COMPENSATING VARIATION: In considering movement from one economic state* to another, the maximum amount of money the individual would be willing to pay to make the move (if he favors the move), or the minimum amount he would accept as compensation for making the move (if he does not favor the move).

CONSUMER'S SURPLUS: The difference between what a consumer would be willing to pay for some good and the price of that good. Measures of consumer's surplus are derived from the consumer's demand curve, and are widely used in cost-benefit analysis when the project being investigated will cause a significant price change in some good. Consumer's surplus is an approximation to the more technically proper compensating variation*.

COST: What must be given up to acquire or achieve something. Costs to individuals are often different than costs to society. This occurs when transfer payments* or externalities* are involved. Examples: Buying a used car is a cost to an individual but is not cost to society, since the transaction represents a transfer payment*. Operating a car is a greater cost to society than to an individual, since pollution is created. This is an external diseconomy.

COST-BENEFIT ANALYSIS (CBA): A systematic evaluation of a project to determine whether, and to what extent, its social benefits outweight its social costs; also, the various techniques used to perform the evaluation, such as shadow pricing* and discounting. CBA draws heavily on the concepts and methods of economics.

COST-EFFECTIVENESS ANALYSIS (CEA): A systematic evaluation of alternative approaches to achieving a specified goal. The object is to select the least cost approach. CEA is most useful when the benefits are not readily and meaningfully translated into dollar amounts.

* Indicates the term itself is defined in this glossary.

COST RECOVERY: The policy instituted by the Federal government whereby some Federally supported IAC's* are required to charge for their products and services where the users can reasonably be expected to pay for these products and services. The term "full cost recovery" normally means the recovery of all direct and indirect costs; however, it is sometimes loosely used by IAC managers and others to mean the recovery of only marginal costs.

CRITICAL DATA: Data which have been reviewed by knowledgeable researchers and are judged to be reliable, i.e., that data which may be used with confidence in planning experiments, reducing results, and interpreting phenomena (Garvin, 1970).

DEMAND: The schedule of the various quantities of some good which will be purchased at various prices during a specified period of time. The concept may refer to an individual good or to the sum of all individual goods - the market. Demand schedules may be represented in tabular, graphic, or equation form.

DETERMINANT OUTPUT: The products and services of an IAC whose content is determined by the IAC;* for example, data compilations, state-of-the-art and survey reports, handbooks, etc., which are directed by the IAC mission or discipline.(Veazie, 1972). See "reactive output".

DIRECT COSTS: Costs that are specifically traceable to or caused by the production of a product or provision of a service; some examples are the labor and materials used in producing a product or service (Anthony, 1970).

DIRECT EFFECTS: Increased real value of output or real cost associated with a project.

DISCOUNT RATE: Given some benefit (or loss) which will be incurred at some specified date in the future, the number which, when the future benefit (or loss) is discounted by that amount, makes that benefit (or loss) comparable to one incurred in the present. The number is usually specified as an annual rate. Example: Suppose $100 is expected to be received immediately. If the discount rate is 10%, 10% x $100 = $10 means the $100 gain now is comparable to $110 in one year.

ECONOMIC STATE (OF AFFAIRS): The distribution of utility, or satisfaction, among the members of society.

EFFICIENCY: A characteristic of a part, or the whole, of an economic system. Efficiency prevails when, for a given amount of input, the greatest possible output is produced. Alternatively, efficiency prevails when, for a given amount of output, the least possible input is used to produce it.

ELASTICITY: A measure of the responsiveness of quantity to price along demand or supply curves. It is defined as the percentage change in quantity divided by percentage change in price.

EQUILIBRIUM: A state of balance between opposing forces. An economic equilibrium is a situation which is gravitated towards and, once achieved, remains. The most common application is market equilibrium, wherein the

EQUILIBRIUM (continued)
forces of supply and demand drive the market price to an equilibrium. At equilibrium, the price tends to remain constant unless disturbed by new forces.

EQUITY: The "fairness" of the distribution of income, or utility, in an economic system. Since the concept inherently involves value judgements, there are no acceptable universal quantitative measures. Ordinarily, in CBA,* the decision maker, when presented all the evidence, must subjectively determine whether reasonable equity standards are satisfied.

EXTERNAL EFFECTS: See "externality."

EXTERNALITY: A factor which causes an individual or firm to become better or worse off, but over which that individual or firm has no control, and for which that individual or firm can be charged no fee (in the case of an external economy) or can exact no compensation (in the case of an external diseconomy). Pollution is an oft cited external diseconomy.

FIXED COSTS: See "nonvariable costs".

FULL COST: The sum of all direct and indirect costs; total cost; the "full cost price" of a product or service is based on all direct costs for that product and service and an allocated share of the indirect costs (Anthony, 1970).

FULL COST RECOVERY: See "cost recovery".

IMPERFECT COMPETITION: A term characterizing a market which is not perfectly competitive, such as monopoly,* oligopoly, or monopolistic competition.

INCOMMENSURABLE: A gain or loss which, while easily quantified in its own dimensions, is not readily translated into monetary terms. The classic example is the loss of human life. Number of lives lost is (usually) easily determined, but the associated monetary value is elusive.

INDIRECT COSTS: Costs not associated directly with the products produced or services provided. Some examples are rent, utilities and taxes (Anthony, 1970).

INDIRECT EFFECTS: The impact of a project on the rest of the economy. Indirect or secondary benefits are a form of external benefits. Their inclusion in cost-benefit analyses has been subject to violent attack in recent years. The logic of counting these benefits should be carefully constructed and justified in terms of the objectives of a project.

INFORMATION ANALYSIS CENTER (IAC): "...a formally structured organizational unit specifically (but not necessarily exclusively) established for the purpose of acquiring, selecting, storing, retrieving, evaluating, analyzing, and synthesizing a body of information and/or data in a clearly defined specialized field or pertaining to a specific mission with the intent of compiling, digesting, repackaging, or otherwise organizing and presenting pertinent information and/or data in a form most authoritative, timely, and useful to a society of peers and management." (National Referral Center, 1974). An "academic" IAC is one which primarily serves academic users and is therefore usually located in an academic environment.

INTANGIBLE: A gain or loss for which there are not apparent dimensions in which to quantify the value of the gain or loss. Examples would include gains or losses in fields of aesthetics, personal freedom, social justice, international peace, or changes in the distribution of income.

INTERNAL EFFECTS: The effects of a project which accrue directly or indirectly to the entity under study. They are the benefits (costs) which are "captured" (suffered) by a project and clearly are included in a cost-benefit analysis.

MARGINAL COST: The change in [illegible] cost that results from producing one extra unit of product or serv[illegible] 100 units can be produced for $500 and 101 units can be produced for $502, then the marginal cost at 100 units is $2. (McCarthy, 1968).

MARGINALISM: A characterization applying to most forms of economic analysis in recognition of the fact that economic decisions are rarely "all or none" but rather "more or less." Thus, economic decisions are most often made "at the margin".

MONOPOLY: A market situation in which there is only one firm selling a product with no close substitutes. Also, the firm itself.

NET PRESENT VALUE: A single number representing the value of a future stream of benefits and cost discounted to the present

NONVARIABLE COSTS: Costs which do not vary at all with volume; fixed costs (Anthony, 1970).

NORMATIVE ECONOMICS: See "welfare economics".

OPPORTUNITY COST: Sometimes called "alternative cost." The value of the benefits foregone by choosing one course of action over another. As an aggregate measure, it is composed of individual shadow price* valuations.

PARETO CRITERION: This is a criterion for judging an economic state* which has achi[illegible] high degree of acceptance among economists. It states that State O[illegible] Pareto) superior to State Two if, in State One, no one is worse o[illegible]an he would be in State Two and at least one person is better off. The problem with the Pareto Criterion is that it fails to be applicable to real situations wherein some persons are worse off, and some better off, in going from state to another. See also "potential pareto criterion".

PECUNIARY EXTERNALITIES: The financial effects of a project on other parts of an economy as felt through price changes for outputs or inputs. They are not generally included among the effects of a project because they do not reflect changes in the real production of goods and services and often would lead to the double counting of project benefits on costs.

POSITIVE ECONOMICS: That branch of economics which describes, explains, and predicts actual economic phenomena. It is devoid of value judgements, saying nothing about whether or not given economic states of affairs* are good or bad.

POTENTIAL PARETO CRITERION: This is a decision criterion used in judging the superiority of an economic state. By this criterion, State One is judged socially superior to State Two if those who gain by the choice of one over two could compensate those who lose such that, if compensation were paid, the final result would be that no one would be worse off. This is the criterion most frequently used in cost-benefit analysis.

PUBLIC GOOD: A good with two characteristics:

i) Non-Rivalry in Consumption
ii) Non-Excludability

The first means that, at least up to some point, the consumption of the good by one person does not diminish the amount available to another person. The second means that, once provided, it is impractical, or impossible, to exclude anyone from consuming the good. Examples of public goods include bridges, parks, national defense, and disease control.

REACTIVE OUTPUT: The products and services of an IAC* produced in response to a specific request; for example simple inquiry answering and bibliographic services (Veazie, 1972). See "determinant output".

SCENARIO: An outline or synopsis indicating scenes, characters, plot, etc. This term has been adopted from theater use to dramatize the need for establishing and visualizing clearly the detailed nature of a project alternative.

SECONDARY EFFECTS: See "indirect effects."

SELECTIVE DISSEMINATION OF INFORMATION (SDI): A type of current awareness service which provides a user with notification of accession of new documents by title and/or abstract, based on the user's probable interest as evidenced by a match between a list of descriptors for the document and his field-of-interest register profile (list of descriptors characterizing his interests) (Weisman, 1972).

SENSITIVITY ANALYSIS: Given some relation $Q = F(P_1, P_2, \ldots, P_n)$, where the P's are parameters, the determination of the responsiveness in Q to changes in the parameters. This is an important aspect of cost-benefit analysis, since values for some parameters must often be crudely estimated. This allows the analyst to determine how sensitive his conclusions are to his choices of parameter values. The sensitivity of Q to a change in P_i from P_i^0 to P_i^1 is $S_Q/P_i^0 = [(Q(P_i^1)-Q(P_i^0))/Q(P_i^0)] \div [(P_i^1-P_i^0)/P_i^0]$.

SHADOW PRICE: The true economic value of a good, as measured by its ability to contribute to social well-being. The shadow price in economics is analogous to the dual variables of linear programming. In a perfectly competitive economy, market prices would accurately reflect shadow prices. Shadow prices are the proper valuations to employ in cost-benefit analysis*.

SOCIAL IMPACT ANALYSIS: The attempt to identify all the significant direct and indirect effects* of a proposed action on man's economic, social, cultural, political, and physical environment. The analysis attempts to assess

SOCIAL IMPACT ANALYSIS (continued)
the magnitude of each impact and its value. Through the process of valuation, an attempt is made to determine, as far as possible, whether the overall effect of the proposed action is socially favorable or not. S.I.A. also attempts to determine how detrimental effects can be circumvented. The analysis is an aid to the decision maker and should present as much information as possible in a digestable and useful format. Care must always be exercised to accurately convey the reliability limits of the analysis.

SOCIAL OPPORTUNITY COST: What society must give up in order to accomplish some goal or achieve some end. It represents the true cost of a project.

SOCIAL RATE OF TIME PREFERENCE: The discount rate* at which society as a whole is willing to give up present consumption for future consumption. Although it cannot be observed in economic data and must be approximated, it is generally considered the correct discount rate for use in cost-benefit analysis.

STATE-OF-THE-ART REVIEW: A review of the most up-to-date literature on a particular subject performed by a knowledgeable researcher in the subject area to determine the level of development; the most common output is a monograph.

SUPPLY: The schedule of the various quantities of some good which will be offered for sale at various prices during a specified period of time. The concept may refer to a single firm or the sum of all firms--the market. Supply schedules may be represented in graphic, tabular, or equation form.

TECHNOLOGICAL EXTERNALITIES: Real consumption or production opportunity changes for other units in an economy which are due to a project. They represent changed social welfare, cannot easily be priced and are frequently incidental joint products. They are normally included in a cost-benefit analysis.

TRANSFER PAYMENT: A shift in income from one person to another or from government to some person for which there is no corresponding increase in current production. Thus, transfer payments are financial transactions which are not reflected in national income or national product accounting statements.

UNIT OF SERVICE: A unit of measurement of the output i.e., a product or service, of an IAC.* In terms of the cost-benefit study, the results must be independent of the particular unit of service selected if the results are to be considered valid. Therefore, the important consideration is to select a unit which can be consistently applied to a given product or service. The unit of service is especially important in pricing studies where the focus is on expanding or contracting output via price changes to customers. Thus, the unit of service must be unambiguously defined so that the price per unit of service can be readily measured at different price levels.

UNIT OF SERVICE (continued):

The units of service defined below for particular products and services are typical. These units of service are based on the assumption that the quantity of information contained is approximately the same from issue to issue (e.g., newsletters) or edition to edition (e.g., handbooks)

Inquiry Response Service - for computer based literature searches, one search of a data base for a given set of descriptors is one unit of service; for personnel time, one man-hour is one unit of service

Handbooks and State-of-the-Art Reviews - one volume distributed to a user is one unit of service

Newsletter - one copy sent to a subscriber is one unit of service.

VALUE THEORY: That branch of economics which deals with explaining and predicting the values of goods, as such values are revealed in economic transactions. Value theory is associated with supply-demand analysis and marginalism.*

VARIABLE COSTS: Costs which vary directly with volume; direct labor is an example (Anthony, 1970).

WELFARE ECONOMICS: That branch of economics concerned with measuring and improving individual and social well-being. It is based on explicitly stated value judgements, or criteria, by which economic states may be compared. The Pareto criterion* is a widely used value judgement in welfare economics.

WILLINGNESS-TO-PAY: The widely accepted measure of the value of some good to some individual. It is used for estimating the value of certain types of benefits, especially when market prices are not available.

APPENDIX C

GOVERNMENT SUPPORT OF (OTHERWISE PRIVATE) SECTORS IN THE ECONOMY: A BACKGROUND DISCUSSION

CONTENTS

INTRODUCTION

This appendix provides a background discussion of the conditions and rationale for government support or subsidy of what otherwise might be private sectors of the economy. The rationale for government support, such as government support of information analysis centers (IAC's), is based on the existence of externalities, i.e., cases in which social and private costs or social and private benefits diverge. The discussion in this appendix is intended to explain and illustrate general situations that may help conceptualize the economic issues facing IAC's.

The discussion proceeds in four steps. The next chapter includes an introduction of the basic concepts of social and private costs and externalities. Next, this chapter discusses and illustrates the relationship of these basic concepts to the central idea of "externality". The chapter concludes with a "laundry list" of externality-inducing situations. This list includes interdependencies between consumption and production, institutionalized rules and procedures, risk, balance of payments, public goods, unemployment, scale effects, noncompetitive markets, and national security. The final chapter summarizes implications for IAC's of these discussions of government support for sectors of the economy.

ECONOMIC CONCEPTS

Private and Social Costs and Benefits

A private cost is what the individual (person, household, or firm) must give up to receive some good or service. A social cost is what society as a whole must give up so that the good or service will be received by some individual. For most goods and services, the social and private costs are identical. For example, the individual who purchases a suit of clothes for $100 gives up $100 worth of other goods and services he could have purchased. Likewise, society as a whole (under fairly general assumptions) gave up $100 worth of other goods and services in order that that $100 suit could be made. Sometimes, however, social and private costs diverge. The individual who pays $500 for one year's worth of courses at a state university has given up $500 worth of other goods and services he might have purchased. However, the year's worth of courses has cost society much more (on average) than $500, since the state university is subsidized. The social cost of a state university education exceeds the private costs. Similar statements can be made about private and social benefits. For most goods and services they coincide, but for many they do not. While the measure, or yardstick, for costs is <u>what must be given up</u>, the measure of benefits is <u>willingness-to-pay</u>. Thus, while some individuals might be willing to pay $500 for a year of state university education, society as a whole might be willing to pay, say, $1,000 for a year's education for that person. The $1,000 would include the $500 the individual would be willing to pay <u>plus</u> very many small amounts other persons would be willing to pay toward <u>that person's</u> education because they feel, for any number of reasons, personally better off if that person becomes educated. They might feel, for example, that that person's education may make him less likely to become a criminal, or to wind up on welfare rolls, or simply that his education will make him a more pleasant potential neighbor. Thus the social benefits of education, as measured by society's willingness-to-pay, exceed the private benefits.

Externalities

When social and private costs, or social and private benefits diverge, we say that an externality exists. Externalities may arise from numerous, and largely differentiated, circumstances. When an externality exists, and is judged significant, there is good reason to suspect that the private sector of the economy is not providing the socially optimal amounts of some goods or services.* In this case, it is considered to be in the best interests of society that an appropriate correction of private activity be effected by the public sector. Typically, the correction can take two forms: direct public intervention or indirect public intervention. The former might be characterized by actual public provision of the good or service, or of regulation of private producers; while the latter by various financial inducements by government to the private sector to encourage a modification of its production plans. With regard to education, the public sector's intervention has been of the direct variety: public education is "produced" directly by local and state governments. A good example of the indirect approach by government is the case of individual home ownership. Society has decided that the social benefits of individual home ownership exceed the private benefit (for reasons too lengthy to get into here). To appropriately modify private sector behavior, the federal government allows interest payments to be deducted from gross income for tax purposes. This reduces the real cost (to the individual) of borrowing and thus reduces the real cost of home ownership. Some individuals who would not have otherwise purchased a home are now induced to do so.

For the mathematically inclined, and for those unconvinced by the foregoing literary argument (the argument being that when social or private costs or benefits diverge, public intervention can improve overall welfare), a more rigorous argument is developed below.

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*By socially optimal is meant that collection of goods and services which maximize the welfare of society, subject to the overall availability of resources.

An Economic Model Illustration

For simplicity, let us focus on a very simple economic model. Our conclusions, the reader will find, are generalizable to more complex situations. The conclusions are simply this: first, in the presence of externalities, the pursuit of individual self-interest does not result in the best interests of society being observed (vis a vis Adam Smith's famous "invisible hand" doctrine which states that usually individuals in pursuit of their own selfish interests, are led, as if by an invisible hand, to do what is best for everyone). Second, it is possible for government action, directly or indirectly, to appropriately modify individual behavior to be in accord with social objectives.

Our model posits two individuals, A and B, each of whom consumes only two goods, X_1 and X_2. However, person A receives satisfaction, or utility, not only from his own consumption of X_1 and X_2, but from B's consumption of X_1. For example X_1 may be landscaping and B's front yard dominates the view from A's front porch.

We represent A's utility function by

$$U^A = U^A(X_{1A}, X_{2A}, X_{1B}) \tag{1}$$

Where X_{1A} is the amount of X_1 consumed by A, and so on.

B's utility function is

$$U^B = U^B(X_{1B}, X_{2B}) \tag{2}$$

We assume both A and B experience diminishing marginal utility in their consumption of X_1 and X_2. That is, the more units of a good consumed (per time period) the less satisfaction is gained from the marginal unit. Nonetheless, we also assume that an additional unit always confers some positive amount of utility. More concisely,

$$\frac{\partial U^j}{\partial X_{ij}} > 0, \quad j = A, B; \quad i = 1, 2 \tag{3}$$

$$\frac{\partial}{\partial X_{ij}}\left(\frac{\partial U^j}{\partial X_{ij}}\right) < 0, \quad j = A, B; \quad i = 1, 2$$

Fig. C-1 illustrates the relevant concepts. Note the upper figure illustrates that more consumption always yields more utility, but at a diminishing rate. The lower figure, derived from the upper, shows that extra (or marginal) utility from another unit of consumption is always positive, but the increment decreases with increasing consumption. Each figure (C-1a and C-1b) reflects conditions (3).

Economic theory posits that each individual allocates his given income among the alternative goods available to him so that he maximizes his utility. Letting I_A and I_B represent the money incomes of A and B; P_1 and P_2 the unit prices of X_1 and X_2; the problem faced by A is

$$\underset{X_{1A},\, X_{2A}}{MAX} \quad U^A(X_{1A}, X_{2A}, X_{1B}) \tag{4}$$

$$S.T. \quad P_1 X_{1A} + P_2 X_{2A} = I_A$$

Note that A's control variables (written under "MAX") exclude X_{1B}: A has no control over the amount of X_1 that B purchases, even though A's welfare depends on it. Necessary conditions for the solution of (4) are derived from the associated Lagrangian expression:

$$\mathcal{L} = U^A(X_{1A}, X_{2A}, X_{1B}) + \lambda(I_A - P_1 X_{1A} - P_2 X_{2A})$$

These conditions are:

$$\frac{\partial \mathcal{L}}{\partial X_{1A}} = \frac{\partial U^A}{\partial X_{1A}} - \lambda P_1 = 0 \tag{5}$$

$$\frac{\partial \mathcal{L}}{\partial X_{2A}} = \frac{\partial U^A}{\partial X_{2A}} - \lambda P_2 = 0 \tag{6}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = I_A - P_1 X_{1A} - P_2 X_{2A} = 0 \tag{7}$$

$$\frac{\dfrac{\partial U^A}{\partial X_{1A}}}{\dfrac{\partial U^A}{\partial X_{2A}}} = \frac{P_1}{P_2} \tag{8}$$

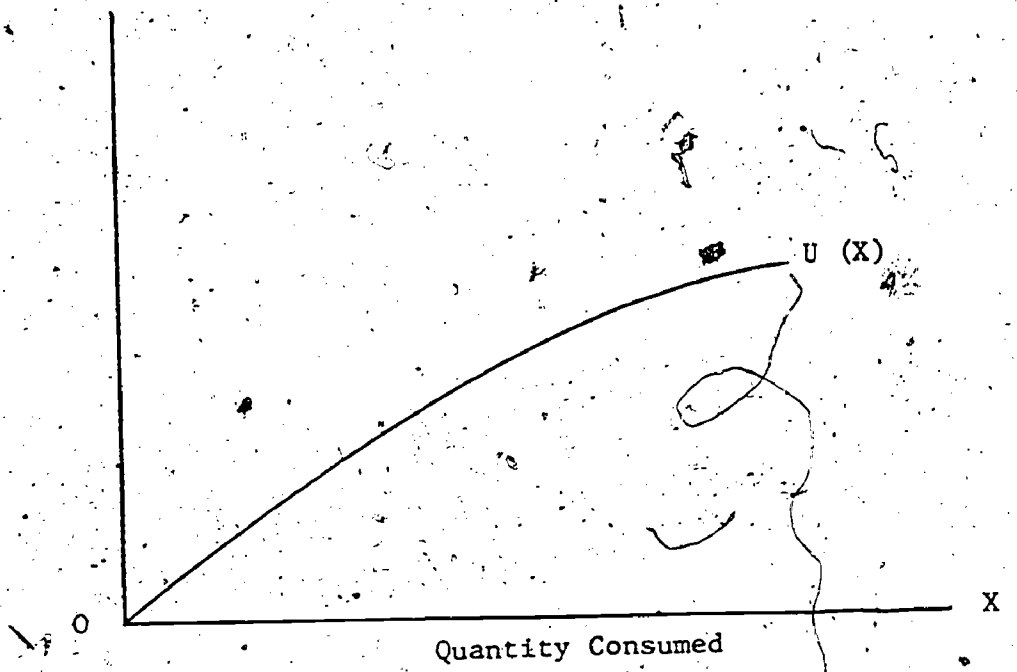

Figure C-1a. Total Utility vs. Quantity Consumed

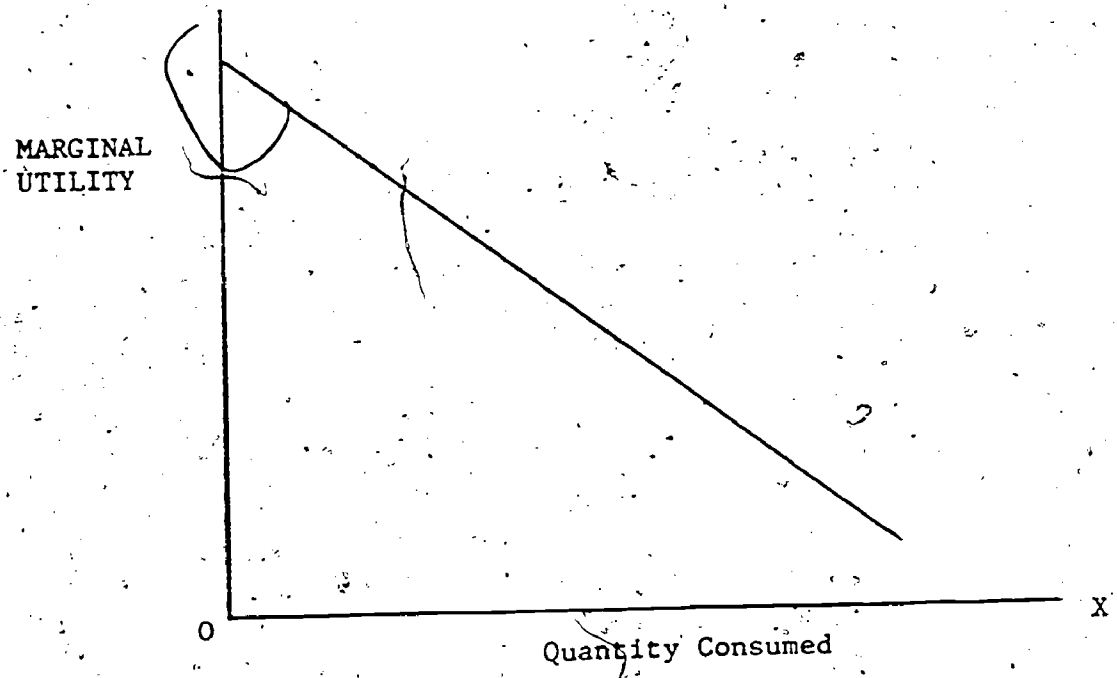

Figure C-1b. Marginal Utility vs. Quantity Consumed

Figure C-1. Total and Marginal Utility Functions for One Good

Dividing (5) by (6), the Lagrangian multiplier, λ, may be eliminated, as is done in (8). Conditions (7) and (8) characterize the optimal solution to (4), A's self-interest problem. Assume the solution to (7) and (8) is $\bar{X}_{1A}$ and $\bar{X}_{2A}$.

In like manner, B's self-interest solution can be computed. It would be some values $\bar{X}_{1B}$, $\bar{X}_{2B}$ satisfying, in particular:

$$\frac{\frac{\partial U^B}{\partial X_{1B}}}{\frac{\partial U^B}{\partial X_{2B}}} = \frac{P_1}{P_2} \qquad (9)$$

Now let us consider the problem from a social welfare point of view. We define the social welfare function $W = W[U^A, U^B]$. That is, society's level of well-being depends on the well-being of its members.

Let us investigate whether the solution to the overall social problem is consistent with

$$\bar{X} = [\bar{X}_{1A}, \bar{X}_{2A}, \bar{X}_{1B}, \bar{X}_{2B}].$$

The social welfare problem is

$$\underset{X_{1A}, X_{2A}, X_{1B}, X_{2B}}{MAX} \quad W[U^A(X_{1A}, X_{2A}, X_{1B}), U^B(X_{1B}, X_{2B})]$$

$$S.T. \quad P_1(X_{1A} + X_{1B}) + P_2(X_{2A} + X_{2B}) = I_A + I_B$$

In words, find the amounts of X_{1A}, X_{2A}, X_{1B}, X_{2B}, which society can afford and which yield the greatest overall level of welfare. The first order conditions are

$$\frac{\partial W}{\partial U^A}\frac{\partial U^A}{\partial X_{1A}} - \lambda P_1 = 0$$

$$\frac{\partial W}{\partial U^A}\frac{\partial U^A}{\partial X_{2A}} - \lambda P_2 = 0$$

$$\frac{\partial W}{\partial U^A}\frac{\partial U^A}{\partial X_{1B}} + \frac{\partial W}{\partial U^B}\frac{\partial U^B}{\partial X_{1B}} - \lambda P_1 = 0 \qquad (10)$$

$$\frac{\partial W}{\partial U^B}\frac{\partial U^B}{\partial X_{2B}} - \lambda P_2 = 0 \qquad (11)$$

$$I_A + I_B - P_1(X_{1A} + X_{1B}) - P_2(X_{2A} + X_{2B}) = 0$$

Let the solution to these conditions be

$$X^* = [X^*_{1A}, X^*_{2A}, X^*_{1B}, X^*_{2B}]$$

Now let us investigate whether $\bar{X}$ is consistent with X*, in particular focusing on X_{1B}, the externality-inducing consumption of X_1 by person B. First, to eliminate the Lagrangian multiplier, divide (10) by (11), yielding:

$$\frac{\frac{\partial W}{\partial U^A}\frac{\partial U^A}{\partial X_{1B}}}{\frac{\partial W}{\partial U^B}\frac{\partial U^B}{\partial X_{2B}}} + \frac{\frac{\partial U^B}{\partial X_{1B}}}{\frac{\partial U^B}{\partial X_{2B}}} = \frac{P_1}{P_2} \qquad (12)$$

Now, in comparing (12) with (9), the RHS (right hand side) of each is identical, which means the solution to (9) must make the LHS of (9) identical to the LHS of (12). That is,

$$\left[\frac{\frac{\partial U^B}{\partial X_{1B}}}{\frac{\partial U^B}{\partial X_{2B}}}\right]_{\bar{X}} = \left[\frac{\frac{\partial W}{\partial U^A}\frac{\partial U^A}{\partial X_{1B}}}{\frac{\partial W}{\partial U^B}\frac{\partial U^B}{\partial X_{2B}}} + \frac{\frac{\partial U^B}{\partial X_{1B}}}{\frac{\partial U^B}{\partial X_{2B}}}\right]_{X^*} \qquad (13)$$

In order for (12) to hold, some reflection indicates that

$$X^*_{1B} > \bar{X}_{1B} \qquad (14)$$

This is because, as stipulated in (3), $\partial/\partial X_{ij}\left(\frac{\partial U^i}{\partial X_{ij}}\right) < 0$ Thus, to reduce the numerators on the RHS, X^*_{1B} must be increased beyond $\bar{X}_{1B}$. This is clear from Figure C-1b. The interpretation of (14) is simply that the socially optimal amount of X_1 for person B to consume is in excess of what his personal self-interest dictates. This is intuitively quite reasonable: since B does not consider the benefit that A derives from X_{1B}, he provides less than would be provided if A's benefit were considered. The social welfare approach considers both A's and B's consumption of X_{1B}, whereas, the self interest approach of B does not.

The conclusion we must draw is that if B were directly or indirectly induced to increase his consumption of X_{1B} from $\bar{X}_{1B}$ to X_{1B}*, the overall level of social well-being would be improved.

This example, then, illustrates the general nature of an externality: one party is affected by the decisions of another party, yet the latter party does not take the former into account in making his decision. If the latter is somehow induced to take proper account of the former, the externality is said to be internalized. Internalizing an externality leads to an overall increase in social well-being. It is generally recognized (at least among economists) that it is government's responsibility to see that significant externalities

become internalized. This is the economic basis for those instances of desirable government intervention in private decision-making.

Classes of Externalities

As mentioned previously, externalities may arise in a number of ways. Following is a listing and discussion of some of the major occasions for externalities.

Public Goods. A public good is any good (or service) with both these characteristics:

(a.) Non-Rivalry in Consumption. This means that some person's consumption of the good does not decrease its availability to anyone else. In order words, it is physically possible for more than one person to simultaneously get the full benefits of the good.

(b.) Non-Excludability. This term means that once the good is provided, it is difficult or impossible to exclude any from freely consuming it.

The classic example of public good is national defense. It is clearly non-rival since my consumption of national defense does not in any way diminish the amount of national defense available for others. Other examples of public goods are: lighthouses, clean air, some large parks or recreation areas, and police services.

Public goods permit explicit recognition of the fact that some goods may at once be greatly demanded by consumers and yet not supplied by profit-oriented firms. This follows from non-excludability, since the firm which provided the good would have no way of exacting payment for its consumption. Put another way, the benefits of providing a public good are non-appropriable: the firm producing the good cannot reap the benefits. This is in stark contrast to the provision of a private good, such as bread. The firm may easily withhold the rights to a loaf of bread pending payment to the firm by the demander of a specified sum of money.

Institutionalized Rules and Procedures. Principally with respect to accepted accounting procedures and the tax system, externalities are built directly into some circumstances. Several examples will illustrate the point. Suppose

that ten years ago a firm signed an agreement leasing office space for $1,000 for 20 years. Suppose the firm is free to sublease, if it desires. Suppose the current market value of the office space is $5,000 per year, and finally, suppose the firm's profits excluding the lease payments are $3,000 per year. The final profit figure based on accounting procedures would be $2,000; $3,000 less out-of-pocket costs of $1,000 for rent. The current value of the space would never be considered. The true final profit figure, as determined from economics, is -$2,000. This is because the firm can shut down, sublease the space for $5,000, and earn a profit of $4,000. By choosing to earn $2,000 instead of $4,000, the firm is really losing the difference: $2,000 per year. Thus profit is -$2,000. A decision to stay in business based on the accounting profit results in a misallocation of resources: the office space is not being used by the firm to which it is of greatest value, i.e., the firm willing-to-pay $5,000 per year.

As another example, consider excise taxes levied on the producers of certain goods. This directly causes private costs to diverge from social costs, and causes a less than optimal amount of the good to be produced and consumed. In the absence of the tax costs, costs to the firm and society are presumably identical: land, labor, capital. With the tax, the firm pays an additional charge, yet social costs are unchanged. This leads to a cut in production.

Interdependent Production or Consumption. This, along with public goods, is perhaps the most significant class of externalities. Our initial discussion of externalities drew on a consumption interdependence: person A's utility depended on B's consumption of X_1. For completeness, we now briefly present a case of production interdependence based on pollution. Assume two firms located along a river, the upstream firm discharges an effluent into the river as a byproduct of its production process, and the downstream firm draws water from the river for use in its production. The downstream firm must treat the water, at some cost, to remove impurities. The more impurities, the greater the cost. Each firm's goal is the maximization of its own profit. The overall social goal is the maximization

of the value of production. Let firm A be upstream and B downstream. It will be convenient to introduce some notation.

Q_i Output of Firm i

C_i Total Costs of Production for Firm i

P_i Selling Price of the Output of Firm i

π_i Profit of Firm i

E_i Effluent of Firm i

V Net Social Value (a market oriented measure of social welfare)

Firm A seeks to maximize $\pi_A = P_A Q_A - C_A$

$$C_A = C^A(Q_A), \frac{\partial C_A}{\partial Q_A} > 0, \quad \frac{\partial}{\partial Q_A}\left(\frac{\partial C_A}{\partial Q_A}\right) > 0.$$

The latter conditions state that marginal cost is positive and increasing over the relevant range. Finally, for firm A,

$$E_A = E^A(Q_A), \frac{\partial E_A}{\partial Q_A} > 0$$

i.e., its level of effluent depends positively on its level of output. Letting $\bar{Q}_a$ be A's profit-maximizing level of output, Q_A is such that

$$P_A = \frac{\partial C_A}{\partial Q_A} \qquad (15)$$

which is simply the first order necessary condition for a maximum for π_A. Similarly, $\bar{Q}_B$ is such that $P_B = \frac{\partial C_B}{\partial Q_B}$. However, $C_B = C^B(Q_B, E_A)$. That is, B's costs depend on A's effluent, which B takes as given. The social objective is to maximize

$$V = [P_A Q_A + P_B Q_B] - [C_A + C_B]$$

i.e., the total willingness to pay for output less the total costs of producing it.

Expanding V, we have $V = P_A Q_A + P_B Q_B - C^A (Q_A) - C^B \left[Q_B, E^A (Q_A) \right]$

A relevant first order condition which the socially optimal production of Q_A, Q_A^* must satisfy is

$$P_A = \frac{\partial C^A}{\partial Q_A} + \frac{\partial C^B}{\partial E^A} \frac{\partial E^A}{\partial Q_A} \qquad (16)$$

Now let us examine the difference between $\bar{Q}_A$ (the self-interest production level of firm A) as given by (15) and Q_A^*, the socially optimal production level given by (16). Figure C-2 illustrates the key aspects. The intersection of P_A and $\partial C_A / \partial Q_A$ at X determines $\bar{Q}_A$ according to (15). Likewise the intersection of P_A and $\frac{\partial C^A}{\partial Q_A} + \frac{\partial C^B}{\partial E^A} \frac{\partial E^A}{\partial Q_A}$ at Y determines Q_A^* according to (16). Note that $Q_A^* < \bar{Q}_A$ as long as $\frac{\partial C^B}{\partial E^A} \frac{\partial E^A}{\partial Q_A} > 0$. And this, of course, is indeed the case.

Thus, a production interdependence - one firm's cost function dependent on the output of another - gives rise to an externality. That is, it results in social and private costs diverging, leading to a non-optimal resource allocation: too much Q_A tends to be produced.

Risk. Many, if not most, commercial and industrial undertakings involve some degree of risk: the possibility that the eventual returns will differ from the planned returns. Most analysts agree that, faced with risk, society's best interests are served when projects and their magnitudes are chosen to maximize expected returns[+] $R_1, \ldots, R_N$ and total financial resources of

$$\bar{C} < \sum_{i=1}^{N} C_i$$

[+]Let $R_{11}, \ldots, R_{1M}$ be the possible returns on Project 1, and let $P_{11}, \ldots P_{1M}$ be the probabilities with which those returns are anticipated, then

$$R_1 = \sum_{j=1}^{M} P_{1j} R_{1j}$$

and likewise for $R_2, \ldots, R_N$

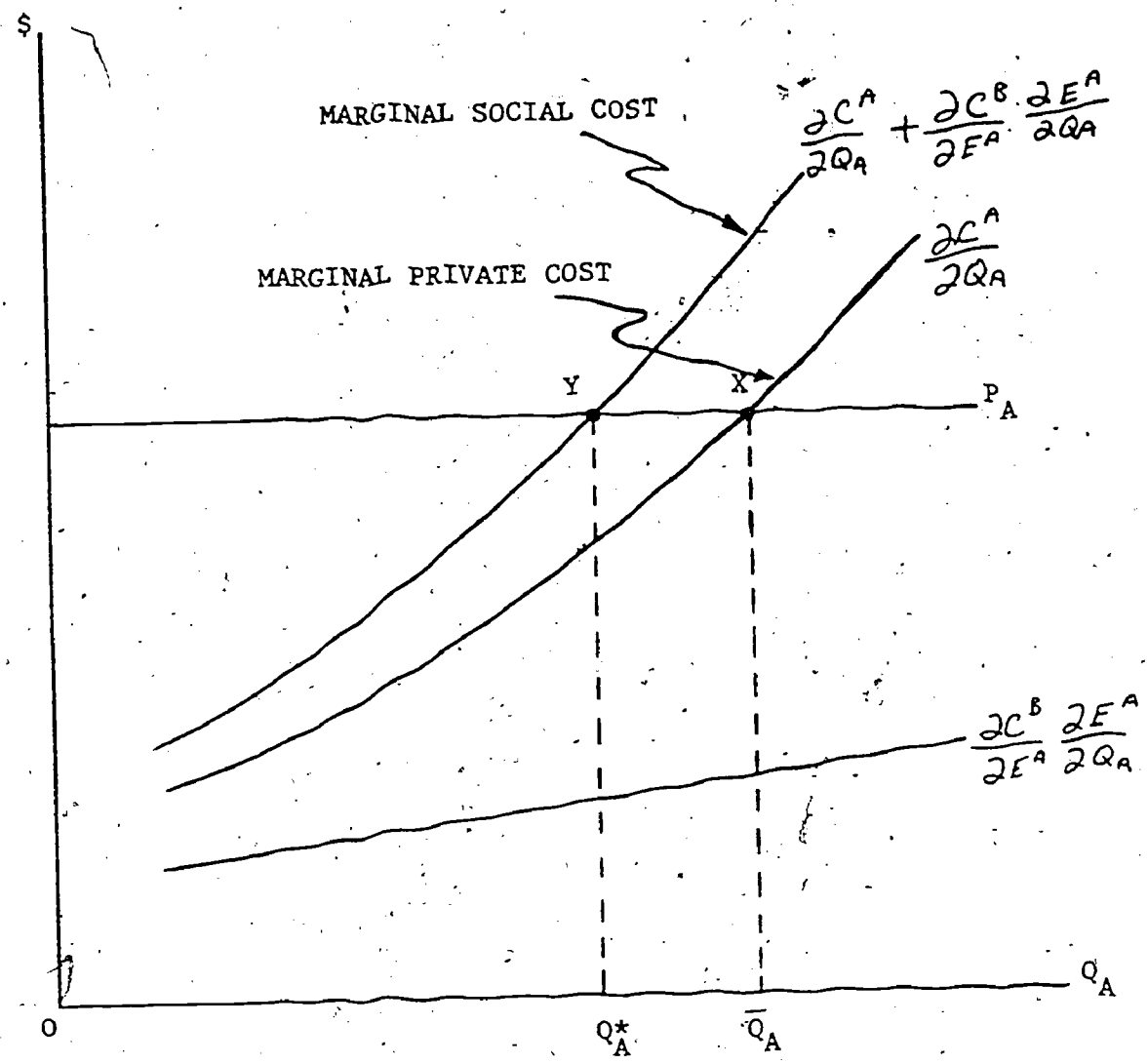

Figure C-2. The Optimal Private and Social Levels of Q_A.

the socially optimal set of projects is that set which maximizes

Net Social Benefit = $\sum_{i=1}^{N} \phi_i (R_i - C_i)$

subject to $\sum_{i=1}^{N} \phi_i C_i \leq \bar{C}$, where ϕ_i is a 0,1 variable: 1 if the project is chosen, 0 otherwise. The underlying rational is straightforward. If a large number of projects are to be chosen, those yielding less than the expected return will be balanced out by those yielding more. Over a large number of projects, the "expected" net social benefit is likely a very good predictor of the actual benefits. Thus, the maximization of "expected" benefits is the best guide to maximizing actual (but yet unknown) benefits.

Leaving aside the issue of whether net social benefits equal net private benefits (for that issue is addressed in other sections of this discussion), the question remains as to whether firms are motivated to adopt the expected profit (granting for the moment that profit equals benefit) criterion. As can be readily appreciated, there are important situations in which the expectations rule is likely to be violated. That is, there are situations when it is in the firm's best interests to not maximize expected profit. These situations occur when only a limited number of projects are to be selected and an adverse payoff on any one may spell disaster for the firm. As an extreme example, consider Table C-I. A firm has $2,000 to commit to projects. The table details the costs, possible returns, probabilities of those returns, and expected profit, E (π), for each project. An example of E (π) illustrates the approach:

TABLE C-I

Example of the Influence of Risk on Private Decision-Making

	PROBABILITY OF POSSIBLE RETURNS					
	Possible Returns					
PROJECT	-100,000	-10,000	20,000	200,000	COST ($)	E (π) ($)
1	.5	0	0	.5	2,000	48,000
2	0	.5	.5	0	1,000	4,000
3	0	.4	.6	0	1,000	7,000

With $2,000 available, the firm can choose to initiate one of the following:

Project(s)	E (π)	Unutilized Capital
1	48,000	0
2	4,000	1,000
3	7,000	1,000
2 & 3	11,000*	0
None	0	2,000

It is clear that the expected value rule gives rise to selection of project 1. Yet, Table C-II shows that if 1 is chosen, there is a 50% chance of a return of - $100,000. A firm, particularly a small firm wherein a major loss would threaten its existence, would reasonably refuse to accept such risk. We would expect that projects 2 and 3 would be adopted.

The example demonstrates that when risks are high, the socially optimal decision rule of maximizing expectations is not likely to be followed. Basically, the cause is divergence of social and private values. The private firm values a 50% chance of a $100,000 loss different than a trillion dollar economy values it. Society can easily bear the loss of $100,000 in goods and services, the typical individual cannot.

International Value of the Dollar. The international value of U.S. currency is determined by the forces of supply and demand in the market for dollars. When a firm in another country desires to purchase goods from a domestic firm, it must pay the American firm in dollars. That is, it must find someone with American dollars and offer to trade its own currency for dollars at some rate of exchange. The more foreign firms desiring to buy U.S. goods, the greater the demand for dollars, and the more must be paid (in foreign currency) to get them. Thus, a higher worldwide price of dollars is established when the demand for dollars increases. U. S. firms wishing to purchase foreign goods and having to pay for those goods in the appropriate foreign currency can now purchase a given amount of foreign currency for less U.S. dollars (or equally, can now purchase more foreign currency for the same amount of dollars). The real effect on an increased demand for dollars, in terms of the flow of goods between foreign

*We assume the projects are independent of each other, so the expected values may be added.

and domestic firms, in that we are now able to trade less of our goods for more of theirs. To that extent competition forces these benefits (in the form of lower prices) to be passed on to U.S. consumers, social welfare is improved by the increased foreign demand for dollars.

It happens, however, that there is a divergence of private and social benefits in this process. The firm which succeeds in developing a new product with substantial foreign demand does not reap all the benefits associated with the more favorable trade balance and thus is not motivated to pursue foreign sales to the extent socially desirable. For the firm, by stimulating foreign demand for a U.S. product, makes the terms of trade (number of dollars per unit of foreign currency) more favorable for all domestic firms. All firms dealing in international trade receive a benefit (lower foreign prices) due to the one innovative firm. Since the latter cannot charge other domestic firms for this benefit, it pursues its foreign sales only to the point where marginal private benefits = marginal costs, not the greater quantity where marginal social benefits = marginal costs. It appears, then, that government has a legitimate role in furthering U.S. exports. There is a caveat in this, however. Higher values for U.S. currency will tend to diminish foreign demand for U.S. products, since their price will have risen. This will be a cost to some domestic firms. This, then is a balance to strike in the price of U.S. currency: too high can be as damaging as too low.

Unemployment. This is a classic case of the divergence of private and social cost, and has far reaching consequences for national economic policy. The basic consideration is simply stated: when a firm hires an unemployed person, that person represents a real cost to the firm: so many dollars per month. Nonetheless, that person's employment costs society nothing: since that individual was producing nothing in his unemployed state, society gives up nothing to have him employed by the firm. This contrasts sharply with the case in which the firm hires a person away from another firm. Society then gives up his production in one employment in return for his production in another. Society gains only if the value of his production now exceeds what it was previously. It follows that it is in society's best interests for government to stimulate the employment of unemployed persons.

Economies of Scale (Natural Monopolies). Increasing returns to scale (or diminishing average cost) presents a situation in which the free market fails to provide the socially optimal amounts of the goods involved, and generally fails to organize

production in the most efficient manner. From elementary economic reasoning, it is evident that the socially optimal production of a good is that amount such that the social willingness-to-pay for the last item just equals the social cost of producing it, as illustrated in Figure C-3.

To see the sense of this proposition, suppose it is not adhered to, and the quantity produced is less than Q* in the figure. Then there is some individual willing to pay, say, 10 for another unit while the cost of producing it is, say, 5. Clearly, to produce the unit and sell it to the demander (for a price $\geq$ 5 and $<$ 10) make him better off. Since he is better off, and no one worse off, society as a whole is better off. A similar argument applies to outputs in excess of Q* : when the quantity produced differs from Q*, society can be made better off by moving toward Q*, and society is best off at Q*.

Economies of scale are said to occur when the cost of producing successive units declines. That is, over the entire range of production, average cost declines. In consequence of this, average cost always exceeds marginal cost (see curves AC and MC in Figure C-4.

Employing the principle illustrated in Figure C-3 (and assuming marginal cost = marginal social cost), Q* is identified in Figure C-4 by the intersection of MC and D. The firm, it may reasonably be assumed, has little interest in maximizing social welfare. Rather, its principal concern must be profit; and profit is maximized where marginal revenue just equals marginal cost, at $\overline{Q}$. Note that at $\overline{Q}$,

Profit = Total Revenue - Total Cost

= (Price x Quantity Sold) - (Average Cost x Quantity Sold)

= $\overline{P} \times \overline{Q} - \overline{C} \times \overline{Q}$

= Rectangle $\overline{P}\ \overline{W} \times \overline{C}$

However, if the firm produced Q*,

Profit = $P^* Q^* - C^* Q^*$

= Negative of Rectangle $C^*\ Y\ Z\ P^*$.

That is, the firm would actually incur a loss if it produced the socially optimal quantity. The situation gets worse, however. So far we have been assuming that the entire market is served by a single firm. Suppose, instead, that two identical firms share the market. In this case it can be shown that each will now produce less than half of what the single firm would produce. In other words, competition actually worsens the situation. The more firms there are, the less is produced; and even one firm alone only produces $\overline{Q} < Q^*$. The example applies to a number

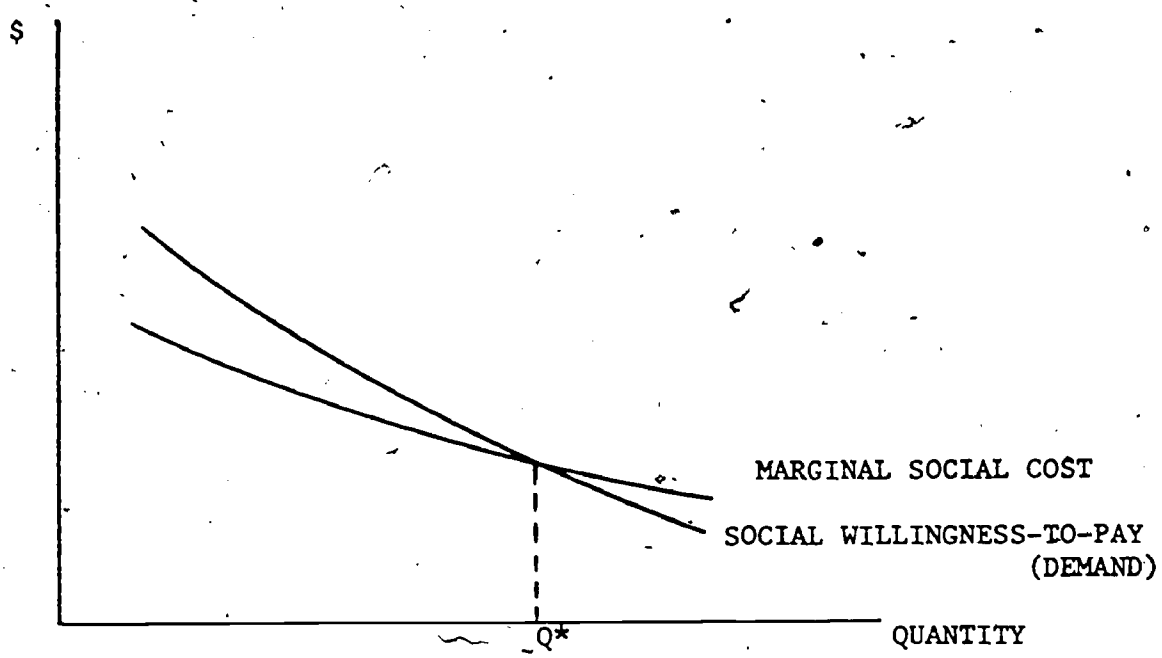

Figure C-3. Socially Optimal Production Level

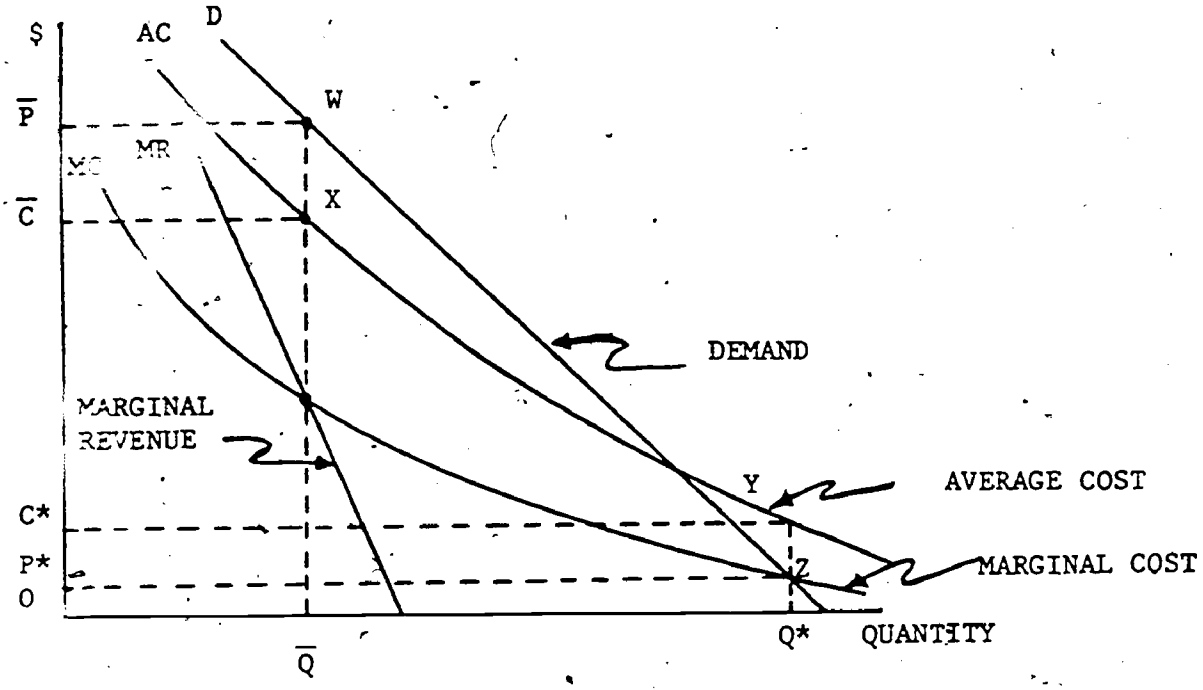

Figure C-4. Profit Maximizing and Socially Optimal Outputs Under Scale Economics

of real situations, particularly the production of utility-type services. In most cases, the government has stepped in, franchised a single firm to provide the good, and has regulated its price and output so that something better than $(\overline{P}, \overline{Q})$ ocurs.

Non-Competitive Markets. The existence of monopoly power in a market obstructs Adam Smith's "invisible hand" from turning the forces of private greed to serve the social welfare. This case differs from the previous one in that, here, more competition improves, rather than detracts from, social welfare. Otherwise, the analysis is quite similar. The indication of monopoly power is that the firm has influence over the market price of the good in question: the firm's market share is substantial enough that, by increasing or decreasing output, it can cause the market price to decrease or increase. The firm need not be the only firm in a market for it to exercise monopoly power, it is only necessary that it have some influence over market price. Figure C-5 illustrates the case. Note that it is the slopes of AC and MC which diagrammatically distinguish Fig. C-4 from Fig. C-5. The profit maximizing output is $\overline{Q}$ (where MR=MC), but the welfare maximizing output is Q^* (where Marginal Social Benefit = Marginal Willingness-to-pay = Demand = MC). When monopoly power of this sort (decreasing returns to scale) persists, a likely cause is the existence of barriers to the entry of other firms. In the interests of social welfare, the effect of various federal laws is to make such barriers illegal. Nonetheless, the laws are effective only in the most blatant cases. Much monopoly power persists, and it is in the apparent best interests of society that it, or at least its effects, be mitigated.

National Security. A great deal of federal activity proceeds under the aegis of national security. The rationale for government intervention in the economy in the name of national security is straightforward; which is not to say, however, that it cannot be abused. Basically, there appear to be two types of situations of interest.

In the first, society has dire, though very infrequent, demand for some perishable good or service. For example, the services of many experienced military-goods firms are required during wartime. It is not prudent to wait for such firms to form when war occurs. However, the peacetime demand for such goods would preclude the economic viability of such firms during peacetime.

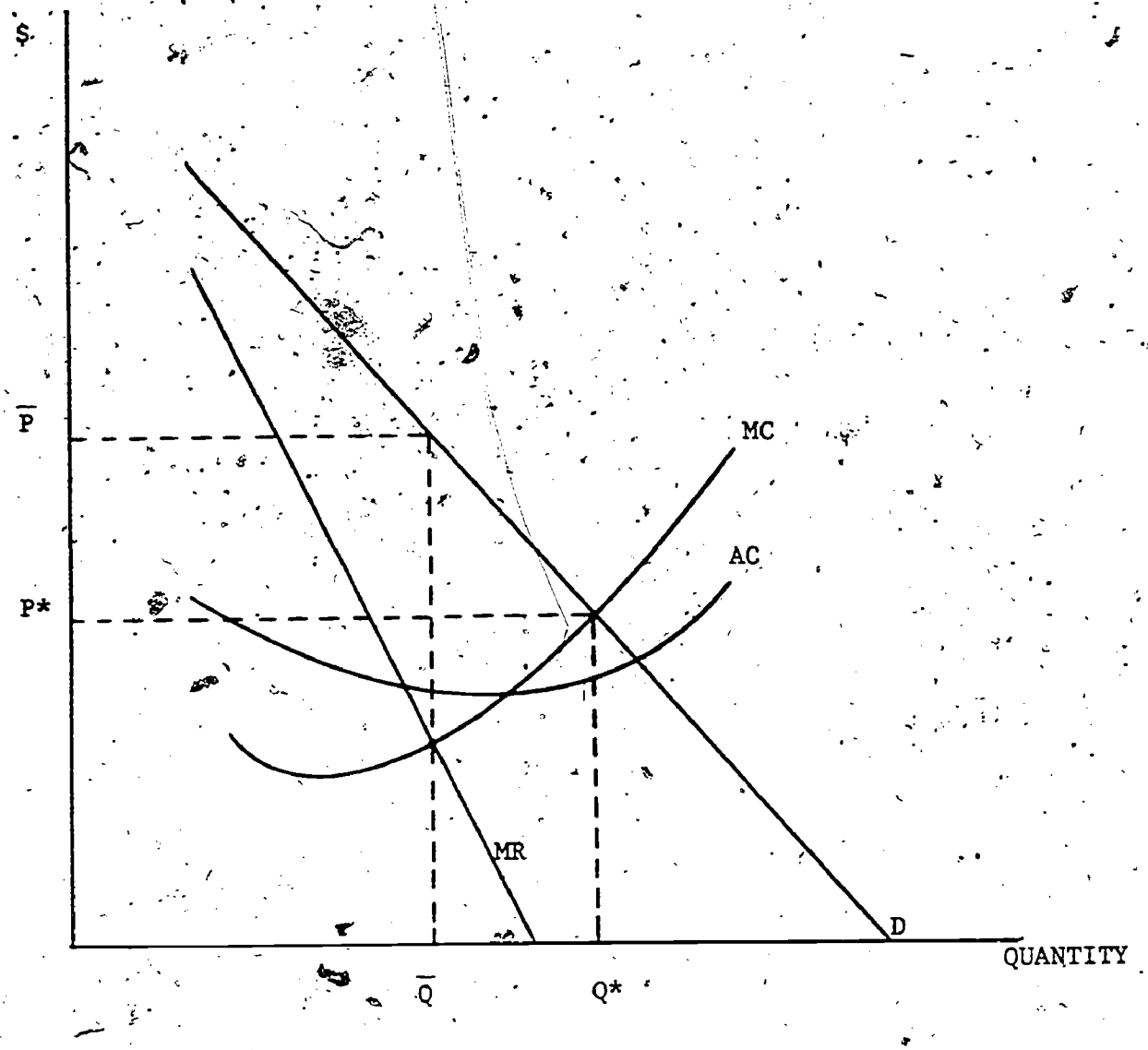

Figure C-5. Effects of Monopoly Power on Social Welfare

Thus, it would appear to be in society's best interests for some such firms to be supported by government during peacetime so that they may be available in the event of war. There is no doubt that much actual defense expenditure is for precisely this reason. The "best" number of firms, or the "best" level of support are important questions underlying the analysis of each year's defense budget. It is obvious there are no easy answers to such questions.

The second case involves U.S. dependence on foreign sources for vital raw materials. The well-known economic argument in favor of trade (namely that by each country's specialization in producing the goods for which it has a competitive advantage, and by trading its goods for those of other countries, the world community becomes as well off as possible) breaks down when political factors begin influencing economic decisions. This appears to be the case in much of U.S. - Third World trade. Oil is a prime example, but other materials are involved as well. Recent events suggest that, in the long run, society might be better off paying somewhat higher prices to domestic producers, and thus sustaining their production capabilities, rather than relying on unstable foreign supplies. This argument does not preclude trade in vital materials, only complete dependence on foreign sources.

IMPLICATIONS FOR IAC'S

The above discussions suggest several relevant issues which should be of concern to IAC managers and policy makers. These issues include:

1. Information, in some situations, has the characteristics of a public good in terms of non-rivalry in consumption and non-excludability. In many cases, however, the condition of non-excludability is not applicable because the information can be excluded from users and payment can be exacted for this information;
2. Several of the situations described in Chapter 2, one can conjecture, could reasonably apply to IAC's, thus externalities could arise.
3. The magnitude of the externalities of interest are not well defined and deserve further investigation.
4. To the extent that these externalities apply and are significant, the amount of information supplied by private firms is likely to be less than the socially optimum, and government support of IAC's would be justified economically.
5. The strongest externality-inducing situation may be the result of the probable decreasing average cost incurred by information dissemination activities such as IAC's. If this is a decreasing average cost industry, then private firms operating under a profit or revenue maximization strategy would not supply the socially optimum quantity of information. As discussed in Chapter 2, if two firms were competing, then the total quantity supplied would be less than that supplied by a single firm. Thus, to the extent IAC's incur decreasing average costs over their range of production, society as a whole would be better off with government supported IAC's rather than with privately funded IAC's.
6. Another important externality inducing condition involves the perceived risk of establishing and operating an IAC. A small firm may not follow the socially optimal decision rule of maximizing

expectations because the risk of loss is too high for it to accept. Thus private firms might not provide any of the information dissemination activities that are provided by the government.

7. National defense was the original justification for the establishment and operation of many of the federally supported IAC's. As evidenced by the institution of cost recovery programs within the Department of Defense IAC's, however, national defense no longer appears to be a sufficient sole reason for the continued support of these IAC's. This may stem from a lack of quantifiable benefits to the national defense that result from the existence of the IAC's. If these benefits could be quantified in a believable manner, then decision makers within DoD might not require cost recovery programs in order to demonstrate the benefits of these IAC's.

APPENDIX D

STUDY NARRATIVE

CONTENTS

Introduction and Highlights

This appendix reports on the project activities in a narrative, generally chronological, format. It presents the project efforts and results as they evolved, thus illustrating the changes in research emphasis, "blind alleys" explored, and the influence of the Overview Committee in the project's development.

Highlights include:

- The project utilized an active, knowledgeable Overview Committee.
- The effort required an analysis of IAC functions and an emphasis on concepts and methodology.
- There were no conceptual problems with cost data, but benefit data were limited and difficult to utilize.
- Interactions among services required the development of concepts that would permit analyses of combinations of IAC services.
- Project results include (A) benefit and cost models based on economic concepts and cost accounting principles and (B) sensitivities of the costs and benefits to changes in parameter values and technology.

The research effort originally was proposed to be a twelve month effort consisting of six tasks:

1. Project Initiation
2. Analyses of IAC Costs
3. Investigation of User Demand Characteristics
4. Example Applications of Results
5. Generalization of the Results to Other IAC's
6. Documentation and Dissemination of Results

The intent of the approach was to select an information area, pick a particular IAC in this area and develop an acceptable model and methodology, and finally to generalize the results to other IAC's. Data on benefits were to be obtained through interviews with end users of the IAC services, and the benefit model was to be based on these data.

The proposed approach and schedule were modified considerably early in the project. An unanticipated long delay in receiving initial notification of the award made impossible the effort planned during the summer (1975) by professors at Emory University. Consequently, the first change in the project was to reschedule the effort over approximately 18 months. Although the actual approach generally followed the initially defined six tasks, the comments and suggestions of the Project Overview Committee substantially modified details of the procedure and the relative emphases on the different task activities. Figure D-1 illustrates the study flow during the project.

Project Initiation

Notification of the award was received in June, 1975. Travel schedules and other commitments of the project team delayed significant effort until early August. Based on a literature investigation of federally sponsored IAC's[1], several IAC's at Oak Ridge, Tennessee, appeared to cover a wide range of subject areas and collectively to offer a wide range of services. After telephone conversations with a previous contact at the Energy Information Center in Oak Ridge, the project team arranged a visit to the Oak Ridge Information Center Complex (ICC) in August. This visit included talks with Dr. Gerry Ulrikson, ICC director, and with staff members of the Toxicology Information Center (TIRC), the Radiation Shielding Information Center, and the Energy Information Center.

An evaluation of the findings of the visit was revealing. The wide range of services offered by the groups within the ICC and the breadth of technical areas they covered indicated that the ICC would be a good focus for the study. The project team planned a second trip to the ICC for data collection in October.

During August and September the project team solicited and evaluated suggestions for members of the Overview Committee. Also during this period, the Principal Investigator attended the Defense Supply Agency (DSA) meeting of the managers of DSA-administered Department of Defense (DoD) IAC's at the Johns Hopkins Applied Physics Laboratory. This meeting verified the importance of the project: financing of IAC's and IAC services was an important topic at the meeting. Information on the

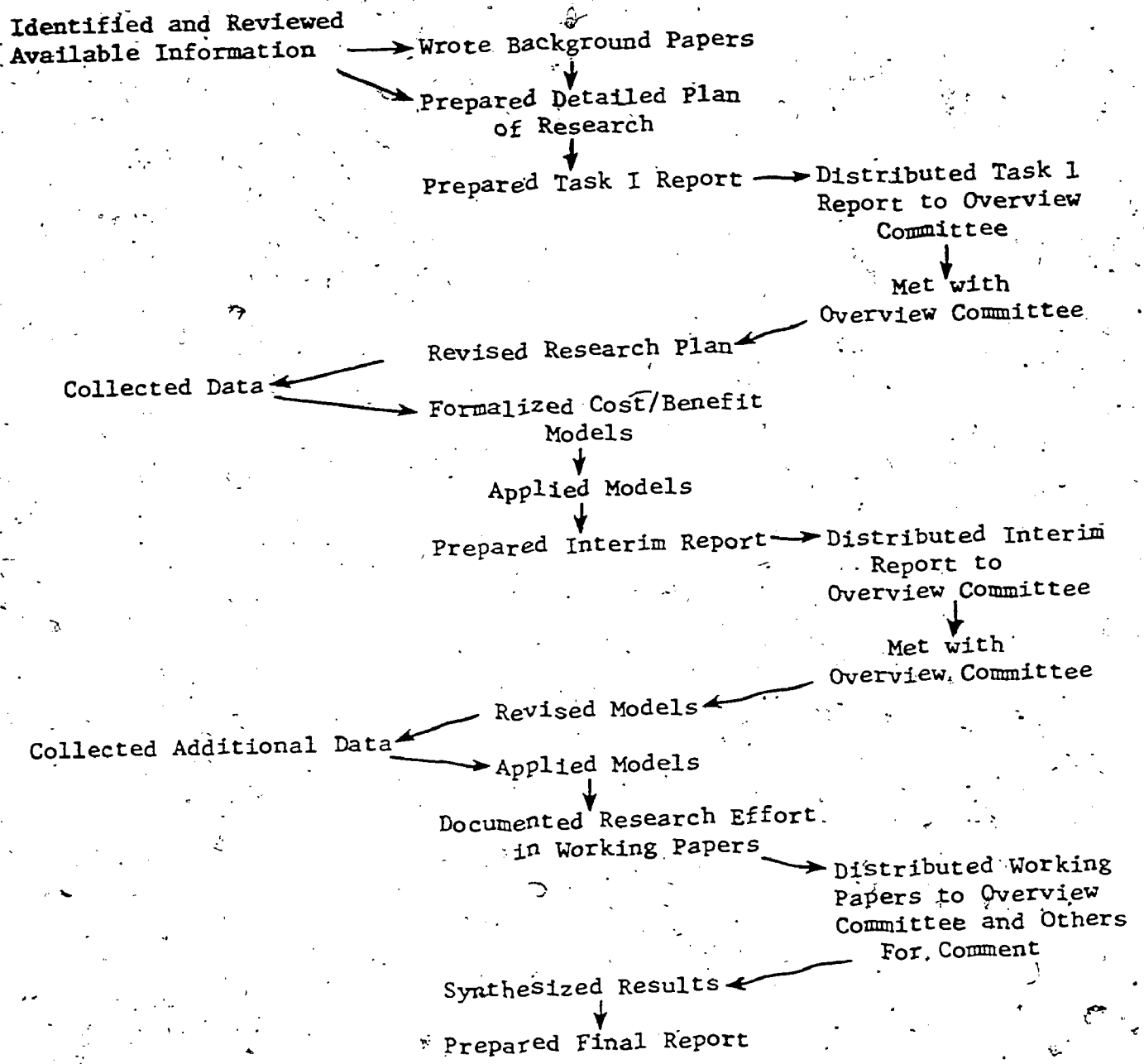

Figure D-1. Summary Study Flow Diagram of Research Effort

EROS Data Center, representative of an IAC which primarily distributes data, was obtained during this period on a previously planned visit to the Sioux Falls, South Dakota, remote sensing data center. The Principal Investigator during this period executed an agreement with the subcontractor, Forecasting International.

During October, the Overview Committee membership was completed and the date set for its first meeting. Members of the project team also made a second visit to the Oak Ridge ICC, attended the American Society of Information Science (ASIS) meeting in Boston, and visited two DSA-administered IAC's. Also during October, the project team completed a report on the efforts to date ("Task 1 Report"), submitted it to NSF, and distributed it to members of the Overview Committee.

Overview Committee. The individuals invited to be members of the Overview Committee included:

Dr. E. L. Brady	National Bureau of Standards
Mr. Richard G. Bruner	Defense Logistics Agency
Dr. Yale Braunstein	Brandeis University (formerly with New York Univ.)
Mr. Davis McCarn	National Library of Medicine
Dr. Gerald Ulrikson	Oak Ridge National Laboratory

Each of these individuals agreed to serve on the committee. In addition, Dr. Y.S. Touloukian and Dr. Vladimir Slamecka, project consultants, agreed to attend and participate in the meetings. The first meeting was set for November 25, 1975.

ICC (ORNL), Second Visit. The second visit to the ICC produced detailed information on available cost data and user demand information. In identifying and attempting to collect these data, several issues became evident. These issues included (1) the privacy question and the apparent conflict between privacy and freedom of information, and (2) the perceived reluctance of users to discuss the benefits of the information services provided.

The project team proposed that all user data (and, where desired, cost data) would be aggregated, summarized in statistical form, and not identified by organizational name in any eventual report. This procedure seemed to be acceptable and to adequately address concerns about privacy.

ASIS 1975. Attendance at the Boston ASIS meeting had significant indirect impacts, but only on later phases of the project; particularly it created a formal opportunity for disseminating results of the research effort. Informal discussions with other attendees at the meeting revealed widespread and apparently growing interest in the economics and management of information centers and services. These discussions eventuated in an Engineering Foundation Conference on the Economics, Management, and Technology of Information Centers and Services.

This Engineering Foundation Conference was held at the Tidewater Inn, Easton, Maryland, August 29-September 3, 1976. Dr. Mason cochaired (with John Creps) the conference, and members of the project team presented results of the research effort in three papers: Dr. Peter G. Sassone presented a paper on the cost benefit methodology, Mr. G. William Spann presented a paper on cost accounting for information services, and Ms. Audrey Clayton and Ms. Ethelyn Bishop presented a paper of the impacts of technological innovations of information services.

MCIC and MDC Visits. Members of the project team visited the Metals and Ceramics Information Center (MCIC) at Battelle in Columbus, Ohio, and the Machinability Data Center (MDC) at Metcut Research Associates in Cincinnati, Ohio. Each of these organizations is a Department of Defense-sponsored, DSA-administered IAC. Both MCIC and MDC provide several services, including inquiry response and handbooks and other publications. However, the project team came away with impressions of distinct differences. The MCIC has a relatively small full-time staff but utilizes the entire Battelle staff as needed for responding to inquiries and preparing reports; its outputs are predominantly responses to inquiries and state-of-the-art monographs. The MDC also has a relatively small full-time staff and makes use of the Metcut staff; its output consists of a comprehensive handbook, educational seminars, responses to inquiries, and state-of-the-art review papers. Compared with the centers at Oak Ridge, both the MCIC and the MDC emphasize the critical evaluation of data and research results.

Task 1 Report

The Task 1 Report completed and summarized the results of the project initiation, Phase I. It provided a background for the Overview Committee

and a suggested framework for conducting the remainder of the study. The report was mailed to the members of the Overview Committee with a note stating that the report was a working document and that their comments were desired.

Scope. The report included an introduction and background to the project and the decisions made during Phase I on the project's scope focus, and IAC's selected for study, and a revised project schedule. The report also included a literature overview and annotated bibliography, a general discussion of the economics of government intervention in what otherwise might be private sectors of the economy, a glossary of terms used in cost benefit analysis, and an interview format and summary information sheet.

Phase I Decisions. During Phase I, the project team selected IAC's on which to focus in developing the methodology. The choice was to work with the Oak Ridge National Laboratory Information Center Complex (ICC) and at least one DLA-administered IAC. These were chosen because of their wide range of technical areas, wide range of services, and apparent availability of data on users and costs.

Typically, IAC services may be grouped into eight categories:[2]

1. Handbooks/Databooks
2. State of the Art Reviews (SOARS)
3. Symposia Proceedings
4. Critical Reviews and Technology Assessments
5. Current Awareness Periodicals/Newsletters
6. Responses to Inquiries
7. Bibliographies
8. Workshops/Seminars

The project team selected two categories for detailed study in developing the cost benefit methodology: 1) handbooks/databooks, as representative of a "mass market" service, and 2) inquiry response service, as representative of a custom, individualized service.

Cost benefit analyses are intended to aid in making decisions and formulating policies. Consequently, the project required a decision or policy issue on which to focus the methodology development. The study team selected government funding of IAC's as the focus for the research effort. This choice was influenced by observations on the

continuing debate about cost recovery through user charges and the role of federal government financing of new and existing IAC's. The particular aspects of this issue included two sets of alternatives:

1. The government continues funding of currently existing IAC's versus discontinuation of government funding; and
2. The government sponsors new IAC's versus a laissez faire attitude (assuming spontaneous development of desired IAC's).

Literature Overview and Background Material. The Task 1 Report provided an overview of the relevant literature, a glossary of terms, and a background paper on the economics and rationale for government financing in what otherwise might be private sectors of the economy. These parts of the Task 1 Report, in revised forms, are included in this report as Appendixes A, B, and C, respectively.

First Overview Committee Meeting

The first Overview Committee meeting was held November 11, 1975. The meeting served (1) to acquaint the members of the committee with the project's purpose and focus, (2) to provide the committee with an overview of the schedule and approach, (3) to furnish details on the anticipated data collection efforts and modeling approaches, and (4) to initiate a dialog between the committee and the project team. The attendees included, in addition to members of the project team and the members of the Overview Committee themselves, Dr. Joel Goldhar and Ms. Helene Ebenfield of the National Science Foundation and Mr. Joe Blue of the Defense Supply Agency. The following paragraphs summarize the discussions on the major issues.

Research Purpose and Scope. The meeting participants agreed on the purpose of the research: to develop a methodology for analyzing the benefits and costs of information services. The participants also agreed that the research should emphasize IAC's and not be a study of information centers in general.

Decision/Policy Focus. The participants discussed the appropriateness of government funding as the policy focus for the cost benefit study, and the general issue of what should be the appropriate level of

government funding seemed to cover the common interests. The relatively new policy of charging for services was an issue of considerable concern to the participants; the traditional concept of information (and the service necessary to make the information available) being freely available, with no direct cost to the user, still lingers.

The participants discussed the scenarios appropriate for evaluating the effect of government policy. For the alternative of "no government funding", resulting in no IAC being available, the participants suggested two possibilities for subsequent impacts: (A) the users themselves will perform (probably at a greater cost) the services which the IAC performs, or (B) another center might arise to fulfill the functions of the IAC.

Data Collection and IAC Functions. Several participants expressed concern about using the inquiry response data collected thus far (from ORNL) as a basis for establishing cost and demand models. The concern seemed to be that these data might not be representative of an IAC which provides substantial data analysis and synthesis (as opposed to what many perceived as primarily a bibliographic search service). Dr. Touloukian offered data from his centers as an alternative; Mr. Bruner promised DLA cooperation in data collecting, pointing out the conflicting considerations of freedom of information and privacy. It was generally agreed that the research team could protect privacy by aggregating data and not identifying the user in disclosing data to NSF or others.

Dr. Touloukian suggested that a useful categorization of IAC's is that of mission-oriented centers and discipline-oriented centers. The mission-oriented center serves a particular set of users and typically will address problems which cut across several disciplines. The discipline-oriented center emphasizes review, analysis, assessment, and synthesis of information within a particular discipline. The latter center is at the forefront of a technical area and, as a result, is likely to be aware of problems in the technical area even before a demand arises for solutions to these problems.

Dr. Braunstein suggested that all information services may be viewed as some mixture of scr- -ing and research. A possible third distinctive function was discussed: data base building and maintenance.

Academic IAC's. The participants discussed the definition of an academic IAC. The discussion resulted in no readily identifiable unique characteristics of an academic IAC and no consensus on a definition. Several participants suggested that such centers, given the difficulty of definition, probably deserved no special attention.

Social Factors. The participants mentioned several factors which are judged to influence utilization of IAC services, particularly services for which there are fees. Many participants expressed the view that such social factors outweighed economic factors in determining the demand for IAC services.

- An engineer may fear to reveal his ignorance through requesting money for an IAC service or through a careful documentation of savings which resulted from using an IAC service;
- IAC personnel may resent the fact that they must charge for a service which appears similar to free services offered by other operations;
- The gatekeeper concept (expressed by Tom Allen and others) raises the issue of how information is transferred when the gatekeeper is not the librarian. In other words, an IAC may not be used if the informal gatekeeper does not have the authority to purchase information services.

At the end of the meeting, the participants agreed that the research effort at best could only identify such factors and discuss them briefly. A detailed discussion or investigation is outside the scope of the project.

Technological Innovations. The plan for identifying and assessing the impacts of technological innovations on the economics of IAC services was discussed. Several of the participants expressed the opinion that technological changes will have a second order impact on costs and that the primary/most important impact will be on benefits through easier use of (access to) the services and, consequently, an increased market for the services. The IAC might be able to serve a larger fraction of its potential market with the implementation of technological innovations.

Factors Affecting Users' Willingness-to-pay. An important consideration in cost benefit analysis is willingness-to-pay (WTP). WTP is evidenced by demand curves for particular services. The discussions at the meeting included considerations of WTP, and the following is a list of factors synthesized from these discussions:

- Money available to the potential user;
- Particular problem/need of current interest;
- State of knowledge of the user;
- Perception of the user as to the nature of the cost: investment (capital) versus a problem-solving expense; and
- Captive versus non-captive nature of the market. (In a captive market, one cannot assume that the market price reflects willingness-to-pay.)

Unresolved Issues. The participants raised and discussed, but did not resolve, the following issues:

- What is the impact of time and circumstances on demand curves? How does one treat the dynamic nature of demand curves?
- How does one handle actual demand versus potential demand?
- Do commercial data bases depend on existing IAC's? Do existing IAC's subsidize commercial data base services?
- What is the value of building and enlarging a data base? How is this value affected by data base size?
- What is the nature of the expected discontinuity in a cost versus price curve for a service? That is, what is the cost of performing the accounting and other functions necessitated by instituting a nonzero charge for previously free services?

Mid-Project Overview Committee Meeting. Members of the Overview Committee generally agreed that a mid-project meeting (possibly around February) would be productive and was desirable. The meeting would review the method or methods for collecting and analyzing data and the preliminary findings on developing the cost benefit methodology.

Summary: Results of the Meeting. The participation of the members of the Overview Committee resulted in the project team having a greater appreciation for the concerns of the eventual users of the research and in the committee members having an exceptional understanding of the aims

and approach of the project. To further assure shared concepts of the project, the principal investigator prepared a summary of the meeting discussions and mailed it to the participants with the request for further comments if they wished. Based on the discussions at the meeting and the subsequent comments, the project team made the following changes in emphasis and approach:

- Terminated the planned intensive investigation of data from the Toxicology Information Response Center (TIRC) because the committee believed that the analysis function at TIRC was limited and not representative of IAC's;
- Decided to collect and analyze data, available from DLA and the Center for Information and Numerical Data Analyses and Synthesis (CINDAS), which the committee believed to be more appropriate because of the DLA center's emphasis on evaluation, analyses, and synthesis functions;
- Changed the technical approach from economic analyses of single services of IAC's to a multi-service economic analysis approach because of possible interactions among costs and demands (thereby benefits) of services; and
- Began an investigation of IAC service demand based on uncertainty (subjective uncertainty of the potential IAC user).

Interim Research Effort

During the time from December, 1975, through April, 1976, the project team collected and evaluated data, developed concepts, designed cost and benefit models and calculation procedures, and performed initial analyses utilizing the models. The results of this period's effort were documented in an interim report and sent to members of the Overview Committee. The second (and, as it developed, the final) meeting of the Overview Committee was set for April 29, 1976.

During this period, the project team received and reviewed user data from DLA and from CINDAS. These data provided additional insight into the nature of benefits but confirmed the difficulty of collecting statistically significant benefit data: the CINDAS data included few examples of services for which there had been a user charge and the DSA information provided episodical/anecdotal examples of cost savings or problem

solutions resulting from someone using an IAC's service. These illustrated the value of IAC services but provided no statistical data nor data which could be aggregated meaningfully.

During this period the subcontractor developed a list of technological innovations suggested for inclusion in the scenarios to be analyzed in the later phases of the project. This list represented a range of communications technology innovations which could impact IAC services and activities. The list was mailed to members of the Overview Committee for their judgments on the relative importance of the various innovations to IAC decisions and policies.

The project team completed the initial formulation and documentation of generalized cost and benefit models. These models and the underlying conceptual framework were described in the interim report and distributed to the members of the Overview Committee for their review prior to the April 29 meeting. The report and the results of the meeting are summarized in the following paragraphs.

Interim Report

The interim report was completed and distributed in April, 1976. It reviewed the research effort's purpose, scope, approach, and status, described the conceptual approach, summarized the cost and benefit models, and outlined proposed future project effort.

Introduction. The introduction to the interim report reviewed the purpose, scope, approach, and status of the research effort. It emphasized the changes in direction and emphases which reflected the comments from the first Overview Committee meeting. These changes, generally resulting in increased effort on Tasks 2 and 3 (Analysis of IAC Costs and Investigation of User Demand Characteristics) and reduced efforts on Tasks 4 and 5 (Example Applications and Generalization of Results), included the following:

- Increased emphasis on the unique capabilities and functions of IAC's;
- Refinement of a functional model of IAC operations;
- Recognition of the critical nature of social factors in determining actual demand (versus potential demand) for IAC services;

- Increased awareness of the possible advantage of viewing the potential user's purchase decision from a probabilistic perspective;
- An awareness of what appears to be high demand-price elasticity for IAC services; and
- An awareness of a desire for measures of benefit other than users' "willingness-to-pay".

Conceptual Approach. The conceptual approach provided a framework for examining the relevant parameters of IAC operation and user behavior. The emphasis in the adopted approach is a model framework that is consistent with the stated observations, namely:

- Low "willingness-to-pay" by actual and potential users of IAC services;
- High apparent elasticity of demand for IAC services;
- Small quantities of IAC services demanded;
- The existence of individuals who are knowledgeable and informed about IAC's but who are nonusers or underusers of IAC services;
- High "real" value of IAC services; and
- Interactions among the demands for different services; in particular, reduced demand for other services with increased handbook sales.

The adopted framework described the demand for IAC services as a residual, risk averse, demand, and the models of the demand were described by graphical representations of supply and demand. The complete description of the conceptual framework is included in Chapter 4 of this report.

Cost and Benefit Models. The interim report described basic models of costs and benefits that were based on discounted projections of benefits and costs to society resulting from the utilization of IAC services. The model utilized benefit estimates based on the value of "time saved" by an IAC user. Cost estimates were based on cost parameters obtained from various IAC's. The report used the inquiry response service and the handbook service as examples.

The project team recognized, a priori, the inadequacy of the value of "time saved" estimates as a measure of total benefits. (The Overview

Committee subsequently affirmed this recognition of inadequacy.) However, this benefit measure provided an indicator of tangible benefits, was useful for communicating the model structure, and could be viewed as a lower bound on IAC benefits.

The adopted cost model utilized a "fixed cost plus variable cost" structure. The total fixed cost for an IAC was calculated by summing the unallocated fixed costs (costs which could not be associated with any particular service) and the fixed costs associated with each individual IAC service. The variable costs were the marginal costs associated with supplying an additional unit for each particular service, holding all other variables constant.

The interim report illustrated the utility of the models by assuming parameter values and illustrating the results of sensitivity analyses of the models. The sensitivity of a model to a change in a parameter value is defined as the ratio of the percentage change in outcome (e.g., benefits or costs) to the percentage change in the parameter value which causes the change in outcome. In more concise terms, sensitivity to parameter P, S_p, is defined by

$$S_p \equiv (\Delta C/C) \div (\Delta V_p/V_p), \text{ where}$$

V_p = original value of parameter P
ΔV_p = change in value of parameter P
C = value of outcome at V_p
ΔC = change in outcome resulting from ΔV_p.

The inquiry response cost model proved to be relatively insensitive to changes in parameter values (all sensitivities were less than unity), but it showed the most sensitivity to changes in values of the assumed time horizon (.7), professional time spent in responding to inquiries (.54), the professional salary rates (.41), and the fixed cost allocation factor (.46). The handbook benefit model showed the same sensitivity to time horizon (.7) but much greater sensitivity to other parameters: assumed annual user benefit (3.0), price charged by IAC (-2.0), and assumed number of users per year (1.0).

Research Emphasis Options. The interim report outlined options for emphasis in the remaining research effort and requested comments from the Overview Committee. The options, which were not mutually exclusive, included:

- Applications of the models to different scenarios;
- Improved estimates of parameter values;
- Expansion of the conceptual approach to include the time dimension from the perspective of the state of technological development and the stage of development of the IAC;
- Expansion of the conceptual approach to include an econometric model of industrial segments (aimed toward a comparison of variables such as industry growth rates in segments similar except for the existence of an IAC); and
- Documentation and further explanations/descriptions of the approach, rationale, models, etc.

The interim report was mailed to the members of the Overview Committee with a cover letter requesting that they review it before the meeting. The letter included questions to guide their review:

1. On the basis of your experience, should the conceptual model explain observations about user behavior other than those accounted for?
2. Are the procedures outlined in the cost and benefit models simple enough to be utilized routinely?
3. Recognizing the inevitable incompleteness of any routinely applicable economic analysis, would you have confidence in using the outlined analytic procedures to assist you in making decisions and formulating policy?
4. Are there issues other than those outlined in Section V which should be addressed by our research effort?
5. What other research issues are suggested by the conceptual model?

Second Overview Committee Meeting

The second meeting of the Overview Committee was held as scheduled on April 29, 1976. In addition to those participating in the first meeting, Dr. Joseph Talavage (Purdue University), who was performing related economic research on IAC's, attended and participated in this meeting. This meeting, as did the first, proved to be useful; the participants freely exchanged viewpoints, suggestions, and their reactions to the research approach and model concepts. A synthesis of notes on the major discussion points at the meeting was mailed to the participants for further comment. The following paragraphs summarize the discussion issues.

Overall Model/Conceptual Framework. There was no strong disagreement with the conceptual framework. However, the participants believed that there were exceptions to the generalized criteria ("stylized facts") used to construct the model and that these exceptions and considerations should be noted. Discussions included the notion that interrelationships among IAC services might be affected by types of handbook users, exceptions to the low "willingness-to-pay" of IAC users, and the fact that there are different types of IAC's (e.g., research focussed vs service/response focus).

Data Collection. The participants discussed the difficulty (and, to some, the apparent impossibility) of collecting benefit data. The consensus was that data currently do not exist for a credible cost benefit analysis; some individuals believed that past attempts to determine values of such parameters as "time saved" did not yield credible results. A related issue is that of the credibility of such an analysis to decision makers (e.g., Congressional Committees), who would require additional explanations and perhaps additional economic analysis procedures.

User Behavior. "Costs" in the model should be interpreted as "perceived costs to the user". The cost curve, according to those expressing an opinion at the meeting, should exhibit a discontinuity when the service is obtained outside the user's own organization. Also, "users" is too generic a term; there needs to be a description of

different categories of users, differentiated according to their own information resources and information needs.

IAC Functions and Benefits. The participants pointed out the importance of the IAC's functions of providing high quality data, recognizing that the naive user may not realize the dangers of using old or obsolete data.

However, there appeared to be a general agreement with Dr. Touloukian's statement that if all the IAC's were closed, the immediate effect would be hardly more than a ripple: a few heavy users would notice and would have to change how they obtain information, but there would be no immediate, widespread effect on individual organizations in the scientific and technical community. The significant impact would be diffuse and cumulative over a few years' time: lowered research productivity and lagging technical innovations would eventually have substantial economic impacts both on domestic industry growth and on the foreign trade balance.

The participants frequently mixed discussions about the value of the information provided by the IAC with discussions about the value of the services provided by the IAC. The project team iterated that the objective of the research is concerned with the value of the IAC service. However, as the discussion focused on IAC benefits, it was tempting to discuss the need for, and benefits of, the information itself rather than the mechanism for providing the information.

Dr. Slamecka suggested that identifying and communicating benefits would be aided by differentiating private/organization benefits from societal benefits. Examples of the former include: time/effort savings from alternative ways of obtaining IAC-type services, data quality (accuracy and precision), data reliability (low risk to use), uniqueness of the data/service, and the (relative) intrinsic value of the information. Examples of societal benefits are the codification of knowledge and second order benefits resulting from utilization of the knowledge produced/synthesized by the IAC. The participants agreed that the principal focus of this project should be on defining and, to the extent possible, measuring the private/organizational benefits of IAC operations.

Meeting Results. The participants agreed that the estimation of benefits was far from simple and that the overall magnitude of the problem of developing an operational cost benefit method exceeded the resources available for this project. Basically, the participants admitted that the problem of determining the value of IAC's was extremely difficult and that this project could not complete the needed research.

The benefit estimation model and procedure, as it had been developed, was judged to be inadequate for satisfying all the requirements of justifying IAC's before Congressional Committees and OMB. The model, although providing a lower bound on benefits, provides a bound that is inadequate for making decisions and budget presentations with confidence. In particular, the model and procedures should more explicitly account for the value of the data quality, timeliness, and reliability (characteristics which seem closely related to the unique, distinguishing aspects of an IAC vis-a-vis other information centers).

Although national defense and other issues of national interest are important, the participants believe that IAC's could not be justified solely on these issues and that more explicit identification and estimation of the benefits listed above are desirable.

The participants agreed that the emphasis in the remainder of the project should be on improving the benefit estimating procedure and on documenting the research results in a report which would be "free of jargon and easily read". Dr. Touloukian offered summary documentation of case studies which might be useful in determining the value of IAC services to user organizations. In addition, Mr. McCarn offered data from the National Library of Medicine on service demand curves. However, the concensus of the participants was that such data would not be representative of IAC services involving analysis and synthesis. The participants also encouraged the investigation, through further literature searching and possibly direct contact with users, the feasibility of quantifying the users' decision processes: i.e., determining what factors are used in making decisions on using an IAC service.

Final Project Effort and Conclusions

Based on the results of the second Overview Committee meeting, the project team emphasized the user aspects of benefit calculation and began documenting the concepts and research results. This final phase resulted in this report.

The project team examined the cases provided by CINDAS. These cases illustrated the organizational issues and difficulties associated with reducing funding for internal library-related information services, but they did not provide economically meaningful parameter values.

The project team also examined available research results on characteristics of users of IAC and related services. The subcontractor members of the project team analyzed the impacts on IAC costs and benefits of technological innovations. This effort examined the effects of two particular innovations - (1) the introduction and widespread adoption of a portable, acceptable microfiche reader and (2) the development within the STI community of a substantial network permitting terminal-to-terminal conferencing - by comparing alternative future scenarios for the IAC.

The project team documented these and other research results in a series of working papers which were then circulated among the project team members themselves, the project consultants, the members of the Overview Committee, and the sponsor for comment. The distribution of these working papers and the resulting comments proved a useful step: understandings of concepts, especially outside the project team, were enhanced.

The results of the project were further disseminated by presentations at the Engineering Foundation Conference in Easton, Maryland (August 29 - September 3, 1976) and by a summary project report in the ASIS SIG-IAC newsletter[3]. Each of these resulted in informal feedback on the clarity of the concepts, mode of presentation, and (usually) requests for additional information. Consequently, the research results have been disseminated and discussed informally prior to the formal completion of this final report.

List of References
for
Appendix D

1. National Referral Center, Directory of Federally Sponsored Information Analyses Centers, Third Edition; Washington, D.C.: Library of Congress, 1974.

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APPENDIX E

THE PRICING OF JOINT PRODUCTS AND SERVICES IN AN INFORMATION ANALYSIS CENTER

CONTENTS

INTRODUCTION

Information Analysis Centers

Information Analysis Centers (IAC's) provide different products and services which depend on common resources: personnel, data bases and documents and facilities. Because normal current policy, especially for the federally supported IAC's, emphasizes cost recovery, it is desirable to base product and service prices on the cost of providing the product or service. However, the utilization of common resources makes an analytic determination of the true costs of providing a particular output difficult or impossible. The problem then becomes one of allocating total costs among the different IAC outputs in a manner that is consistent with and that will facilitate the socially optimum levels of production and consumption.

The Joint Cost Problem

The General Problem. The problem of joint costs arises when there does not exist a unique relationship between the marginal costs of producing some output and the level of that output. Two outputs, X and Y, share the joint costing problem if the cost of producing an extra unit of X (the marginal cost of X, MC(X)) is not independent of Y. For example, if the total cost, TC, of producing X and Y is given by $TC = \partial_0 + \partial_1 X + \partial_2 Y^2$, there is no joint cost problem since $MC(X) = \partial$, and $MC(Y) = 2\partial_2 Y$; neither marginal cost depends on the level of the other output. However, if $TC = \partial_0 + \partial_1 X + \partial_2 Y^2 + \partial_3 XY$, then $MC(X) = \partial_1 + \partial_3 Y$ and $MC(Y) = 2\partial_2 Y + \partial_3 X$. The marginal cost of one product is not uniquely related to the level of that output, and thus there is a problem of joint costs.

A classic example of the joint costing problem is the cost of producing beef and leather from a steer. There is no apparently meaningful method to differentiate the costs of leather from the costs of beef,

and economists have failed to provide a general solution to this problem and to the general problem of joint costs.

The IAC Problem. There is one key difference between the general joint costing problem and the IAC problem. In the general problem (as in the beef and leather from cattle), the outputs are produced in fixed proportions. An IAC is not limited to producing services and products in any fixed proportions, however, and this fact permits the development of an operational, relatively simple solution to the problem of allocating costs to the different IAC outputs.

Criteria for Selecting a Cost Allocation Method. There are numerous methods for allocating costs, but the desire for an operational method (i.e., the assigned costs should be meaningful for control and pricing) suggests three criteria which the cost allocation should satisfy:

1. Assuming that the unit costs will provide the basis for pricing the output, the costs (and thus the prices) should induce an optimal mix of the outputs, as gauged by traditional measures of social welfare;
2. Assuming the unit costs will be used in production control decisions, the costs should induce the most efficient use of resources.
3. Assuming the unit costs will provide the basis for pricing the output and assuming a regulatory mandate that the facility earn only a normal return on investment, the assigned unit costs should cover the total costs of production and no excess profits. In other words, if the outputs are priced at unit costs, the resulting revenue should yield only a normal rate of return above total production costs.

Overview of Paper

The remainder of the paper consists of four major sections. The section following the introduction presents a basic conceptual model for an IAC with two outputs, the derivation of unit costs based on the assumption of an optimum production level, and a discussion of the model

and derivation. Chapter 3 extends the presentation to include the condition of non-optimum levels of production and describes an iterative procedure to determine optimum levels. This chapter also extends the approach to situations of decreasing marginal costs.

The final chapter is a brief summary of the significance of the model and its application. The paper concludes with a list of references.

ALLOCATION OF COSTS AT THE OPTIMUM PRODUCTION LEVEL

Basic Model

Assume that an IAC produces two services: an inquiry response service and a handbook. (Two services are used to keep the model formulation and discussion concise; the extension to more than two services is straightforward.) The generalized inputs to producing these outputs, in keeping with economic tradition, may be taken as land (nonrenewable resources), labor (internal staff and external personnel), and capital (equipment, building, computers). Let

I = Number of units of inquiry response service provided (e.g., number of pages of documentation or number of hours spent in answering inquiries)

H = Number of handbooks produced

L = Number of units of "land" used

N = Number of units of "labor" used

K = Number of units of "capital" used

The production function can be represented by the implicit function:

$$F(I,H,L,N,K) = 0. \qquad (1)$$

In words, the specification of the inputs (L,N, and K) allows certain maximum joint outputs I and H. Graphically, the function can be represented by a set of product transformation curves (PTC's) such as those shown in Figure E-1.

In Figure E-1 $(\bar{L},\bar{N},\bar{K})$ represents a particular level for each input, and the lower PTC represents all possible combinations of I and H which this particular input combination can produce. For example, $(\bar{L},\bar{N},\bar{K})$ can be used to produce either (I',H') or (I",H"). The set of particular input levels represented by $(\hat{L},\hat{N},\hat{K})$ is higher than $(\bar{L},\bar{N},\bar{K})$, thus the corresponding PTC is higher in the northeast quadrant than the first PTC. The slope of the PTC is the marginal rate of product transformation, or MRPT.

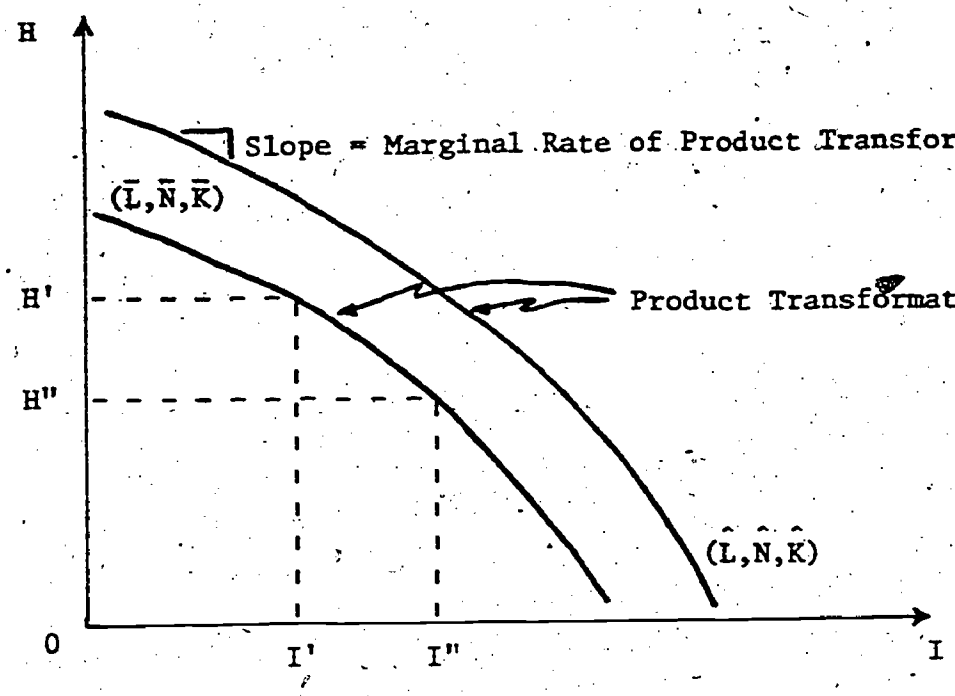

Figure E-1. Product Transformation Curves for an IAC

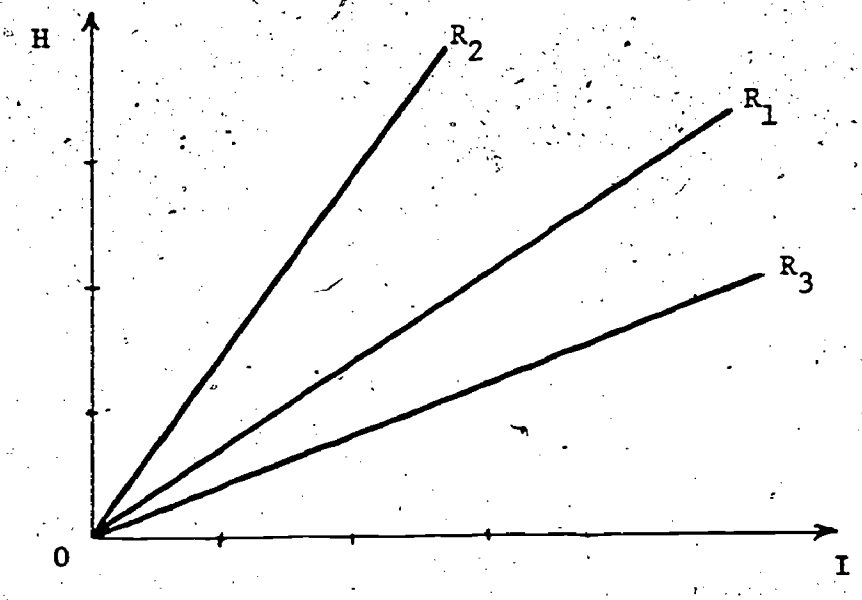

Figure E-2. Lines Representing Different Output Proportions

Note that different proportions of outputs can be represented by lines of different slope, each passing through the origin. For example, Fig. E-2 illustrates output proportions of R_1 (one handbook for each unit of inquiry response service), R_2 (two handbooks for each unit of inquiry response service), and R_3 (one handbook for each two units of inquiry response service).

Derivation of Unit Costs

This section derives unit costs by determining the implications of each of the criteria presented in Chapter 1. Initially, assume the optimal production decision has already been made and the only task is to assign unit costs. This restrictive assumption later is dropped.

The first criterion presented in Chapter 1 demands that unit costs (and by implication, prices) be consistent with optimizing social welfare. Social welfare is optimized when the value of the consumed goods most exceeds the cost of production.

Thus MAXIMIZE $\int P(H)dH + \int P(I)dI - C(L,N,K)$

SUBJECT TO $F(H,I,L,N,K) = 0$

where $P(H)$ and $P(I)$ are the ordinary demand curves for H and I, $\int P(H)dH + \int P(I)dI$ measures the gross benefits of consumption (area under the respective demand curves), $C(L,N,K)$ is the cost of inputs, and F the production function relating outputs to inputs. Using the Lagrangian approach to characterize an optimum, we have

$$L = \int P(H)dH = \int P(I)dI - C(L,N,K) + \lambda|F(H,I,L,N,K)|$$

whose first order conditions imply that

$$\frac{P_H}{P_I} = -\frac{\partial F/\partial H}{\partial F/\partial I} \qquad (2)$$

and, by assumption, the price of H will be its unit cost; and the price of I will be its unit cost. Letting C_H and C_I be the unit costs, we have

$$P_H = C_H \qquad (3)$$

and

$$P_I = C_I \qquad (4)$$

The second criterion presented in Chapter 1 demands that the assigned unit costs induce efficiency. That is, for any given quantities of H and I which are produced, the minimum cost of that production must be achieved. The objective therefore is to

$$\text{MINIMIZE } C_H \cdot H + C_I \cdot I$$

$$\text{SUBJECT TO } F(H,I,L,N,K) = 0$$

The Lagrangian first order conditions imply

$$\frac{C_H}{C_I} = - \frac{\partial F/\partial H}{\partial F/\partial I} \tag{5}$$

Finally, the third criterion demands that the IAC just break even, i.e.,

$$P_H \cdot H + P_I \cdot I = C(L,N,K) \tag{6}$$

or, total revenue must equal total costs.

Conditions (2) through (6) summarize the requirements that a <u>good measure</u> of unit costs should satisfy. Fortunately, there is some redundance in the equations. In particular, using (3) and (4), one observes that (2) and (5) are equivalent and that (6) may be expressed as

$$C_H \cdot H + C_I \cdot I = C(L,N,K) \tag{7}$$

Thus the issue reduces to finding (or assigning) unit costs so that both (5) and (7) are satisfied simultaneously. The optimum production decision determines the production levels (e.g., H* and I*) and the lowest cost, C*(L,N,K). Equations (5) and (7) then become two independent equations in two variables C_H and C_I, and a unique solution always exists. This is easily shown.

Note that $\frac{\partial F/\partial H}{\partial F/\partial I}$ evaluated at (H*,I*) has a particular value; let this value be K. Equation (4) may be rewritten as $\frac{C_H}{C_I} = - K$, or $C_H = - K\, C_I$, or $C_H + K\, C_I = 0$. Likewise C(L,N,K) at (H*,I*) is a particular, constant TC. The system comprised of (5) and (7) may be written as

$$\begin{bmatrix} 1 & +K \\ H^* & I^* \end{bmatrix} \begin{bmatrix} C_H \\ C_I \end{bmatrix} = \begin{bmatrix} 0 \\ TC \end{bmatrix}$$

The system has a unique solution as long as the 2 x 2 matrix has an inverse, and an inverse exists as long as the matrix is non-singular. Its determinant is $D = I^* - K H^*$. Both H^* and I^* are positive, while K is negative. It follows that D is necessarily positive. For later reference, the solution to the system is

$$C_H = \frac{-K \cdot TC}{I - KH}, \quad C_I = \frac{TC}{I - KH}$$

In order to make the approach operational, we need to show that the right hand side (RHS) of (5) is a meaningful expression. In fact, it is easy to show that the RHS is (5) corresponds to the slope of the isoquant in Figure E-1. That is, it is the rate at which the handbook and inquiry response services must be traded off when inputs are kept constant. To see this, start with the production function, (1),

$$F(H,I,L,N,K) = 0$$

and take the total differential

$$\frac{\partial F}{\partial H} dH + \frac{\partial F}{\partial I} dI + \frac{\partial F}{\partial L} dL + \frac{\partial F}{\partial N} dN + \frac{\partial F}{\partial K} dK = 0$$

Note that along a PTC, L,N,K are constant, so dL,dN,dK each equal 0. Using that result, and rearranging, we find

$$\frac{dI}{dH} = -\frac{\partial F/\partial H}{\partial F/\partial I}$$

That is, the slope of the PTC (the marginal rate of product transformation) is the negative of the RHS of (5).[1]

A simple example will show how the above approach, summarized by (5) and (7), can determine meaningful unit costs.

Suppose one has determined production levels of I = 200 and H = 400, and the minimum total cost is 100. Suppose the marginal rate of product transformation is 1.2, i.e., to produce one more unit of inquiry response while keeping all inputs constant, 1.2 fewer units of

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[1] Note that in the case of joint production with outputs in fixed proportions, $\frac{\partial F/\partial S}{\partial F/\partial E}$ is not defined since output substitution is not possible. Hence, as mentioned above, this approach will not solve the general problem of costing joint fixed proportion outputs.

handbooks must be produced. From (5) we know that

$$\frac{C_H}{C_I} = 1.2$$

and from (7),

$$C_H \cdot 400 + C_I \cdot 200 = 100$$

These can be solved to determine that the unit cost of handbooks, C_H, is .176, and the unit cost of inquiry response, C_I, is .147. These unit costs

1) induce an optimal consumption pattern
2) induce efficiency in resource allocation
3) provide a fair return to the information center

Discussion

This approach to costing joint information outputs leads to the somewhat surprising conclusion that it is not necessary to dissect the operations of the information center in order to determine the unit costs of the various information products and services. This is not to suggest, however, that the approach is completely divorced from the operational parameters of the system. Rather, the approach identifies and circumscribes the minimum requisite operational information: the trade-off rate between or among the various information output forms in the neighborhood of the desired output levels as inputs are held constant. Although this trade-off rate rarely is readily apparent, it usually can be estimated by a combination of design and operating data. Given our criteria for judging the "goodness" of estimated unit costs, the unit costs derived using the above approach must be judged superior to unit costs which are based on a thorough analysis of the information service process, even though far more information presumably would be required, by the latter approach. The merits of our approach thus include economy of information as well as improved unit costs.

The model thus far has been concerned with the purely static problem of assigning unit costs in a joint product situation after the production decision has been made. In particular, if the socially op-

timum production level has somehow been determined, then the unit costs defined by (5) and (7) have the three especially appealing properties discussed in Chapter 1.

Now suppose the optimum production level must be determined. Can prices based on our unit costs aid in this determination? Are conditions (5) and (7) consistent with the socially optimum production level? The latter question is important because we have not yet established that the quantities demanded of the various energy forms at the unit prices defined by (5) and (7) will be consistent with the quantities supplied which gave rise to those prices. The remainder of this paper defines the concept of optimum production level, examines the relation between production levels and unit costs, constructs an iterative approach which drives production to its optimal level, and finally demonstrates that the solution iteratively achieved is consistent with the static costing conditions represented by equations (5) and (7).

DETERMINING THE OPTIMUM PRODUCTION LEVEL

The Optimum Level of Production

From society's viewpoint, the best output level for any good is that level at which its marginal revenue product (MRP) equals its marginal cost (MC). A good's MRP is the value added by the last unit produced of the subject good in the production of some other good. MC, of course, is the cost of producing the last unit of the subject good. To see that MRP = MC is the condition for optimality, assume it is violated. Specifically, assume MRP > MC. This means that, for example, if the last copy of a handbook used in the production of widgets adds $50 to the value of widgets produced, while the cost of the last is $20, then the production of one more handbook yields a net benefit of $30 ($50 in gross benefits less $20 in cost). Equally clear is that the initial production level of handbooks improves social welfare. Only if MRP = MC is no improvement possible, and thus the output level at this point is optimal.

Figure E-3 illustrates this argument. At low levels of H, MRP exceeds MC and benefits are derived by increasing H. At high levels, the converse is true. The MC curve for H can be considered as being constructed in terms of the number of units of inquiry response, I. The MC of a unit of H is, indeed, the units of I sacrificed. Thus the MC curve reflects the values of the slope along a product transformation curve of Figure E-1. Since more and more I must be sacrificed to successively increment handbook output, MC_H necessarily rises to the right. MRP_H slopes downward to right due to the law of diminishing marginal productivity. Extra copies of the handbook add less and less to the value of widget production, ceteris paribus.

Unit Costs, MRP, and MC

The approach detailed in Chapter 2 is based on the premise that output levels are used to determine unit costs. These costs, or prices,

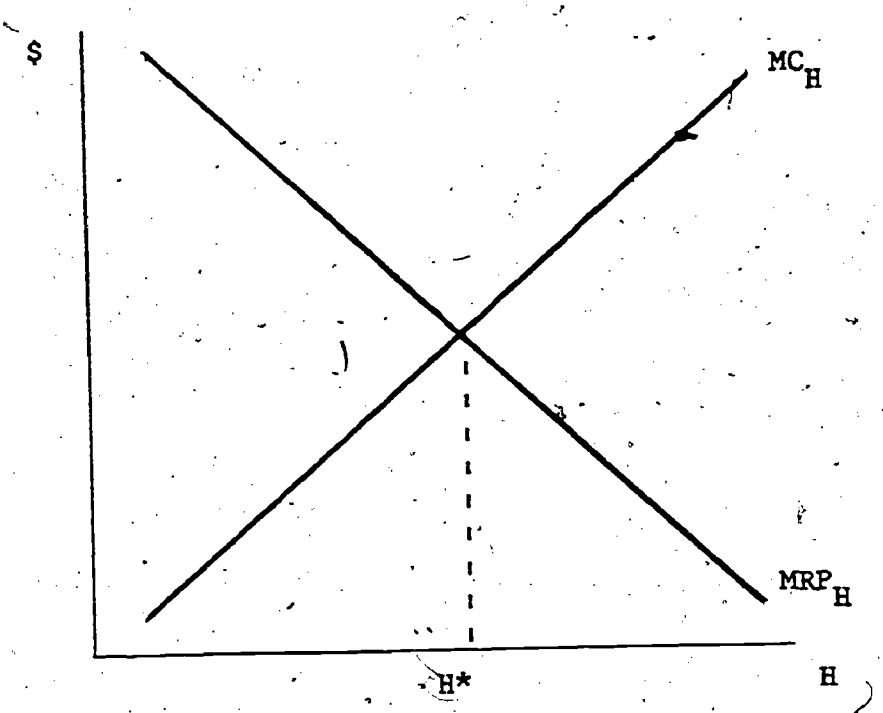

Figure E-3. The Optimal Level of Handbook Production

are then used by production management to efficiently channel resource use and by customers as the basis for their purchase decisions. It is well known from economic theory that customers will purchase H and I in amounts such that

$$\frac{MRP_H}{MRP_I} = \frac{P_H}{P_I} \qquad (8)$$

and that efficient production managers will produce H and I so that

$$\frac{MC_H}{MC_I} = \frac{P_H}{P_I} \qquad (9)$$

(8) and (9) are first order optimizing conditions for customers and managers, respectively.

Before proceeding we add an additional assumption to the model: assume the total cost function for H and I is linear homogeneous. That is, if the total cost (TC) is

$$TC = g(H_0, I_0), \text{ then } \quad a \cdot TC = g(aH_0, aI_0) \quad \text{for } a > 0 \tag{10}$$

It must be stated that (10) is merely a simplifying assumption and will be discarded in later discussions. Nonetheless, there is a good deal of evidence that cost relations do tend to be linear homogeneous, and this assumption enables us temporarily to avoid second-best problems.

Suppose the current level of handbook output is H^S (handbooks supplied) and the current level of inquiry response output is I^S. At these output levels there is defined a Marginal Rate of Product Transformation (MRPT). The MRPT determines the ratio of the unit costs C_H to C_I from (5). Equation (7) determines their absolute level. The solution to this set of two simultaneous equations yields unit costs

$$C_H = \frac{-K \cdot TC}{I - KH} \tag{11}$$

where $K \equiv \frac{\partial F/\partial H}{\partial F/\partial I} = -$ MRPT between H and I

From (3), (4), and (5), we see that

$$K = -P_H/P_I \tag{12}$$

and from (9) and (12) we have

$$K = -MC_H/MC_I \tag{13}$$

Substituting (13) into (11) yields

$$C_S = \frac{\left(MC_H/MC_I\right) \cdot TC}{E + \frac{MC_H}{MC_I} H}$$

Multiplying the right hand side by $\frac{MC_I}{MC}$ results in

$$C_H = \frac{MC_H \cdot TC}{MC_I \cdot I + MC_H \cdot H} \tag{14}$$

Now, by assumption, the total cost function, $TC = g(H,I)$ is linear homogeneous. By Euler's theorem we have

$$TC = \frac{\partial TC}{\partial H} \cdot H + \frac{\partial TC}{\partial I} \cdot I \equiv MC_H \cdot H + MC_I \cdot I \tag{15}$$

Substituting (15) into (14) and simplifying yields

$$C_H = MC_H \tag{16}$$

and it is easily shown that

$$C_I = MC_I \tag{17}$$

Thus if the total cost function is linear homogeneous, the unit costing approach defined by (5) and (7) is nothing more than assigning marginal costs as unit costs. Using these unit costs as prices thus is simply marginal cost pricing.

An Iterative Procedure to Determine the Optimum Level

Having shown that the unit costs are, in fact, marginal costs, an algorithm to find the optimal output level is easily constructed. As might be expected, the algorithm simulates a competitive market. At the current (assumed non-optimal) output levels, H^S and I^S, the unit costs defined by (5) and (7), C_H and C_I, are simply MC_H and MC_I. Consider MC_H and refer to Figure E-4. Since H^S is less than H*, the unit cost (price) defined by H^S (found on the MC_H curve) elicits a quantity demanded in excess of H*. An excess demand for the handbook is management's signal to increase H^S, which defines a new C_H, a new H^D, and so on. At each step, excess demand (or excess supply) signals the direction of changes needed in H^S. Convergence toward H* is assured.[2] A similar series of steps is, of course, carried out in the I market. It is worth noting that the MC curves are not fixed. Rather, because H and I are joint products, MC_H shifts with changes in I and MC_I shifts with changes in H.

Note also that each step in the dynamic process of moving toward the optimum is consistent with (5) and (7). This unit costing approach is appealing not only at the optimum but at sub-optima as well. Applied in an iterative fashion, the same unit costing rules which support an

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[2] We have not defined a rigorous convergence process since the literature abounds with examples. The precise convergence process is only a tangential issue here.

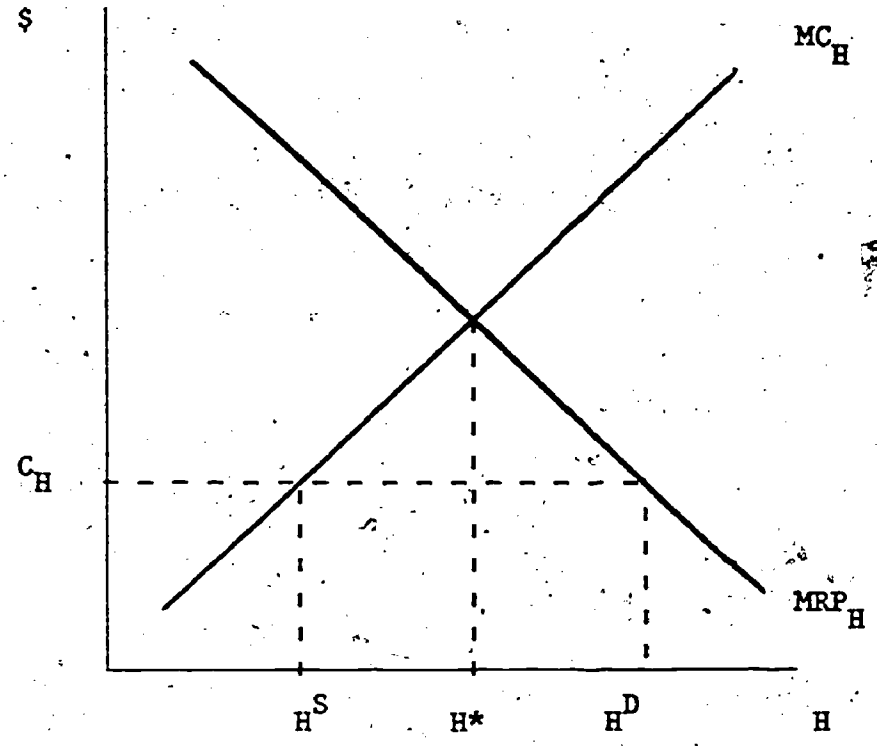

Figure E-4. Non-optimal Levels of Handbook Production

optimum can lead production decisions toward that optimum. The optimum and the unit costing rules thus form a stable equilibrium, with deviations from the optimum signaling for decisions which return the levels to the optimum point.

Extension to Decreasing Marginal Costs

This section briefly indicates how the above approach to determining unit costs in a joint production situation can be extended to the case of decreasing marginal costs. It is well known that marginal cost pricing in the presence of decreasing marginal cost results in negative profits. Clearly then, marginal cost pricing cannot be adopted by an IAC which desires to break even. With the constraint to assure a violation of the social production optimality condition, the problem is to find the "second-best" conditions. The problem is to choose unit costs

which satisfy (7) and yet yield the greatest social welfare. Operationally, the produced quantities of H and I will be less than their socially optimal ("first-best") levels. How should the production cuts be distributed between H and I?

The problem can be formulated as follows: maximize the net benefits from the consumption of H and I while maintaining total revenues equal to total costs.

Net Benefits = Gross Benefits - Gross Costs

$$= \int_0^H P(H)dH + \int_0^I P(I)dI - g(H,I) \tag{18}$$

where $MRP_H = P(H)$ and $MRP_I = P(I)$. These, of course, are the demand curves for H and I, respectively. The total cost function for H and I is g(H,I).

$$\text{Total Revenues} = C_H \cdot H + C_I \cdot I \tag{19}$$

where C_H and C_I are the unit costs to be determined.

The appropriate Lagrangian expression is, using (18) and (19),

$$L = \int_0^H P(H)dH + \int_0^I P(I)dI - g(H,I) + \lambda(C_H \cdot H + C_I \cdot I - g(H,I)) \tag{20}$$

Observe that if C_H is the unit price of H and $\hat{H}$ units are demanded at C_H, then the MRP_H at $\hat{H}$ is C_H and

$$\frac{\partial L}{\partial H} = C_H - MC_H + \lambda\left(C_H + H\frac{\partial C_H}{\partial H} - MC_H\right) = 0 \tag{21}$$

$$\frac{\partial L}{\partial I} = C_I - MC_I + \lambda\left(C_I + I\frac{\partial C_I}{\partial I} - MC_I\right) = 0 \tag{22}$$

Now recall that elasticity of demand (for H) can be expressed

$$E_H^* = -\frac{C_H}{H}\frac{\partial H}{\partial C_H} \tag{23}$$

Using (23) and the analogous expression for E_I, (21), expression (22) may be rewritten as

$$C_H - MC_H + \lambda\left(1 - \frac{1}{E_H} - \frac{MC_H}{C_H}\right) = 0 \tag{24}$$

$$C_I - MC_I + \lambda\left(1 - \frac{1}{E_I} - \frac{MC_I}{C_I}\right) = 0 \qquad (25)$$

Solving each of (24) and (25) for λ, equating, and rearranging terms results in

$$\frac{(C_H - MC_H)/C_H}{(C_I - MC_I)/C_I} = \frac{E_I}{E_H}$$

The solution to this second-best problem is that each unit cost must be set so that its percentage deviation from marginal cost is inversely proportional to that good's elasticity of MRP[3]. Thus, while retaining condition (7), expression (5) must be replaced by (26). The simultaneous solution of (7) and (26) define second-best unit costs under joint production. An iterative procedure may also be constructed on (7) and (26) to drive production toward its second-best level.

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[3] Baumol and Bradford derived this result in [1]; however, our derivation seems somewhat more straightforward.

DISCUSSION

Unit costs of production form the basis for crucial resource allocation decisions. Especially in the case of joint products, unit costs tend to be computed from crude conceptual dissections of the engineering operational production system and arbitrary rules of thumb for allocating joint costs. Using the example of an IAC, this discussion has shown that even in the cases of nonseparable production of joint products, meaningful unit costs may be constructed with a minimum of information. The approach is to characterize "good" unit costs and derive the costing rules from these characterizations. The paper demonstrates that when total cost is a linear homogeneous function, the unit costs are simply marginal costs. The unit costs assigned by conditions (5) and (7) not only support an optimum production level, but are the foundation for a sequential decision process which drives output levels toward the optimum. Finally, in second-best cases, the unit costing approach must be modified by substituting expression (18) for (5).

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