AN APPROACH TO THE VALUE OF INFORMATION: EFFECTIVENESS AND PRODUCTIVITY OF INFORMATION USE IN RESEARCH WORK

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SUMMARY

The economics and value of information have been analysed in this study. Efforts have been made to deepen our understanding of the value of information in information work. The literature of information science and economics were reviewed but suitable ready-to-use methods and techniques for the assessment of the value of information in the research work tasks were not found. A dual approach to the value of information was developed from the theoretical analyses and later tested in empirical studies: (1) The exchange value of information products, services, channels and systems should be studied using economic methods. (2) The value-in-use of information should be studied using the cognitive approach which takes the user, the use and the effects of use of information into consideration. The approach was used in the empirical studies in a research organization. A model was developed for optimizing the value of information for research work. The following 'management actions' are needed: (1) ensure that results of research are 'published'; (2) ensure that there is a rich information environment for research; (3) encourage joint efforts in information seeking and use; (4) ensure that information found is actually put to use; (5) improve the seeking of methodological information; and (6) ensure that the time used for information seeking and use is appropriate to the project. Data for the model have to be collected in respect of the present state of affairs under investigation concerning each of the above actions.

PREFACE

This work is about the economics and value of information. The aim is to deepen our understanding of the value of information in knowledge work. It is impossible to indicate the exact beginning of this work although it has mainly been carried out over the last three years. There are a number of occurrences which have provided a background for my research interests. The most important ones have been my working at the Ministry of Finance in Finland in 1979 and in 1980, a phone call from Professor Marjatta Okko in autumn 1983 which led to my holding an acting assistant professorship at the University of Tampere, Department of Library and Information Science until the end of 1984, and my participation in the instigation of research activities at the Information Service of the Technical Research Centre of Finland (VTT) during the early 1980s.

Some preliminary work was done while working at the University of Tampere and later at VTT. However, a one year stay at the University of Sheffield, Department of Information Studies in 1985/86 allowed me to dedicate myself to research on the value of information. The theoretical studies and a pilot-study as well as a preliminary plan for the empirical studies were done in

Sheffield. The empirical work took place at VTT in 1986/87/88 as an internal research project.

I owe a number of people a debt of gratitude for their help and support. My supervisor Professor T. D. Wilson is the first to whom I am indebted. Bureau chief Tarmo Lemola has been my closest adviser and supporter at VTT. Dr. Norman Roberts and Mr. Kevin Barkla in Sheffield, and Mr.Bo-Crister Björk, Mr. Rauno Heinonen, Mr. Anssi Hyvärinen, Mr. Sauli Laitinen, Dr. Matti Leppihalme, Mr. Raimo Lovio, Mr. Reijo Miettinen, Dr. Erkki Ormala, Dr. Tapio Reponen and Mr. Jaakko Virkkunen in Finland have given valuable help, support and encouragement in various phases of the study. I wish to thank also Mr. Pete Thomas for his linguistic revision of the manuscript.

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Part I: Introduction

1. INTRODUCTION

1.1 General

In the past two or three decades the economics of information has become a popular issue among information scientists and economists. The reason for this has been said to be the growth of the importance of information activities for societies, organizations and individuals. Alternatively, is it just that the economic role of information has only recently been recognized?

The role of information in future societies has been emphasized by many futurists (Russel 1986; Toffler 1981; Cleveland 1982; Masuda 1975). Russel, for instance, states the new nature of information as follows:

> "in the Industrial Age, when our whole emphasis was on a manufacture of things, information was a necessary evil, like janitoring, Governments gave it away, treated it like a public good, valuable but unsellable. As the Information Age rolls in, the task before us is to economize the flow of information. This means learning how to measure its quality at each stage in the process, and putting a price on it. Once we have learned to do that, we can begin to improve the

productivity of the information process, assure its quality, improve its input into the production of other goods and services, and create a fair, honest and efficient information marketplace, in which we all may prosper." (Russel 1986, p. 8)

While Russel (1986) emphasizes that information is a main resource in the future society, Masuda (1975) and Cleveland (1982) suggest entirely new economies based on the emerging role of information. Cleveland's "sharing democracy" and Masuda's "individualized leisure-time value" propose fascinating scenarios for the future but lack continuity in respect of historical development. On the other hand, such ideas offer refreshing new thoughts for avoiding problems of those who treat information identically to other resources.

The value of information, on which we focus our attention in this study, has been studied recently by library and information scientists, economists, management scientists, accounting researchers, and computer scientists (Taylor 1986; King et al. 1983; Martyn & Flowerdew 1983; Machlup 1980; Black & Marchand 1982; Agrawal & Zunde 1985). A lot of research in this field pays tribute to an early communication engineering study by Shannon and Weaver (1949). Some behavioural and social scientists have also touched on the issue of the value of information (see e.g. Larsen 1980; 1985; Newman & Newman 1985).

A tentative description of the nature of the earlier research on the value of information can be obtained from Black and Marchand (1982). They list six approaches taken:

1) Information Technology or Data Processing Approach: used in computing,
2) Information/Library Science Approach: which concentrates on the use of documents,
3) Information Resource Management (IRM) Approach: which concentrates on accounting and budgeting information in organizations,
4) Value/Burden Approach: a special form of IRM approach widely discussed in connection with the Paperwork Reduction Act in the U.S.A.,
5) Organizational Theory Approach: which analyses human decision making and organizational communication patterns, and
6) Economic Theory Approach: which uses statistical and probability theory in describing the value of information.

1.2 Emerging Paradigms

This study is based on the research done by information scientists and economists. Attention is focussed on the value of information, one of the key issues in the research on the economics of information. The initiative for this "dual approach" derives from an awareness of the problems scientists in both areas have faced in considering the value of information. There are also explicit pleas for this kind of study in the literature of information science (Martyn & Flowerdew 1983). However, others such as Urqhart (1976) regard studies on the value of information as fruitless. In spite of these controversial views there seems to be general consensus on the practical need for assessing the value of information, information products, systems and services; and it is to this end our efforts are aimed.

It is possible to simplify and perhaps also broaden the picture of the past valuing approaches as described above by Black and Marchand (1982). There are three paradigms (see NOTE 1) used to study the value of information:

1) Economic Paradigm,
2) Cognitive Paradigm, and
3) Information Theory Paradigm.

The Economic Paradigm deals with exchange and measurable values (Marchak 1968; Machlup 1980; Machlup 1983). The paradigm can be characterized by the quotation: "... stocks of knowledge are neither measurable nor comparable, whereas flows of knowledge can be quantified and appraised by the "measuring rod of money" applied either to what is being paid for the knowledge by those who buy it ... or to what is being given up for it to be made available."

(Machlup 1980, p. 178). This paradigm is behind the modern IRM approach.

The Cognitive Paradigm focusses its interest on the understanding of the dynamics of scientific thought. An internal model or representation of the environment which individuals operate plays an important role in the paradigm (Mey 1982). There is no agreement about the paradigm of information science. One could say however that cognitive processes play an important role in many approaches taken and thus the use and value-in-use of information have been of interest (for discussions of information science see, for instance, Belkin 1978). This paradigm is often behind organizational theory approaches.

The third, Information Theory Paradigm, which uses statistical and probability measures has been broadly discussed especially in the theoretical literature of economics and accounting (Hirshleifer 1973; Lawrence 1979; Demski 1980). While the basis of the paradigm has its origin in Shannon's ideas (Shannon & Weaver 1949), many of the interpreters broaden the original communication engineering problem.

The paradigms are thoroughly discussed in reviews of research on the value of information. There are attempts to overcome the problems each paradigm has met in describing the value of information, information products, systems and services, and there have also been attempts to use paradigms jointly (e.g. Mock 1971). This study uses the cognitive paradigm of the social sciences but also tries to integrate other paradigms. As Roberts (1976, p. 257) puts it:

> "... the requirements of social explanations imply that the individual, the ultimate justification of all information work, services and theorising, cannot be excluded from the considerations of information scientists. This does not imply reliance upon the psychologism ... but it does mean that expressions and observations of individuals in 'information situations' have a crucial role to play both in the resolution of practical problems and in the formulation of theories and that a concern solely with linguistic, or statistical, or other external attributes of documents and document collections is ultimately stultifying."

1.3 The Aim of the Study

In the study, research on the value of information in the fields of information science and economics is reviewed and analysed. The study of the value of information is of importance because it offers a means to increase productivity by better management of available information, by the creation of better information products, and by the development of better information handling skills of both information professionals and information users (Brinberg 1982). Our research sets out to:

1) analyse and assess the research done heretofore in order to find methods and techniques for research managers to measure the value of information in practical situations. Fairly broad reviews are needed because the earlier reviews have not paid much attention to these considerations and empirical research is still hard to find in the bulk of theorising and discussions papers. The result of this research will provide a framework for further research.

2) study the value of information in organizational settings. Empirical studies of the use of information are needed because it is understood that the value of information cannot be studied at a general level and because past research does not offer ready to use models or tools. The result of this research is a model for optimizing the use of information in research work which gives an indirect measure for the optimal value-in-use of information.

Special attention is paid to the analysis of earlier research findings and efforts which are made to bridge the gap between economists and information scientists in the issue of valuing information. Although it often proves impossible to integrate paradigms, for practical purposes, the arguments are put forward to use the economic paradigm and the cognitive paradigm simultaneously. The present low state of awareness of the economics of information use means that one cannot get much out of information use in pure economic terms. The cognitive nature of information use also means that economic analyses are unable to fully explain the value-in-use of information. On the other hand, emerging information markets push forward the economic analysis of information products and services.

1.4 The Course of the Study

The study began with two reviews. The first, 'Economics of Information' (Appendix 1) reviews the empirical research performed in information science and neighbouring sciences. A fairly broad background for assessing the value of information is produced in order to find an extensive methodological basis for further efforts. The second review, 'THE VALUE OF INFORMATION: APPROACHES IN ECONOMICS, ACCOUNTING AND MANAGEMENT SCIENCE' (Appendix 2) concentrates only on studies on the value of information. Although it was supposed to be a review of empirical research, the theoretical emphasis of the research directed us to study different approaches taken to the value of information by economists. These reviews are aimed at giving the reader a broad enough background for a joint information science and economics approach and they also offer an updated reading of the research on the value of information.

The second chapter, 'The dual approach to the value of information: an appraisal of use and exchange values' presents the theoretical framework for studying the value of information. The framework is used to analyse some earlier studies and references are made to the two reviews mentioned earlier. The third chapter, 'The value of information: a framework for research' summarizes the study heretofore. Special attention is paid to earlier research on the value of information, on the pilot study of a biomedical information service and its users (full report in Appendix 3) and on the framework for further research.

The fourth chapter, 'The value of information in organizational settings - background, scope and methods for a study at the Technical Research Centre of Finland' presents the main empirical work. A selective review of the studies on the use of information in engineering is given and methodological issues appropriate for our study are dealt with. The following three chapters (Chapter 5, Chapter 6 and Chapter 7) report on the results of the VTT studies. The results are documented in the order in which the studies have advanced.

The eighth chapter, 'The value of information in organizational settings: a framework for managaging information use' draws together the main findings of the empirical research and presents research managers a framework for monitoring the effectiveness of information use in research work. In the nineth chapter the summary and conclusions of the whole study are presented.

NOTE 1. Paradigm concept is used simply as a means of grouping research on the value of information. Whether or not the concept is useful in describing the development of sciences is not an issue here.

Part II: Literature reviews and methodology

2. THE DUAL APPROACH TO THE VALUE OF INFORMATION: AN APPRAISAL OF USE AND EXCHANGE VALUES

2.1 Introduction

In this chapter we focus on the value of information, information products and services from the viewpoint of information use. Our approach is based on two principal considerations. The first one is the philosophical value consideration of information, and the second is the classification of information and knowledge needed in a knowledge-work task. By knowledge-work we mean here work where the acquisition, processing, storing and communicating of information plays a major role (Järvelin & Repo 1982). For our purposes there is no need to speculate on which occupations belong to the category of knowledge workers and which do not - most people still perform knowledge-work tasks every now and then. Our aim is to develop a framework for analyzing the value of information from the viewpoint of information use. The framework is used in the analysis of some research already performed in the field.

The chapter starts with a brief review of the economics of information (Section 2.2) and the conceptual analysis of the value of information (Section 2.3). Section 2.4

presents our approach to the value of information in greater detail and in Section 2.5 the approach is used in analysis of the empirical research already performed on the value of information. The literature reviews upon which this chapter is based are in Appendix 1 and Appendix 2.

2.2 The Economics of Information in Information Science

Classical economic theories are based on concepts like production, supply and demand, markets, scarcity, resource allocation, exchange, and private and public goods. The production costs of most information systems and products are fairly easy to deal with and even to measure, but problems arise in measuring the outputs, "information resources" and "information goods". The straightforward empirical economic analysis of information products has met serious problems especially in describing the benefits the use of information products really give (see Mason & Sassone 1978). On the other hand, despite the substantial research activity, recent economic research has been unable to introduce any practical means of broader use for valuing information (Hirshleifer 1973; Repo 1988, Appendix 2).

Interesting views on problems of economic theories of information have been presented, for instance by Newman (King et al. 1983) who introduced an institutional perspective on information. Others, like Horton (1982) and Cleveland (1982) have expressed thoughts on special features of information in comparison with other resources. Cleveland (a political scientist) gives an exhaustive list of the characteristics of information as a unique resource:

1) Information is human. It exists only through human perception.

2) Information is expandable. The free flow of information maximizes the use, but in many cases this is against the economic thinking of those who know something valuable. However, the bulk of useless information products around us has made this argument sometimes questionable.

3) Information is compressible. The increasing deluge of information is possible to control - at least in principle - by concentrating, integrating and summarizing it from different points of view.

4) Information is substitutable. It may save money by substituting the use of other resources.

5) Information is easily transportable by using applications of new information technology.

6) Information is diffuse. It tends to leak, though we material-minded people try to own it.

7) Information is shareable. By giving away information one does not loose it, as is the case with things.

Given these special features of information it is not surprising that the analysis of information, information services and products has tended to be carried out from the viewpoint of the user. However, Rich (1980) criticizes this viewpoint in connection with paperwork reduction efforts in the United States, because he believes that there is always someone to whom information is of value. The criteria for valuing should be taken from the broader context, from increase of citizen well-being in Rich's case. This is a preliminary hint of the need to have several viewpoints while analyzing the value of information. In an economic sense the most commonly used method here is cost-benefit analysis (CBA) which is also used among information scientists (as the review of Flowerdew & Whitehead (1974) reveals). CBA has been broadened recently to include value considerations, which should result in more emphasis being placed on the non-monetary benefit side of the analysis (see review in Griffiths 1982).

The economics of information has been an issue among information scientists for more than two decades. During the past few years this subject has aroused interest for two main reasons: libraries and other nonprofit information units in many Western countries are suffering from the budget-cuts, and other organizations have widely introduced the Information (Resources) Management approach that emphasizes the economics of information, information systems and products.

There are already many reviews on the economics of information (Flowerdew & Whitehead 1974; King et al. 1983; Martyn & Flowerdew 1983; Casper 1983; Roberts 1984). While studying the empirical research in the area we have found nine main research topics (Repo 1987b, Appendix 1):

- costs of information products and services
- price of information
- evaluation of effectiveness and efficiency of library and information services
- cost-benefit analysis of information transfer
- value of information in the light of examples
- information service as a value-added process
- economics of information retrieval
- macro-economic studies of information and productivity
- economics of information processing.

These groups were derived from about 100 empirical studies. The list is hardly exhaustive, but reveals the research done so far. Additionally, several other studies as well as most empirical studies, present theoretical discussions and expressions of opinion on the problems of measuring information systems and products (reviews of Flowerdew & Whitehead (1974) and Griffiths (1982)). During the last decade, there has also been a clear shift from cost and effectiveness/efficiency studies towards the value and benefit considerations, which has also meant that the issues now being handled are far more difficult to deal with using classical economic theories.

2.3 The Value of Information: A Philosophical Approach

A preliminary definition of the value-concept is obtained from Croft (1977): "A value is an enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end state of existence." Rothenberg (1975) divides values into market values and social values. Market values are determined by what individuals are willing to pay for trade commodities or services. However, many economists see that there are also "general welfare", social benefits which influence the value considerations (Martin 1986). While dealing with the use of information the social values are very important, but they are hard to define. This specification is also too general for value considerations (see also Rich 1980).

Our analysis of the value of information has a philosophical background. We see values as phenomena which make man aim at a certain goal instead of other alternative goals. Values can be divided into two main categories:

- philosophical (or intrinsic) values, and
- practical (or instrumental) values.

The philosophical values have intellectual or emotional meaning to a person, but are very hard to specify - sometimes it is possible only to name them. Emotional, ethical and spiritual values are examples of philosophical values. Information and information products usually have philosophical values, but our 'practical' orientation leaves them almost entirely unexplored.

The practical values can further be divided into

- value-in-use (or use values), and
- exchange values.

As also in this paper, the value-in-use of information is taken as a basis for the value consideration of information by many information scientists and practitioners (Griffiths 1982). The value-in-use is that benefit which the user obtains from the use and the effect of the use. The value-in-use of information is most often described by such measures as willingness to pay and time savings. Value-in-use can be further categorized according to the facts of use (measured by payments for information and reading time), the way information is used (described by users), and the benefits of use (measured by time and money savings). Willingness-to-pay has been used to describe expected value-in-use.

Exchange value, on the other hand, is an economic concept which has quite a different role in valuing information, or merely information products as we shall point out later. The economists who usually speak of the value of information in terms of exchange use this distinction only for solving the "paradox of value": value-in-use is attached to such important but cheap things as water and air. We believe that in connection with information this distinction has more significance.

For us this value analysis is a tool for describing the value of information in situations where information need and use are explained by value-in-use. Information services and products are assessed in exchange values. We define value-in-use of information in three parts each of which has a particular role in assessing the value of information in practice:

- subjective expected value-in-use of information. This valuation takes place when an individual decides whether or not to seek and use the information product or service. The valuation is based on past experiences and/or expectations of the information products and services available.

- subjective value-in-use of information. Opinions of individuals on the value of information used in their work. Reduction of uncertainty is a commonly used expression of this value.

- objective value-in-use of information. The value of the effects the use of information has had on a task and its results.

The exchange value of information refers to information products and their exchange value in the market. The exchange values can be derived from the value-in-use if we can find its money-value and then use "opportunity costs" for comparing other possible usage for the costs invested. If this is possible it should always be done because only at exchange value level can one make any direct comparisons of values. However, information seems to belong to that group of phenomena where we have to live with these two categories. As long as the actual decisions of information seeking and use are in the hands of individuals (this is usually the case in practice) the expected value-in-use of information is also of interest. While value-in-use is usually studied by interviewing individuals, more "objective" results can be gained by collecting information about knowledge-work.

For our analysis of the value of information we define information in terms of a value-added process. Here data are unorganized information about facts, events and ideas;

information is both organized data which can be transferred between individuals as well as the act of transferring. Knowledge is the state of someone knowing (includes understanding) and knowing must be treated as a cognitive process (Cleveland 1982; Machlup 1980; Machlup 1983; Taylor 1982). The criteria for the determination of the value of information arise out of the process of use and the seeking of it. Taylor (1982) uses the expression "information environment" for the use situation, but we disregard this concept and take the use of information (and "knowledge-work") as the basis for determining the value of information. This approach provides some preliminary tools, or ideas at least, for the analysis of the use of information. In order to get a better understanding, however, one should go much deeper into the analysis of the knowledge-work actually done. For somewhat supporting ideas see (Rasmussen 1985) where the value of information, and information seeking and decision making in connection with systems control are analysed.

Although a decision for information seeking and use is a personal one, the use of information will depend not only on its validity, quality or ease of use (the examples of determinants for value-in-use) - but also on a degree of fit between the information provided and the environment within which the user operates and makes decisions (the world of exchange values) (see also the somewhat different ideas of Taylor 1982). Thus, we have to deal with these "two separate worlds" while describing the value of information instead of putting everything together.

2.4 The Value-In-Use and Exchange Value of Information

In this section we demonstrate our value approach to information and knowledge-work. Our aim is to analyse the valuing process from the viewpoint of information use. This can be seen as a minor exercise in opening the black box of information use, which is often thought to be insufficiently studied (Caplan 1984; Järvelin & Repo 1984).

Our starting point here is the hypothesis that the user of information gives value to the piece of information when the information is used. This takes place in relation to a knowledge-work process (for instance, a research project) so that the information must first have expected value-in-use to awaken the interest of the user, who actually decides whether to use the information or not (subjective expected value-in-use). The best representatives of knowledge-work processes are problem-solving or decision making (see, for instance, Järvelin (1985) for a more detailed discussion). Actual value-in-use can be identified if it is possible to trace the role of information for a knowledge-work task (subjective value-in-use) and isolate the impact of that particular information on the output of the task (objective value-in-use).

The philosophical values may have the role of an umbrella: they provide a framework for a knowledge-work task, though they seldom have direct connections to it. In practical situations these value considerations are seldom conscious, but they often have some "background role" in human reasoning. For an individual, exchange values only have meaning at the level of the results of knowledge-work where he may trade his information products. Only if there are clear practical alternatives available in information-seeking may one consider the situation in terms of the exchange values. But even then it is merely a question of information products, services or channels to choose from, where the information content is more or less the same.

We argue that the analysis of the value of information has not, as yet, really reached value-in-use. This is true mainly because the different aspects of values have not been analysed clearly enough. It is necessary to analyse more deeply the knowledge-work situations and the use of information in them before one is able to analyse the value of information to its user and in use. Previous research is analysed in Section 2.5, below.

A problem solving task gives rise to the need for value-added information: data organized into information and information synthesized and judged to be knowledge for that particular problem. It may contain subtasks like interpretation, diagnosis, monitoring, prediction, planning and design, which are examples of nonroutine tasks requiring expertise. Of course, within these tasks one must acquire, process, store, transfer and use data and information.

A knowledge worker (a person performing knowledge-work tasks most of the time) having a problem, first shapes some kind of pre-understanding of the problem and its environment. If the task is given to him, someone may also give him some preliminary information. All the background knowledge, beliefs, and values gained from education, previous tasks and other experiences influence how he understands the problem. Solving the problem then usually gives rise to the need for new, problem-oriented information.

One can find five kinds of knowledge and information which are needed and processed during a problem solving or handling task (Järvelin & Repo 1984):

1) Task Knowledge - knowledge that determines the problems and tasks in the domain.
2) Domain Knowledge - earlier produced and organized data and information about the facts and relations which contribute to the problem.
3) Problem Knowledge about the conditions of the problem on hand.

4) Problem Solving Knowledge - methodological know-how needed.
5) Outcome Knowledge - new knowledge produced in the task: part of this is often presented as output information in the form of reports, manuals etc.

These five different types of information have varying roles for a knowledge-work task. Task knowledge may be given or 'found' for a knowledge-work task to be done, and valuing of it requires objective information and knowledge requirements to be known. Domain, problem and problem-solving knowledge and information can be valued by the knowledge worker.

There may already be "value-added" domain information, but it still needs to be interpreted and evaluated to become knowledge for that particular task. Problem-solving knowledge is especially important when choosing a knowledge worker for a task, because methodological know-how is usually more difficult to obtain than domain or problem knowledge. For instance, it may take months to learn how to analyse the composition of certain materials while the actual analyses are often quite straightforward tasks. It is also far easier to give definite values for domain and problem information than problem-solving information, because the latter is usually in too general a form to be evaluated for a particular task. For instance, it is easy to see the value of a piece of stock-market information but how to estimate the value of the know-how of ,say, a good software specialist. Problem data and information, on the other hand, must be processed for use, but in principle it is a straight-forward process, as is the valuation of them.

Outcome knowledge is the new knowledge that is generated during the knowledge-work task. For example, quantum physicists generate new quantums with their cyclotrons. Outcome knowledge must be formulated into output information in order to determine its exchange value. Output information is a medium for a person communicating with other people in the community. This is how a person can give exchange values to information, or information products. Thus, the exchange values can be identified and measured at the community level via markets, but in practice the indefinite markets of information make precise valuation difficult.

There are several other classifications of information (see, for instance, Järvelin 1985), but for our purposes this analysis is sufficient. Because this classification links information to the work for which it is used, it can already be used to destroy the illusion that the value-in-use of information could be defined outside the knowledge-work process.

We have three information requirement-levels where valuing of information takes place: objective, normative and subjective (Järvelin & Repo 1984). We use these levels to analyse further the problems of assessing the value of information. As stated before, knowledge-work is done by individuals and raises differing subjective information needs and requirements. These needs are influenced by the professional environment (especially within an organization) where and for which the work is done, and this environment forms the normative information requirements for knowledge-work. For the knowledge-work itself there are requirements which must be fulfilled in order to get the work done: we call these objective information requirements and they refer to the task knowledge.

The objective requirements should form the basis for determining the value of information, but the problem is that one can seldom attain these requirements. Although they are not achievable, approaching them is possible and even desirable - in philosophy this attitude towards the truth as the task of science is known as "critical scientific realism". In information science (or studies), for instance, Derr (1983) has emphasized this kind of thought while rejecting the idea of the information need as a psychological state.

The normative requirements are a result of interaction between people in the community who are involved in that particular knowledge-work process, and these requirements also create the general framework for exchange values. At the community level the value of information or rather information products and services can only be realized either through exchange values in "the information markets" or through objective value-in-use whenever expressed in exchange-terms.

So, by definition, the measuring of the value of information should take place in those three requirement-levels. This means that measuring the total value of information is usually not possible. The effects of information on the results of the task reveal objective value-in-use of information. Those objective values can seldom be defined and even more rarely can they be measured. At a community level we can measure exchange values of information products and services. The value-in-use of information is determined, in practice, by individuals (or a group working together on the same problem or task). It is a basis of value considerations. The use of information starts with expected subjective value-in-use and continues or stops with actual subjective value-in-use when information is used in the task. The effects of information on the results of the task then reveal objective value-in-use of information.

2.5 On Empirical Research into the Value of Information

In this section we review some studies on the value of information (Christie 1981; Griffiths 1982; Repo 1987b, Appendix 1; Repo 1988, Appendix 2). Certain remarks are made to show how superficial the analyses of information use have been in these studies. Our argument is that although these studies have contributed useful descriptive information they have only scratched the surface of the value of information understood in the sense presented in Section 2.4. We concentrate here on those studies which include also some empirical analysis, because we consider them still the most interesting ones.

For the presentation we divide the studies into four separate groups:

1) studies using statistical or mathematical models,
2) studies using classical economic approach,
3) surveys on willingness to pay and time savings, and
4) studies using examples.

2.5.1 Studies Using Statistical or Mathematical Models

A number of studies using statistical models base their analysis on the idea of the multidimensional value of information. Such attributes as relevance, usefulness and informativeness are often used among sometimes tens of other attributes to describe the phenomenon more thoroughly (Christie 1981; King & Epstein 1976). Furthermore, Rich (1980), for example, identifies four categories of use for assessing the value of information: intended use, actual use, instrumental use and conceptual use. His conclusion is the opposite of ours: use is only marginally helpful in specifying the criteria for judging value-in-practice (see also Pejtersen 1985).

Multidimensional models on valuing information are presented in several studies: McKendry et al. (Christie 1981) try to solve the problem of measuring the value of information by splitting the sources of information into pieces (for instance, a book into chapters and sections) which users are asked to give values to. Yovits and Abilock (Christie 1981) assess probabilities for different courses of action in decision making. Also, Christie (1981) builds up a probabilistic model for valuing information in connection with office automation decisions. The multidimensional approach is also used among economists (see references in Epstein & King 1982 and Appendix 1).

Morehead et al. (1984) have also done interesting work which uses the multidimensional value concept. They have used man's value structure as a framework for evaluating online searching. The multidimensionality is, in their fiction retrieval case, described by the subject matter, frame (time, place,setting), author's intention and accessibility. The problems in identifying and rating specific components of the value function without examining each information searching or use-situation individually, were also documented in this study. Still, one has to say that such approaches using subjective value statements and opinions of more or less carefully chosen variables for "the multidimensional formula" can make value analysis look good (and scientific), but this does not necessarily guarantee the practical usefulness of them. These analyses are supposed to describe the value-in-use of information, but the values are usually sought from users without any deeper consideration of the actual information-use situation. These subjective statements of the importance of some indicators of value are based on the selection of indicators suitable in a particular case. The selection of indicators is not analysed in the research reports.

2.5.2 Studies Using Classical Economic Approach

A pure economic modelling approach is sometimes used in assessing the market-value of information services (Appendix 2). Mason and Sassone (1978; Sassone 1981) developed a framework for understanding observations about the demand for scientific and technical information and integrating these observations with fundamental economic principles (demand and supply curves, rational behaviour of users of the services by saving money, private and social costs and benefits). An example is given of an information centre economic model that provides "a lower bound on benefits" in money-terms. It is emphasized that these values have nothing to do with value-in-use. Braunstein

(King et al. 1983) used a similar approach while analyzing costs and benefits of library services to the user.

These economic models are useful in a rough evaluation of the exchange values of information services and products. These models tend to concentrate on costs of services though some benefits in money-terms are also measured. There are also problems in gathering appropriate data for models like these. Therefore, for the information user, the economic analyses are useful only when the user has several channels or services to choose from while seeking the particular pieces of information (usually domain or problem information). For information providers, on the other hand, these analyses give useful data on the market situation.

2.5.3 Surveys on Willingness to Pay and Time Savings

The way chiefly used by information scientists to study the value of information is that of surveying the users of information or merely users of information services and products. There have been several more or less careful inquiries into willingness to pay and time savings. We present here some examples with comments (for reviews, see Flowerdew & Whitehead 1974; Griffiths 1982; Appendix 1).

Wolfe et al. (1971) performed a broad, economic-theories-based, study on the cost-effectiveness of technical information services. Both the users of these services and the providers of them were asked about time savings and about additional salaries demanded in the event of losing those services. The research report makes quite convincing reading to a non-economist by its broad theoretical discussions. However, it leaves some open questions on the basic assumptions. An example involves the optimal behaviour of a scientist reading only information needed for his job (Flowerdew & Whitehead 1974). We should collect more data on information seeking and use, and also on research work in order to get deeper understanding for the analysis. It seems that only some parts of information use (primarily use of domain information) can be studied this way.

Hawgood and Morley (1969) collected information from the users of SDI-services about how much they were willing to pay for the services and how much they think the university would be willing to pay. Here we have a problem of validity of answers. Who can best state the value of information, an information user not paying personally or an organization represented by the actual users of information? Furthermore, how realistic are the answers to such hypothetical questions? Even more confusing was the result of the Hawgood and Morley study: correlations between answering the above mentioned two questions were not noticed. More information on the actual use of information would have been needed for a reasonable understanding of the value of these services.

Interesting surveys on value assessments were recently performed by King Research Inc. The study on the energy database (EDB) of the United States Department of Energy (King et al. 1982) is perhaps the most appropriate to look at here. In this study the extent of use of the EDB and other identification methods of needed information and the resultant readings were analysed by a broad set of questionnaires. "The apparent value" was measured in terms of willingness to pay (actual payments), both for the searches performed and for articles and reports read. The apparent value consists of the time and money associated with the identification, location, ordering, receipt, and use of information. "The consequential value" was measured in order to establish the effects at two levels: (1) for searching by the cost of reading which resulted, and (2) for reading by the savings which resulted from application of the information obtained in reading. The resulting estimates (sums of money) are said to reflect the value to the searchers, the readers, and the reader's organization or funding sources.

In the report of the study, the problems experienced in the measurements are discussed broadly, and it is explicitly said that the measurements only reflect the value of information, information services and products. It is important to notice that in this study there was an effort to bridge the gap between an information product or service and the information itself. The apparent values deal with information products and services and with the knowledge-work process. The consequential values, the effects of obtaining information, deal directly with the information content (the measurement used examples in this study).

From our point of view the problems arise when one starts to use these different values for total value estimates. These impressive sums (billions of dollars) are useful in showing politicians how important it is even for a big research organization to utilize the research done elsewhere; and in revealing the shares of information seeking, identification, access and reading per article or report. Thus, the sums have value in a descriptive sense, but according to our approach they are insufficient as they neglect the distinction of value-in-use and exchange values. One cannot bridge the gap between the value-in-use and the exchange values solely by explaining the use values in money terms derived from examples of savings given by individuals. In the study it was emphasized that the value of information must be explained from the viewpoint of the information user.

2.5.4 Studies Using Examples

The easiest way to explain the value of information is to use examples (Griffiths). For instance, my apartment is worth $80,000 (exchange value), my lego-house is twice as valuable as your doll (emotional value), or that air-raid shelter takes 80 people (value-in-use). If you ask an information specialist about the value of information, he presumably starts recalling examples like the damage caused by a chemical accident due to a lack of information during the rescue operation, or the great success he or his friend had once when finding quickly an important piece of information for the boss (see also Appendix 1).

In the information science literature there are surprisingly few studies collecting information about examples of value of information, though it seems to be the only effective way introduced so far to measure the benefits gained from the use of information. Nevertheless, King Research Inc. have done so in their studies (King at al. 1982; Roderer et al. 1983) and Ljungberg (1978) also lists such examples in his study. The lack of information and the penalties of ignorance have been studied by Brittain (1984) but he ran into problems of defining ignorance in his concrete examples of medical information.

Roderer et al. (1983) collected information on savings from reading particular technical reports of the Department of Defense in the U.S. The readers gave money values to savings, which were used to calculate the average value of a reading ($4,700 in this case). Even more interesting were the statements on the reasons for savings because they revealed that it is often hard or even impossible to give money-values to information:

- new contact information,
- some information possible to get only through the information services studied,
- the information gleaned from the search gave insight into something the researcher had not thought of before, and
- savings in writing and research time since someone else had tested the information already.

Still, it seems that in practice examples are the best way to describe the value-in-use of information in the empirical research conducted so far. This means difficulties in generalization. While the lack of a suitable theory is obvious, conclusions are often made by rough estimates - possibly supported by the examples. We believe that our approach presented in Section 2.4 could help to clarify the starting point of value considerations by the distinction of use and exchange values. In addition, the analysis of different types of information can give hints of the fact that it is possible to measure the exchange value at the level of information products and services. Information itself and its value-in-use is at best only touched on by such measures as time spent for reading and time and money savings. In order to get any further, deeper analysis of the information use situations is certainly needed.

2.6 Conclusions

The study analysed the value of information by using the specifications of the value concept. Values can be divided into philosophical values and practical values. Philosophical values give a background for our behaviour, but they are hard or sometimes even impossible to detect. We have concentrated on practical values further divided into value-in-use and exchange values. The value-in-use describes the value of information from the information user's and use viewpoint. The exchange value considerations are needed in order to compare values either in comparison with the values of information channels, services or products in an information need situation, or in a marketing situation for determining the price of a piece of information. Research on the economics of information has not used these classifications so far.

The value-in-use of information can only be stated by the user of information while he is performing his knowledge-work task and from the results of the task. In order to avoid subjectivism, the basis for determining the value of information even from an information use viewpoint has to be in the knowledge-work itself. Measuring the value-in-use of information in practice is a demanding task. Objective value-in-use is often impossible to measure in full, only some indicators may be available from individuals as to how the information influenced the task and the results. It is also necessary to study expected subjective value-in-use because it gives possibilities to study valuing processes of individuals while they value information products and services. For value-data we have to ask the actual users, but their estimates can be more reliable if we distinguish between the kinds of information they need. In this study five types of information and knowledge were identified and used to support our approach: task knowledge, domain knowledge, problem knowledge, problem solving knowledge and outcome knowledge. In order to get even better answers we have to study the specific information and knowledge-use situations more thoroughly.

Some general findings of the study:

- One should speak of the value of information at the user level only in terms of value-in-use. Because the value-giving situation of information products and services is a need-oriented situation, there is a need for expected value-in-use studies. Reference to use values in money terms makes it easy to mix value-in-use with exchange values. Only seldom is it possible to derive exchange values from objective value-in-use in full.

- The organization, or the community more generally, provides the framework for knowledge work and it operates with exchange values. There are seldom real measurements for such a concept as the value-in-use of information at the organizational level. Should we only speak of the exchange values of information products, services, systems and channels?

- One should not mix a user's viewpoint and a community's viewpoint when determining the value of information and, on the other hand, the value of an information service or a product.

- Different kinds of information and knowledge have varying values for a user of information: domain, problem and problem solving information are the most interesting ones when determining the value-in-use. Also the information use context is of major importance here.

- Specification of the exchange values of information systems and products is an issue entirely different from specification of the value-in-use of information - the exchange values deal with information production, transfer and market, not with the use.

Some practical conclusions:

- There is no sense in trying to count the total value of information. Different viewpoints and observation levels result in different emphases.

- When an organization measures the value of information in some particular situation, it has to ask the information user's opinion on information needs and to study the information-use contexts - here the examples of the use values are the most useful tools available at present. In finding the most cost-effective information products, services, systems and channels, one needs to consider exchange value in the information market.

For future research on the value of information we suggest more specific (and perhaps also more modest) goal setting and definitions of what values are actually being measured. Research in this area is certainly needed, but in order to achieve more reliable results the basic approach has to be clarified.

3. THE VALUE OF INFORMATION: A FRAMEWORK FOR RESEARCH

> "Perhaps the unexpected and intangible benefits from computers (and information) are always going to outweigh the cost/benefit analysis of the accountants. If so, we might just as well dump cost-justification methodology in the nearest lake."
>
> Richard Sarson in Computer Guardian 21.08.1986

3.1 General

The purposes of the theoretical part of our study were to analyse research on the value of information heretofore and to find methods and techniques for research managers to measure the value of information in practical situations. These goals were accomplished by reviewing the literature of information science (Appendix 1; Repo 1987b) and economics (Appendix 2; Repo 1988), and developing a framework based on the philosophical concept of value. The framework was then tested against former research and in the light of a pilot study among scientists in biomedicine (Appendix 3; Repo 1987a). In this chapter the main findings of this work are summarized.

In addition to being a summary of the research so far, we also try here to put forward a sound basis for our empirical studies and those of others. It is our belief that most of the empirical research completed earlier has paid too little attention to the basic assumptions of the studies and, on the other hand, those building theories have been left without much empirical evidence of real life problems. Some remarks are made to clarify useful levels of research, productive methodological approaches and needed future research.

3.2 Theoretical Economists and the Approaches of Information Scientists

One can find three paradigms 'ruling' research into the value of information: the economic paradigm, the cognitive paradigm and the information theory paradigm. Interestingly economists have recently concentrated their interest around the information theory paradigm and the economic paradigm is only used in some empirical studies, while information scientists mainly use the cognitive or economic paradigms. Although there have been few attempts to cross the boundaries the main share of the research is completed under one paradigm. For instance, those information scientists who emphasize information markets and Information (Resource) Management clearly concentrate on basic economic thoughts, and other information scientists who study, say, the use of information and information systems usually stress the cognitive paradigm.

3.2.1 Information Theory vs. Economic Theory

Economists define information as a phenomenon to reduce uncertainty, and information is usually studied in terms of exchange values. The main interest has been directed to such areas as information production, information systems, information products in the market and product-information. Economists have used their basic assumptions for these analyses but, in addition to this, most studies on the value of information have tried to apply information theory. Economists have used the following approaches:

1) equilibrium approach,
2) statistical decision theory approach,
3) multidimensional value approach, and
4) cognitive approach (Appendix 2).

The studies of the value of information have been mainly theoretical: this is especially true for the studies where the first two approaches are in use. The multidimensional value approach is used in connection with information systems and the cognitive approach is 'found' by, for instance, some accounting researchers not satisfied with other approaches. At a practical level cost-benefit analysis is usually applied as a framework for the assessment of information, information products and especially information systems. Although the idea of information as a means to reduce uncertainty and the need to express values in exchange terms sounds reasonable, economic approaches using probabilities have not been successful in producing practical means for measuring the value of information. So far, only a few interesting case studies and examples of the values have resulted from the extensive theoretical research.

Although economists have not provided new, useful tools for measuring the value of information in practice, the exchange values can still be studied using basic economic assumptions. However, the new approaches emphasize some interesting characteristics of information:

1) Information reduces uncertainty. Instead of trying to develop mathematical formulae one should perhaps collect descriptive statistical data from individuals in order to understand the nature of uncertainty more thoroughly.

2) The idea of optimal information is introduced in connection with market information. Optimal acquisition of information products and services becomes more and more important because of the deluge of information products.

3) The role of learning in assessing the value of information gives a point of reference for looking at different types of information.

3.2.2 Scattered Research in Information Science

Research on the economics of information in information science has arisen from practical needs to justify the existence of libraries, information services and individual information products. A lot of discussion has taken place as to whether assessing these phenomena is possible. Also hundreds of empirical studies have been completed by using approaches influenced by several fields of science. The core of empirical studies can be described in nine groups:

1) costs of information products and services,
2) price of information,
3) effectiveness and efficiency of information services,
4) cost-benefit analysis of information dissemination,
5) case-studies on the value of information,
6) information service as a value-added process,
7) economics of information retrieval,
8) macro-economic studies of information and productivity, and
9) economics of information processing (Appendix 1).

There are several important areas of study in economics of information but the value of information is often the key issue behind the analyses. This issue has also been the subject of many discussions, and misunderstandings as well. One example is that the cost-benefit analysis concept is used to describe almost any kind of study in the economics of information. There is a real need for better understanding of basic economic and cognitive assumptions made in empirical studies. The most interesting empirical studies have analysed these assumptions before completing case-studies and collecting data on examples of the value of information.

3.2.3 Summary

While economists have failed to introduce any new practical means to measure the value of information in spite of a lot of research based on information theory, the research in information science seems to split into two groups. There are those who believe strongly in economics. After the cost-benefit analysis there is the information accounting and budgeting boom at the organizational level, better known as the Information Resource(s) Management (IRM) - approach. On the other hand, there is much research going on into the use of information, which, at its best, applies a cognitive approach in the analyses.

It is necessary to organize the research on the value of information by using the economic and cognitive approaches simultaneously because neither of them describes the phenomenon fully alone. By simplifying, one can introduce a dual approach to the value of information for practical studies:

1) The exchange value of information products, services, channels and systems should be studied using economic methods.

2) The value-in-use of information should be studied using the cognitive approach which takes the user, the use and the effects of use of information into consideration.

3.3 Framework for Research

The dual approach to the value of information is presented fully in Chapter 2. In this section we summarize some of the main points of the approach and the pilot-study in biomedicine (see Appendix 3, Repo 1987a), and also discuss briefly the interesting directions of empirical research using the approach and some methodological issues.

3.3.1 Dual Approach to Practical Values

The value concept in philosophy forms a starting point for the analysis of the value of information, see Figure 3.1. It must be emphasized that the above classification is developed for practical purposes. It does not fully explore the important role of philosophical values (emotional, spiritual, social, etc.). This is so, because in practice those values can only be studied through individuals and their importance is reflected in the value-in-use

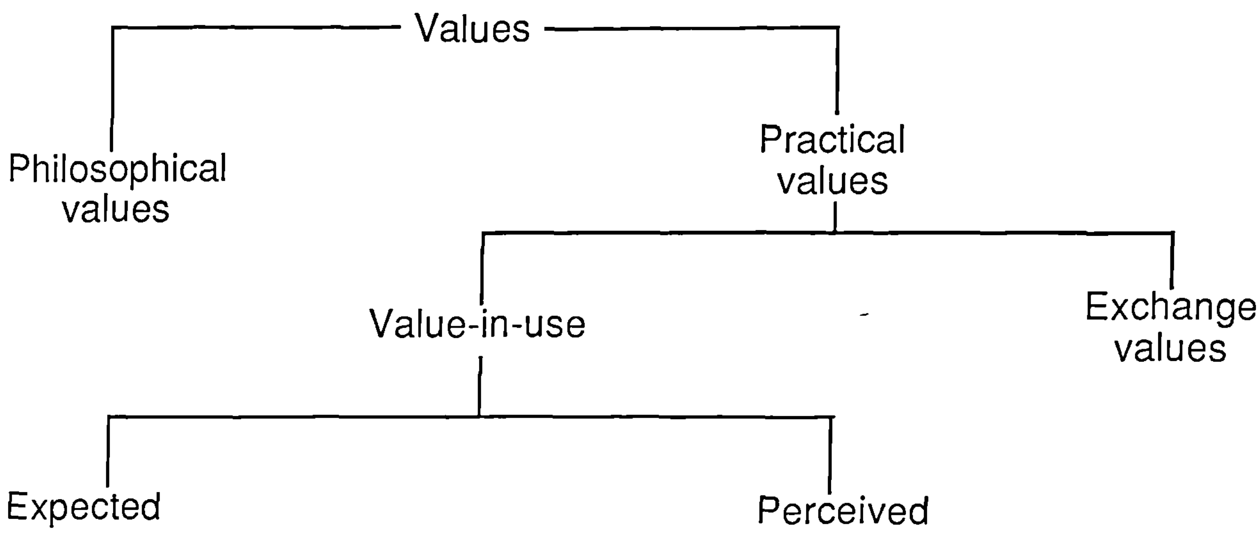

Figure 3.1. A taxonomy of practical values

statements of individual information users. The part of practical values which can be described in exchange terms is the area economists have been working on (information as a product or commodity). Information scientists have mostly been interested in value-in-use as described by individuals. It is useful to make a further distinction between expected and perceived values. Expected value-in-use is of importance because the use or non-use of information is almost always decided on the expectations of individuals. Perceived value-in-use describes the actual experiences of information use in a particular use-situation. This latter value provides the core for assessing the value of information. It can sometimes be made objective using such measures as time and money savings and then there is a possibility of comparing the exchange values of an information product and the value-in-use of its content. Still, more often than not this can be done only partly and the value-in-use can only be characterized by qualitative measures.

General models of the role of exchange values and value-in-use in information flow are presented in Appendix 2, Figure 1. Value-in-use and exchange values have clearly separated areas in the flow but they are both needed in order to describe the value of information. The same Figure 1 also shows that the emerging information market emphasizes two levels: information products and services which have economic character and information contents which have cognitive character. It is of course true that a lot of information does not follow the path presented. There is free and important information available which does not have exchange value, and the use of information introduces social values etc. These issues must be remembered when our model is used. Our model is provided for practical purposes to give as holistic an approach as possible to monitor the value of information in practical situations.

3.3.2 Pilot-Study in Biomedicine

The subject of the pilot-study was the value of current awareness information in biomedicine. Providers of a service and a small group of scientists as users of that and other services were interviewed. The study was supposed to test the dual approach to the value of information described above (see Appendix 3 or Repo 1987a for a broader review of the study).

The pilot study gave support for a dual approach to the value of information problem but it also demonstrated the differences that exist between primary and secondary information considerations. The value of secondary information can be studied in terms of exchange by comparing the service to other, more or less identical, services. The problems of hypothetical questions about the values can be reduced by asking users detailed questions: for instance, on ways in which the savings could be achieved. Answers to time-saving questions seem to be much more reliable than answers to questions about willingness to pay. Because of the lack of economic awareness of subscribers to the services descriptive data about subjective value-in-use are often the best means to evaluate the services in practice. Even in a clearer exchange value context the value-in-use descriptions are significant, if not at cognitive, then at 'affecting' level. For instance, earlier experinces of a current awareness service influenced upon the use of that particular service eventhough another system could offer the same information cheaper. It is possible to find measures of the objective value-in-use of secondary information services by time and money savings in some situations but, in practice, this is very seldom the case. Even in the case of 'savings' these are often underestimated because of people's inability to think in exchange terms which means that these measures only give some estimates of the lower-limit values. It must also be remembered that these perceived values-in-use are not directly comparable with exchange values because the former are values connected with use of information (content) and the latter with the market value of information (product or service).

The pilot study produced data which formed the basis of a critique of some earlier studies. Subscribers to secondary information services use several services at the same time and are mainly interested in the information references offered. Therefore, they are seldom able to answer hypothetical questions on the value of the secondary information. More concrete questions are needed for reliable answers. The answers to questions, like "How much money or time does service x save annually?" or, "How much would you pay for service x ?" are unlikely to add usefully to existing knowledge. Although it is possible to advance the above mentioned recommendations for useful questions to ask, when considering the results one has to remember that 'value-giving situations' vary considerably. For example, such factors as the nature of the field (e.g. engineering or science), and the nature of the work (e.g. basic research or contract projects), greatly influence the ability to give answers to the valuing questions. There are those who advocate abandoning studies of individual users of secondary information in favour of concentrating upon markets. Thomas (1981) writes about organizational buying as the decision-making process by which formal organizations establish the need for purchased products and services, and identify, evaluate, and choose among alternative brands and suppliers. On the other hand Wilson (1982), for instance, emphasizes the use of qualitative data on individuals in valuing information. In a study it is possible, and often necessary, to concentrate on a particular end of these extremes. It is still useful, however, to realize that both these ends exist and are of importance.

The value of secondary information needs to be studied using the dual approach because the lack of economic awareness of the subscribers to that information makes pure exchange valuations difficult, if not impossible. The study proved also that information products have value-in-use through the information they carry which cannot be described in exchange terms. Nevertheless, there is a clear economic case for assessing the value of secondary information by individuals working on particular research projects and value-in-use has its importance when market-comparisons cannot be made.

3.3.3 The Framework in Use

We have now tested the developed framework and the next step is to implement it. The following discussion is aimed at giving support for the selection of an organizational setting for further empirical studies.

3.3.3.1 Levels of Research

The research interests can be directed to two separate areas where the value of information has a different meaning, see Figure 3.2. The Figure is a simplification from the viewpoints of individuals and organizations, and

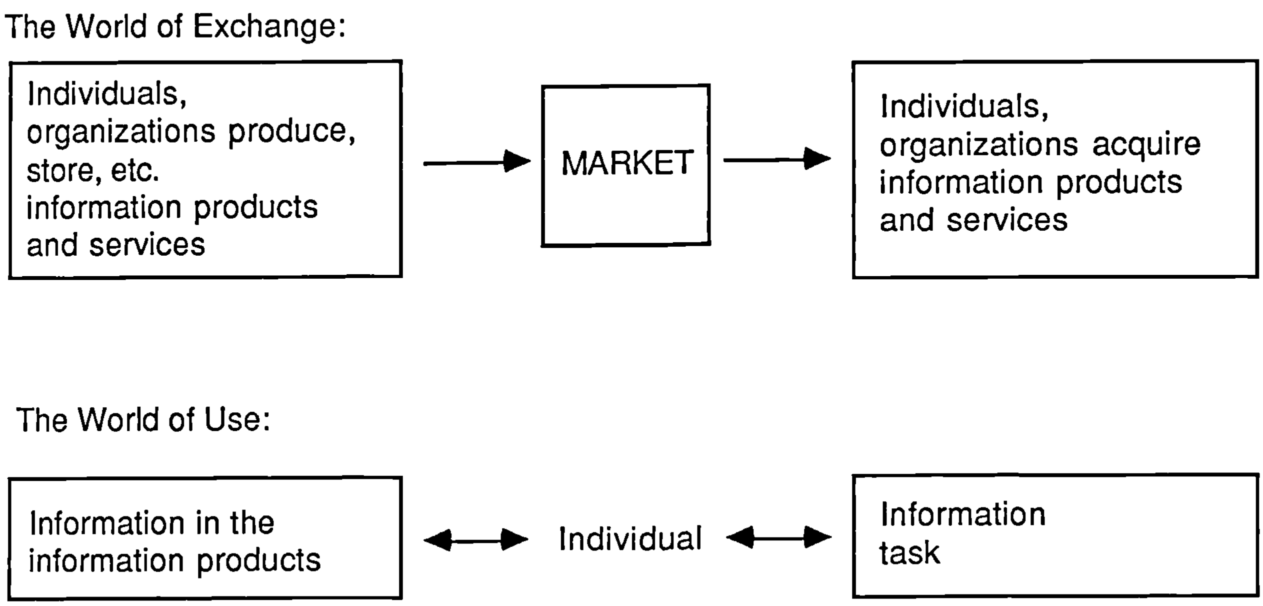

Figure 3.2. Two worlds of the value of information

does not consider the role of societies in supporting information flow.

Much research has concentrated upon one of the above worlds. The information life-cycle runs across both worlds and it seems that it is most interesting to study the value of information by following information flow through these worlds. This often takes place in an organizational setting where the acquired information product is 'opened' and used in a particular information work with possible consequences, see Figure 3.3.

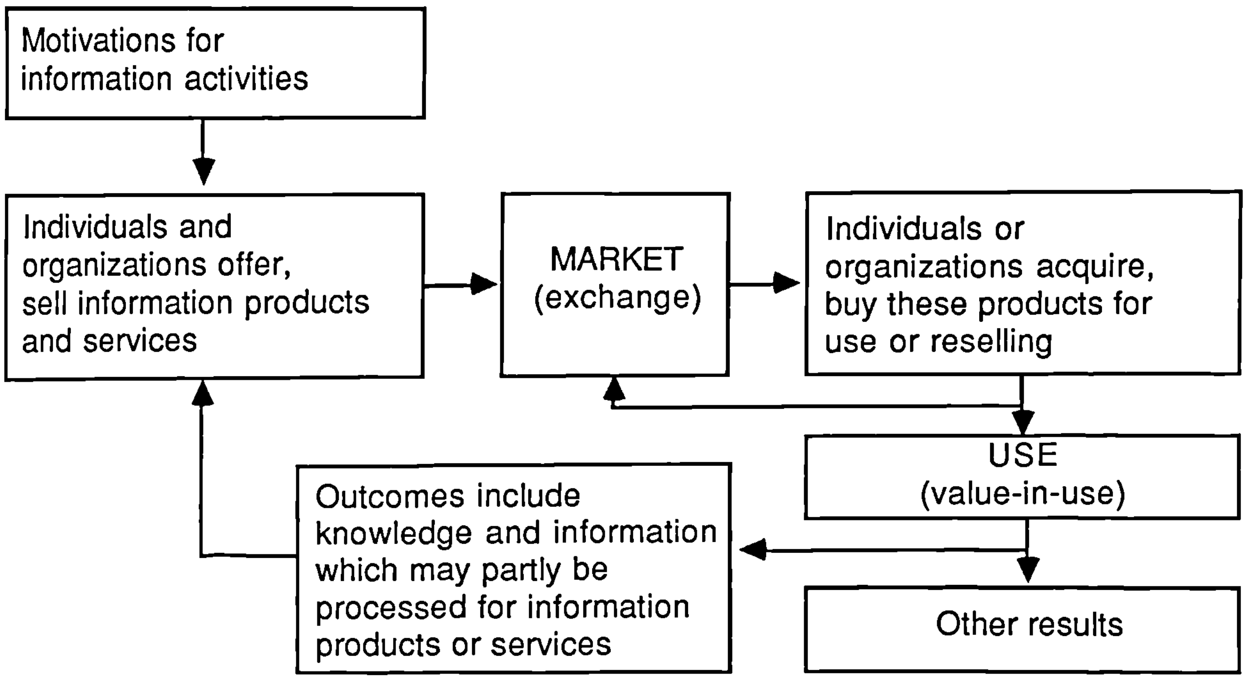

Figure 3.3. Information flow and the value of information

3.3.3.2 Methodological Approaches and Future Research

Information is acquired as information products and services. The value of information is fully explicated in its use. This means that the cognitive processes of individuals involved in information tasks, and such issues as time and learning for different types of information have to be studied. Descriptive statistical data have been collected using a multidimensional approach which have given means to compare, for instance, the value of information systems. Even this approach does not offer any means to find the hierarchy for the dimensions which must be 'found' from the empirical data (Snavely 1967 has introduced one in connection with accounting information systems).

It seems that the case-study approach is the only means at the moment available for studying the value of information deeply enough. Data have to be collected from information work and individuals performing the work using several collection techniques (interviews, questionnaires, diaries, content analysis etc.). For instance, successful or unsuccessful research processes could be studied both retrospectively and longitudinally. Tests on providing a lot of information for information tasks and following the consultation of information problems could also produce useful data on the value of information. The action research approach could be used in developing information use in organizations.

3.4 Conclusion

It is not possible to develop a general model for studying the value of information. We have developed a framework which can be used to analyse the past research and guideline studies in the future. More detailed methods and techniques for assessing the value of information must be developed for the particular research task at hand. It is hoped that the framework helps in setting up research or development projects for more productive information work.

Value-in-use is a key to value of information. Exchange values have to be studied because the information is transmitted in the form of information products through information systems, channels and services. An organizational setting is selected as a site for empirical studies because it is a surrounding where both values are of importance. A research organization provides an ideal subject for a study because a research project is one of the most typical and complete forms of information and knowledge work. Research and especially technical research is also an area with which the author of this study is most familiar.

Part III: The approach implemented

4. VALUE OF INFORMATION IN ORGANIZATIONAL SETTINGS - BACKGROUND,SCOPE AND METHODS FOR THE STUDIES AT THE TECHNICAL RESEARCH CENTRE OF FINLAND (VTT)

4.1 Introduction

There are two distinct categories of practical values of information: (1) exchange value (market orientation, information as a product), and (2) value-in-use (information content, effects on work and impacts on the results). In an organizational setting both of these values are of importance. Without the value-in-use all the information products and services the organization puts up for the employees are a waste of money and effort. On the other hand, the right selection of information products and services which deliver the value-in-use is essential and this can only be achieved by studying the exchange values of information products and services available or to be produced. These values are traced by studying the use of information in a set of research projects. Successful use of information indicates maximized values. Through the information-use process we also hope to be able to deepen our understanding of the factors influencing the effectiveness of research work as such, an issue which has proved difficult to study directly.

There have been a number of attempts to categorize the studies on measuring the use of information (Rich 1980; Griffiths 1982; Dunn 1983a; Agrawal & Zunde 1985; Chapter 2). Rich (1980), for instance, found four kinds of approaches: (1) Tracing the flow of information, (2) Measures of instrumental and conceptual use, (3) Information use and MIS, and (4) Budgetary analysis. Dunn (1983a) uses similar categories: (1) Composition. Individual vs. collective use, (2) Expected effect. Conceptual vs. instrumental use, (3) Scope. General vs. specific use.

Our study concentrates on tracing the flow of information in connection with research work. In view of the problems of 'input-output analyses' and especially the problems of identifying the effects of information we attempt to collect data also from the use process as such. Although information often offers 'enlightenment' collectively we concentrate on particular use situations and individual users. We will cover instrumental (or practical) use in broad terms which means, for instance, that both short- and long-term use are taken into consideration.

The idea is to study the inputs, the process and the outputs of a set of research-projects in an organization. The important factors for optimal information use in the projects are modelled. The aim is to produce indicators for research managers to study whether the information-seeking and information-use practices in the research projects are effective or not. Figure 4.1. presents the management task (see also Freeman 1982, p.8).

We seek answers to the following questions:

- How do researchers make decisions about what sources of information they should use and about the kind of information seeking patterns they should adopt?

- What are the inputs to the research projects?

- How does the research advance and what is the role of information in the research process?

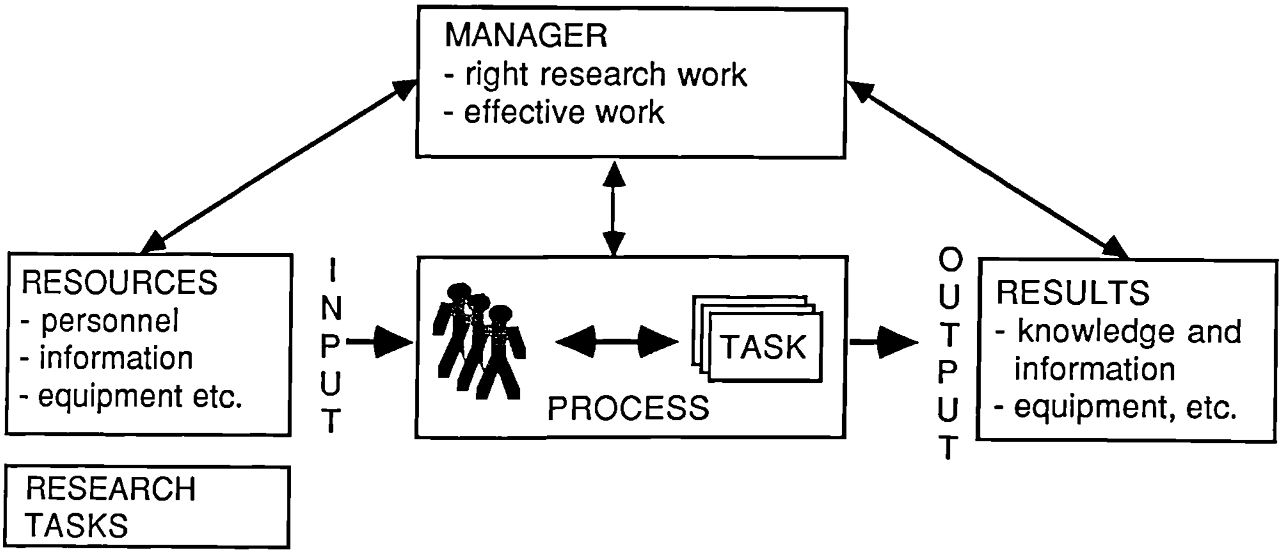

Figure 4.1. Management of a research project

- What are the outputs of the research projects and what kind of impact do the projects have?

- What kind of impact does the use of information have on the outputs of the research projects?

- THE PRACTICAL QUESTIONS: How could we make the use of information optimal? Are there defects in the present use of information, information services and products? What kind of indicators could one produce to follow the situation continuously?

The data from a set of research projects are collected using our theoretical value concepts (Chapter 2). Subjective expected value-in-use (practical example in Morehead & Rouse 1985 about the value of bibliographical information) is studied for recognition of the role of individuals' expectations in the use of information products and services. Subjective value-in-use is described through questionnaires and interviews of the research workers. This subjective data are supported by introducing data of the actual research processes through the project documents. By doing this we hope to approach the objective value-in-use of information. The exchange value of information products and services available and used are discussed and the attempts to transform the value-in-use to the exchange values are made.

The multi-level and indirect approach is taken because the impacts of information (objective value-in-use of information) have proven to be quite impossible to study (see Wills & Oldman 1977; McCain 1981; Harmon 1985). Harmon (1985, p. 308) even states: "Perhaps we will never be able to measure information directly, but will be forced to rely on the black-box models, stimulus-response mappings, intervening variables, and hypothetical constructs so familiar to experimental psychologists." The study uses several methods and techniques common to the social sciences. Although economic indicators are produced whenever possible the study does not use the theoretical approaches developed by economists because of their limited practical usefulness (see Appendix 2). Also such recent approaches as value engineering (Maurer 1984) and decision analysis methodology (Owen 1984) are excluded because they pay attention only to the exchange values while our main emphasis is on value-in-use.

It is our belief that the study of the role of individuals and their research tasks are essential in describing the value of information. Rich and Goldsmith's (1982) model in Figure 4.2 describes the use of information in the R & D process. Our aim is to elaborate the model by studying the use of information in the research projects at the Technical Research Centre of Finland (VTT).

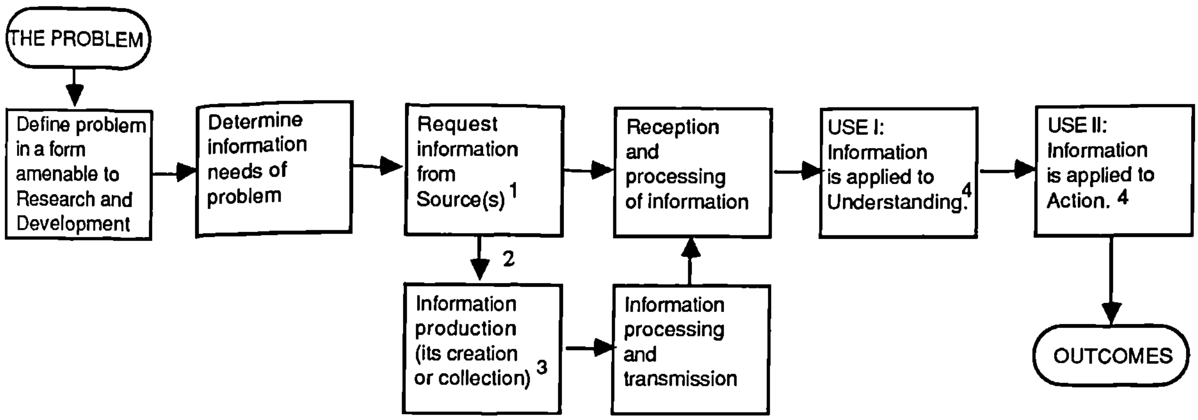

Figure 4.2: The R&D Process

1. Information may be requested of a variety of sources (e.g., from oneself, an expert, a commissioned study, a library search, etc.)
2. Information source(s) may be inside or outside the requesting organization.
3. Information which already exists is collected; that which doesn't is created.
4. Use may occur directly, through the activities of the R&D sponsor, or indirectly through dissemination and diffusion of information to third parties.

Figure 4.2 The R&D process

4.2 Engineering Research Projects under Investigation

In this section some studies of the use of information in engineering research are briefly reviewed. The role of time and learning for the use of information are then discussed; it is necessary to emphasize these often neglected issues. The section ends with a description of VTT and its research activities.

4.2.1 Engineering Research and Information Use

Research work is commonly characterized as an activity where human skills advance knowledge creation, as a creative process done under uncertain circumstances, as a part of social process, and as an activity producing results available to the research community for valuation (Miettinen 1983). Freeman (1982, p.225) states that "research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications." The contract research in which VTT is much involved necessitates restrictions on the publication of the research results.

Research is done by individuals. Their skills and motivation as well as working conditions (social contacts, information enlightenment etc.) play an important role in whether they succeed in the research tasks appointed to them or not. Research is also an iterative process with continuous interaction between human actors and research tasks under way in order to increase understanding of the problem and resulting knowledge, information and artifacts (see e.g. Smith 1982).

The special characteristic of engineering research is that some concrete artifacts are usually produced and they are, in fact, often seen as the only result of research. Engineering research tasks also produce new knowledge and information either new to everybody or new to the community involved in that particular work. The value of this new information can only be seen when it is used as an input to some new research tasks. This means that only rough measures of the value of engineering research can be obtained by studying the (exchange) value of artifacts produced.

Because direct data on the value of information are difficult to find, it is useful to collect some descriptive data on information flows in connection with research work. For a general review of the studies on communication in organizations see Porter & Roberts (1977). The importance of communication in engineering research is emphasized in many studies, for instance, Klemmer's and Snyder's extensive questionnaire (1972) showed that in a large research laboratory 70% of the time was spent in communication (20% face-to-face; 8% telephone; 20% reading; and 22% writing). Information clearly has a vital role in research work.

Allen (Allen & Cohen 1969; 1977) collected an extensive amount of data about engineering research in his broad set of studies. He emphasizes the differences between engineers and scientists: engineers are more practical, learning is a tool for them not an end in itself, and they separate the work and their personal life more clearly. Engineers write and read less than scientists. They work happily under supervision and prefer communication within their organization. Group-work with colleagues plays an essential role in their work, and established information services and literature has only a minor importance.

Allen's observations have been broadly recognized but his suggestions for improving the effectiveness of engineering research have given rise to some doubts. Allen (1977) explored the communication networks of engineers in research laboratories and found 'gatekeepers' who passed information from external sources to other engineers. "All a good manager has to do is to be sensitive to the concept (gatekeeper). He will find his gatekeepers. The only thing remaining is to reward them, organize information dissemination around them, and if they are to be lost through promotion, replace them." (Allen 1977, p. 180).

Engineering gatekeepers have been studied quite extensively (see Holland 1974; Bozeman & McGowan 1982) and their existence is confirmed. Doubts have arisen over whether to support 'gatekeepers' or not, and how to support them. Pettigrew (1972) suggested that 'gatekeepers' would support themselves rather than an organization needing to and Persson (1981) argues that the gatekeeper concept is not very useful because it does not indicate with whom the gatekeeper is communicating, what is being discussed, and what effect the gatekeeper has on internal information dissemination. Another possibility is to start to support non-gatekeepers ('sinks') who have external contacts, instead of gatekeepers. It seems that it is useful for the research manager to know his gatekeepers (and non-gatekeepers) but he needs also to know their information seeking and communication behaviours, and, to a certain extent, the content of communications, to be able to measure the effectiveness of their information activities. In addition, it may be advisable to support communications of all employees, instead of a small group of gatekeepers, in order to avoid relying too much on a few individuals.

Apart from studies on information sources, channels and services of engineers (e.g. Shuchman 1981; Raitt 1985) Bitz and Owen (1981) carried out interesting case studies on the importance of information in engineering. They found that successful engineers in innovative design are those who, in addition to being aware of particular information, are also well aware of the background knowledge likely to be relevant. The most important information inputs originated with the engineers themselves, colleagues who were officially helping with aspects of the projects, past work within the organization on these problems, and lastly contacts outside to those who had some formal connections with the work or who were met in the course of the work.

Allen's experiences of the low use of information services was confirmed by Bitz and Owen. It seems that there is too much general and too little specific and detailed information available. Capabilities to find the right information from the bulk of information products and services were not developed. Information services should further the more effective use of information. Services should also concentrate on offering new ideas of information needs and approaches to the problems at hand both for managers and engineers. Although Bitz and Owen had witnessed low use of information services in their case-studies they suggested that these services provide a cheap way to success in research work.

4.2.2 Time and Learning in the Use of Information

Information is a resource for research work and one with special characteristics. The roles of scientists and engineers and their cognitive processes have been taken into consideration when developing practical approaches to the valuation of information. Here we discuss two related issues, time and learning, which have often been neglected in the use of information studies. In addition to the information contents, learning over time is of importance in establishing the impact of information inputs on a piece of research work. While it is often impossible to trace each impact the information has had it is necessary to understand their complex nature in the research process.

It has been experimentally determined that humans prefer to employ a known procedure for solving problems (procedural or 'symptomatic' approach) and only use more general ideas and structures (theoretical or 'topographic' approach) when there are no procedures available (Morehead & Rouse 1985). The theoretical approach gives rise to a need for learning and usually means time delays. On the other hand, this approach also offers possibilities of creating something new. Real life situations are much more complicated. However, one could perhaps say that, depending on the user needs, it is sometimes better for the information service and products to move from theoretical approaches to a problem towards known procedures. In the interest of good research, managers should perhaps force engineers to use more information and also allow them time to learn it. In practice, the task of managers is to find the balance between the best and the easiest.

Organizational learning has been studied by sociologists (Argyris & Schön 1978; Holzner & Fisher 1979) and learning-by-mistakes has been the most commonly applied approach. Wileman and Meyers (1984) studied learning strategies in high technology teams using a questionnaire. Mistakes arose due to unclear goal setting (in 35% of the cases); problems in project management (19%); lack of communication, insufficient dissemination of learning (18%); problems in team management (17%); and other reasons (11%). Improving learning was seen as difficult because about 50% of the communication was done by using unofficial channels. When engineering research projects are usually carried out it is necessary to monitor the interrelations of individuals.

Furthermore, Bitz and Owen (1981) remarked that the information as such is not enough, scientists have to be trained to use it.

Time has also sometimes been considered in the studies on the use of information. Morehead and Rouse (1985) modelled the valuing of bibliographic information on three levels: while searching, in connection with a database, and when studying the results of the search. Carter (1985) has also three points for valuing management information: before any effort for information acquisition was made, after studying possible ways to acquire information, and after information is used. Larsen (1985) strongly criticizes earlier studies of information utilization for neglecting the role of time. Presentation of information to a user does not automatically translate into information use. She presents seven categories of use (Larsen 1985, p. 149):

1) information considered and rejected,
2) nothing done,
3) information under consideration,
4) steps taken towards utilization,
5) information partially used,
6) information used as presented, and
7) information used and adopted to fit the user's needs.

These examples of valuing levels and use levels deepen our understanding of the complex nature of information utilization. They are used here to support our selection of the multi-method approach in valuing the information used in a set of engineering research projects. It seems quite clear that in practice we have to be satisfied with examples and hints at the value-in-use of information. It is hoped that descriptive data collected are useful in modelling the valuing process so that more coordinated approaches and tools may be offered to research managers rather than a vast set of ideas and pointed out difficulties which have resulted from earlier studies.

4.2.3 Project Work at the Technical Research Centre of Finland (VTT)

The Technical Research Centre of Finland (VTT) is a research institute carrying out work in a wide range of technological fields. Its role is to create, maintain and develop technical expertise for Finnish industry. The bulk of VTT's activities is directed towards the application of research and development to concrete problems. A significant part of its work also compares basic research in addition to testing and inspection.

VTT has 32 laboratories dealing with almost all areas of technology which are of importance to Finland. Most of the laboratories are within the Helsinki area and the total work force is over 2500 people, about 1300 of them being university graduates. The fields of research may be divided into six groups: energy technology, information technology, chemical technology, mechanical technology, building technology, and urban technology. For the organization see Figure 4.3.

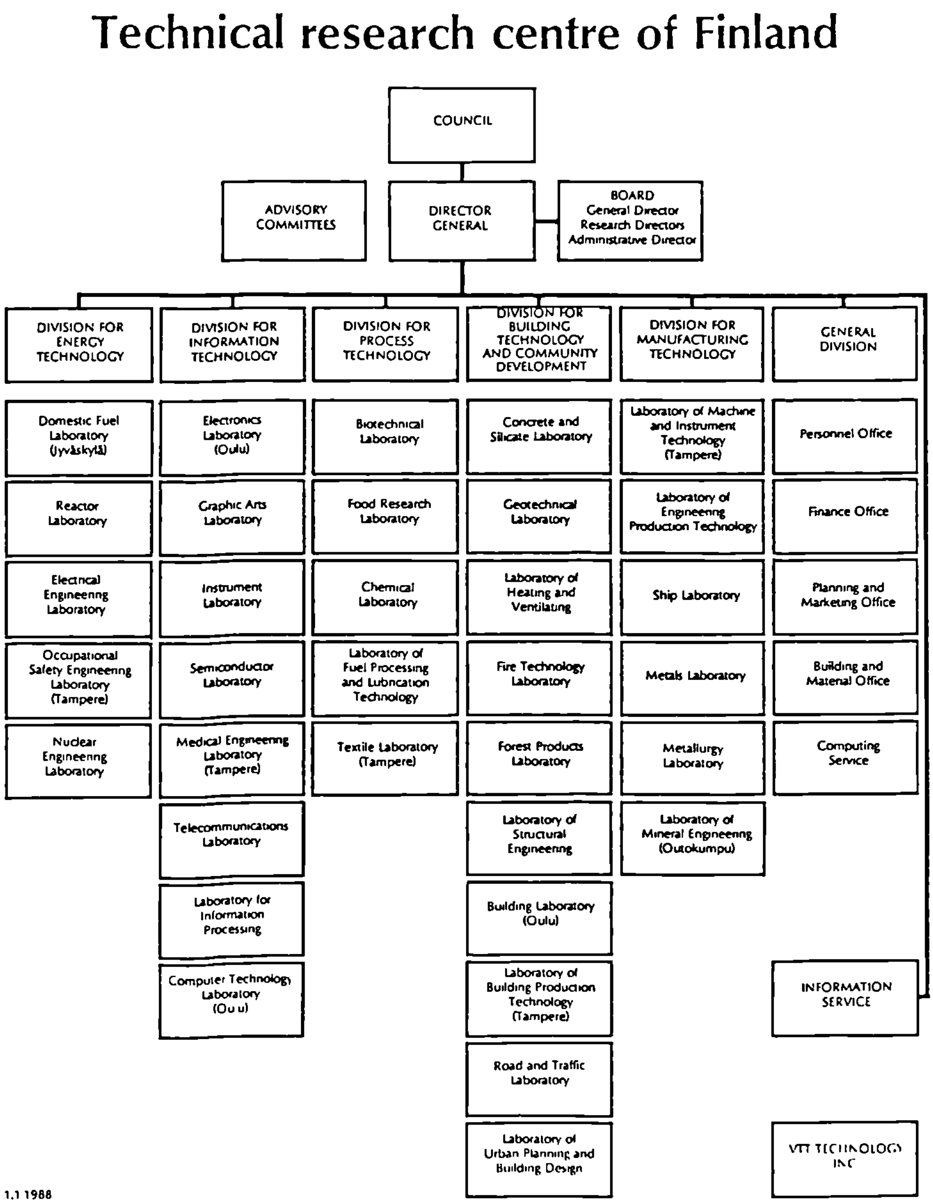

Figure 4.3. VTT's organization as of 1.1.1988

VTT performs research using funds provided by the state budget as well as by contract research for Finnish and foreign companies and authorities. At present contract research accounts for over half of all the activities of VTT and the research is invoiced at cost price. Complete impartiality and confidentiality are strongly emphasized features of all activities.

The research on information technology, for instance, is aimed at developing both information processing and communications as well as at process control and production automation in order to improve profitability, product quality, and the working environment. Research covers the improvement of technical methods used for information retrieval, processing, transfer, storage, and output. Basic research is centred around research in electronic components, computer technology, and electronics production technology. Currently, research is being carried out on the design and fabrication of semiconductor components, optoelectronics, computer-aided design, automation of serial production, automation of machinery and equipment, integration of teleinformatics, expert systems, and applications of image processing. The exploitation and application of information technology are also studied by other divisions in connection with their main research interests (for a broader review of the research at VTT see the most recent Annual Report).

The research is mainly done in projects which may include personnel from several laboratories. The laboratories are the main economic units but joint work is encouraged by the central body, for instance, in the form of research programmes which are sets of projects in certain areas. At present there are about ten research programmes under way, for instance, Applications of Artificial Intelligence; Measuring Techniques, New Materials, Optoelectronics, Plactics Technology and Under-Water Technology. However, it must be emphasized that the majority of the projects are carried out independently under contracts with the clients.

Miettinen (1983) studied means and possibilities in the development of skills of research workers at VTT. He characterizes the research at VTT as a group activity with increasing social and economic connections, and internationalism. The issues in developing the skills of engineers at VTT include furthering education, training, work control, management practices, career planning, exchange of personnel with other organizations, external professional contacts, participation in organizational planning, and teaching activities. The activities for the development of personnel as well as continuous monitoring of the quality of research work by means of, for instance, discussions with experts on the results of some research projects (e.g. Lemola et al. 1983) form the framework for our study. Our research findings will hopefully contribute to these developments from the viewpoint of information use.

4.3 Information Use in Engineering: Methodological Discussions

> "The truth is something you get on toward and never to, and the way is filled with ingenuities and excitements. Don't take the straight and narrow path of the stodgy positivists; be gay and optimistic, like Galton and you will find yourself more toward than you had ever expected."
>
> E.G. Boring (Denzin 1970, p.455)

As seen in the earlier reviews there is no consensus of useful approaches to the value of information. There is seemingly a need for understanding the phenomenon more thoroughly in practical surroundings. Qualitative research produces this kind of data; it has its roots in phenomenology and hermeneutics, sociologists call it the interpretivist approach (Juntunen & Mehtonen 1977; Halfpenny 1979; Putnan & Pacanowsky 1983).

There is not much point in arguing here against positivism or empiricism generally but it is worth emphasizing that

> "... the world of observables is not simply 'out there' to be described and measured with measurement systems of modern science, but the course of historical events and the ideologies of a given era can influence what is

'out there' and how these objects and events are to be perceived, evaluated, described, and measured." (Cicourel 1969, p. 38).

In more practical terms this means that we have to study the use of information as a continuing process and understand the value in the context. We are trying to perform our valuing exercises accordingly but also to find simple means for the research manager to evaluate the use of information. Thus we hope to be able to introduce some fairly straightforward models of this complex phenomenon.

Although we collected all the quantitative data available on the use of information in a set of research projects our emphasis is on qualitative data. The following basic assumptions are made (Dunn 1983b):

"1) Knowledge creation, dissemination, and utilization are particular forms of subjectively meaningful behaviour.

2) The subjective meaning of knowledge to the knowers can and should be understood in terms of the frames of reference of individual and collective actors themselves.

3) Observations should be made in natural settings where the everyday, practical character of knowledge creation and use may be discerned.

4) The aim of qualitative research includes the

exploration or discovery of new patterns of subjectively meaningful behaviour, as well as the confirmation or verification of possible hypotheses deduced from prior theories."

4.3.1 Triangulation

Triangulation is a term for an approach in sociological research where multible methods, data types, observers and theories are used for increasing the confidence in the observed findings. Method triangulation is either with-in-method or between-method triangulation. In the former a method, say interviews, is used for several data gatherings in the study while in the latter, for instance, interviews and content analysis are used simultaneously to describe the same phenomenon. In addition to method triangulation, theoretical triangulation involves the use of several different perspectives in the analysis of the same set of data, data triangulation means gathering observations with multiple sampling strategies and investigator triangulation is the use of more than one observer in the field situations. It is believed that the greater the triangulation, the greater the confidence in the observed findings (Denzin 1970, p. 471 -475). In this study method triangulation and data triangulation have been used.

The literature on research methodologies is full of debates about best methods in particular research settings. For instance, in Weinshall's (1979) book, different methods have been used to study managerial communication and time used in communicating. There are three basic sets of methods available: estimating (questionnaires and interviews afterwards); diary-keeping by the subjects of a study; and observation. Observation, which is often seen as the best method to study managers, is very expensive and is perhaps not good for studying researchers because they can more easily change their behaviour when observed. Diary-keeping is useful if one succeeds in persuading researchers to co-operate but the data have to be cross-checked by other means. Although estimating by interviews and questionnaires is often seen as the least desirable possibility of the above three it is the most used means. We use this cheapest method as a basic means for collecting data, supported by diary-keeping in time-allocation and content analysis of project documents. There have been attempts at diminishing the problems of estimating in several interviews and questionnaires conducted during and after the research projects. For practical advice on this kind of study see, for instance, Hoinville & Jowell (1978).

Bitz and Owen (1981) used triangulation in their case studies. They collected data from seven projects using diaries, weekly forms, periodic interviews during the projects, project documents, and retrospective interviews and questionnaires. They used retrospective studies .

because, according to Bitz and Owen (1981), only these provide the opportunity to move beyond the simple recording of information flow towards the critical assessment of information inputs. Retrospective studies make case-studies on several projects economically possible. Long-term projects can also be studied as a whole, and it is possible to compare given information with the actual results of the projects. On the other hand, obvious problems surround the selective memorizing of respondents and thus it is advisable to support these studies with data collection in real time. The avoidance of problematic samples in studies in the value of information was suggested. One must reckon with them, however, if large projects are studied.

The Solution Development Record (SDR) method which was successfully used by Allen (1977) was recommended to be used with caution by Bitz and Owen (1981) because it emphasizes only the dramatic changes in the course of the project. SDR required engineers to define the goals of their research and break the research down into sub-problems. The possible solutions of each sub-problem were assigned to their likelihood at different points in time. The influence of new information of different types from various sources is thereby measured. We use SDR as a general framework in both the interviews and the content analysis of project documents.

Besides SDR, Allen (1977) used daily time allocations of information activities, interviews before and after the projects, and tape-recorded progress reports of some projects. Allen applied a "twin project approach" where the information activities of twin projects dealing with the same problem were analysed. In all some 30 projects were thoroughly studied. Descriptive data on information use were collected but later Allen concentrated on communication networks within research laboratories.

In a case study the following triangulation approach was taken by Bitz and Owen (1981):

1) Brief diary on selective days to record information and communication flow on those days.
2) Continuing questionnaires every second week over a six week period.
3) Retrospective questionnaire after the period.

It was noticed that researchers do not remember their information use in detail when asked afterwards. The need for a fourth phase arose but the organization where the study took place did not consent.

4) More detailed continuing diary and retrospective interviews.

In another case study carried out later by Blitz and Owen (1981) somewhat different ideas were applied:

1) Interview of researchers in the project about their sources and channels of information etc.
2) Preliminary assessment of the appropriateness of the information being used through reading, discussions with experts, etc.
3) Seeking of additional information for the project from:
   (a) other researchers in the organization
   (b) online searches
   (c) consultants
   (d) representatives of other British companies in the field.
4) Evaluation of the use of information in the light of new information.

Some ideas from the described case studies are used in our studies. The approach in the latter study is not used because of the difficulties in finding other experts willing to co-operate and because of the necessarily time consuming nature of the study. In general, Bitz and Owen (1981) produced much interesting data on the use and value of information and their triangulation approach seems worth following.

4.3.2 Surveys on Knowledge Utilization

The most frequently used methodological approach in knowledge and information utilization research is the survey. Typically, the respondents are asked to describe the details of the information they use, and especially the channels and sources of information. Based on these responses, a utilization score is assigned to each respondent. This serves to determine the impact of information or the amount of use of information services and products (Larsen 1980).

Such descriptive data have also been collected on the information use habits of engineers. Shuchman (1981) sent a questionnaire to 89 companies (39% returned the questionnaire) employing some 15000 engineers, 37 engineers were also interviewed. A lot of detailed data on information sources were collected but in general the following answers on the use of different sources of information were given: own files 93%; personal contacts 87%; unguided use of library 38%; external consultants 33%; online databases 20%; and consult librarian 14%. Waterman (1982) produced similar results by just commenting on the main sources of information for engineers based on the experiences of Michael Neale & Associates Ltd. Gralewska-Vickery (1976) studied the communication and information needs of earth scientists thoroughly. Raitt (1985) asked scientists and engineers in aerospace of their information needs and use.

Mick, Lindsey and Callahan (1980) modelled the use of information of engineers by collecting data from some 560 engineers. They stated that to get a total picture of all factors affecting the information behaviour of individuals in organizational settings there must be:

- a detailed description of individuals,
- an assessment of the individuals' attitudes concerning information,
- an assessment of the individual's perception of management attitudes towards information behaviour,
- an assessment of information behaviour and practice, and
- attitudes towards specific attributes of information products and services.

The conclusion from the large data set was that environmental and situational constraints play a major part in determining information behaviour. Kaufman (1984) collected data from 147 engineers on their use of information in problem solving. The following findings describe the results of the study: "... there appear to be two conflicting forces affecting the use of external information sources. One was generated by the positive stimulation of the organization climate and challenging work; the other resulted from a poor work and organization climate which created internal communication barriers that forced engineers to turn to external sources." (Kaufman 1984, p. 423). Thus, the use of external information was either good or bad. Should we not need to know why and how to support 'goods' and block 'bads'?

There is also substantial literature on the critique of surveys on the use of information (Allen 1977; Mick, Lindsey & Callahan 1980; Bitz & Owen 1981; Larsen 1985). Larsen (1985) describes the development of the research on information utilization by saying that until recently it assumed straightforward utilization or non-utilization of the pieces of information. Now that the multi-dimensional nature of the utilization process has been acknowledged the studies have shifted away from general surveys. Still, small and specialized surveys produce interesting new data. Rogers (1982), for instance, studied with a small set of interviews, information exchange among some private firms in Silicon Valley. He produced data on the patterns of private exchange of top secrets in local restaurants and bars. Managers of those firms would probably prefer more guarded ways of communication and the awareness of this kind of exchange must be essential.

The value of information has been touched upon in some surveys. Shuchman (1981) asked respondents to her questionnaire to rank the importance of some 30 sources. Raitt (1985) asked about the time used for information seeking (under 2 hours per week on average). In most surveys respondents find it difficult to answer questions about the economics of their information use behaviour. Mick, Lindsey and Callahan (1980) "found little awareness of the cost of information. Respondents were obviously aware of the time they spent on information activities but were completely unable to respond to questions concerning how much money they could spend on information." (p. 349) (see also Appendix 3).

4.3.3 Case Studies

The case study approach offers a flexible study design. Data gathering and analyses are largely determined by the subject matter, and specific procedures are decided upon while the study progresses. Virtually every textbook on social science methods reinforces the common stereotype of the "case study": it should be used at the exploratory stages; it leads only to unconfirmable conclusions; and it is really a method of last resort (Yin 1981).

The continuous failure of the positivistic approach in studying such a complex phenomenon as the use and the value of information has given rise to the interest in case studies (Yin 1981; Fidel 1984; Yin et al 1985). Case studies have been considered appropriate for investigating phenomena when:

1) a large variety of factors and relationships are included,
2) no basic laws exist to determine which factors and relationships are important, and
3) when the factors and relationships can be directly

observed (Fidel 1984).

Case studies pose more problems than many other methods because they burden the subjects of the study substantially. This means that in practice the opinions of the subjects of the study and their managers have to be consulted in study planning and it is seldom possible to collect all the data that would have been desirable. Another problem is generalization. As Halfpenny (1979) states, "generalization from case studies is possible but not in the same way as from comparative statistical studies... case studies have the advantage that they permit researchers to hypothesize generalizations about the structural relations between different properties of the one case and between properties of the case and properties of its contents" (p. 810).

Case studies are relevant in studying the use and value of information because the topic covers a phenomenon that seems to be inseparable from its context. Knowledge utilization (or use of information) is composed of a series of decisions that occur over a long period of time with no clear beginning or end. It produces outcomes whose direct and indirect implications are too complex for single factor theories. It usually has a large number of relevant participants and takes place in situations that are special in terms of agency context, historical moment in time, and other key elements (Yin 1981).

Case study design has to specify the main topics to be covered by the study, the type of individuals and other sources from whom information might be obtained, and the units of analysis at the case level as well as within each case. Case studies produce detailed descriptive data for understanding the role of information, they give ground for building and testing theories and hypotheses, and they promote research as a learning process. A successful case study has the following aspects:

1) clear problem definition (theoretical and empirical issues in harmony),
2) study design with argued selection of subjects,
3) several data collection techniques used,
4) argued analysis and interpretation of data, and
5) detailed enough and clear presentation of the approach and the results. (see Yin 1981; Yin et al. 1985)

We have earlier discussed Allen's (1977) and Bitz' and Owen's (1981) case studies on the use of information by engineers. Triangulation is an essential feature of a case study. In addition, for instance, Wolek (1969) used this approach to study the use of information in the development projects of a group of engineers. Bitz and Owen (1981) completed an experiment on the influences of rich information input on a research project so as to monitor difference from 'normal' use of information, and also suggested 'a more rigorously experimental approach in artificial situations using the technology and methods of small group research'. The aim of these 'Intervention Studies' "... should be to answer the practical questions concerning the amount of usable information available (to a field or organization), the amount that is used, the difference that unused information can make, and the problems and costs of bringing that information into use." (Bitz & Owen, Part two, p. 101). Although interesting the latter studies are hard and expensive to realize and some doubts could be cast on their cost-effectiveness.

The types and sources of information and knowledge are of importance when analysing the use of information in research projects. We used task, domain, problem, problem solving and output information and knowledge in our earlier theoretical analysis. Bitz and Owen (1981) determined also five types from a set of 278 pieces of information: logistical (16%), planning/progress (31%), experimental (25%), analytical (23%) and general technical (5%). The final question of the types must be left open until some data have been collected but it may be that useful classification could be done even with three or four groups: domain (earlier information and knowledge of the problem), problem (experimental information and knowledge), methodological information and know-how - and perhaps general or background information.

Sources of information have been discussed more often in the studies on information use (Allen 1977; Bitz & Owen 1981; Shuchman 1981; Waterman 1982; Lingam 1983; Swanson 1984). Our approach is going to use such categories where both the external and internal nature of sources, and the types of sources become clear. The likely set of categories include books, articles, online databases, trade literature, manuals and handbooks, patents and standards, internal reports, internal personal contacts, own files, external personal contacts, conferences and seminars, external consultants and other bought help.

4.4 Outlines of the Study Plan

OBJECT:
To study the value of information in research projects.

PRACTICAL GOALS:
To develop means for research managers to evaluate the effectiveness of the seeking and the use of information in research projects (these serve also as indicators of the effectiveness of research processes as such because they are difficult to study directly).

SUBJECT:
A set of different kinds of research projects picked from research programmes in different phases, the key-scientists in those projects are interviewed. For generalization purposes questionnaires and time-allocation forms are

sent to representative sets of scientists at VTT. The managers of the research laboratories are interviewed as well.

RESEARCH TASKS:

1) Selection of 12 projects to be studied at VTT (nine finished and three ongoing). Inputs to and outputs from the research projects and their information seeking and use are to be studied in order to find out the important factors in optimal information seeking and use.
2) Retrospective study of the nine finished projects:
   - three phase interviews of the project staff
   - content analysis of the project documents
   - interviews of some experts on the quality of the results of the projects
3) Study of the ongoing projects
   - interviews of the key-scientists in the projects three times within the first year of the projects
4) Questionnaire of information seeking and use patterns at VTT
5) Time-allocation study of the research projects at VTT for explaining the labour-costs of information seeking and use.
6) Interviews of the research managers about the effectiveness of information seeking and use in their laboratories.

DOCUMENTATION:

The results of the studies at VTT are reported in the following three chapters. Value-in-use of information is examined in twelve research projects by interviewing the engineers running the projects and some experts outside the project groups (Chapter 5). A questionnaire survey was completed to describe information seeking and use at VTT-level (Chapter 6). Finally, a time allocation study and interviews of the research managers explain the economics of information use (Chapter 7).

The sample and methods of each piece of research are described in the beginning of the Chapters. The results try to answer the following questions: What is information use at VTT? What were the consequences of information use in a representative set of research projects? How can values of different consequences be measured? The sections are tied together with comments on the value of information comparing earlier theoretical analyses to the present data. Overall summary and generalizations are discussed in Chapter 8 and Capter 9.

5. VALUE-IN-USE OF INFORMATION: TWELVE RESEARCH PROJECTS UNDER INVESTIGATION AT THE TECHNICAL RESEARCH CENTRE OF FINLAND (VTT)

5.1 Sample

When it was decided to use the case-study approach it was quite obvious that a set of projects would form the main subject of the study. There are some 1000 projects underway at VTT which meant that we had to spend some time in negotiating over which ones to use. Although contract research to private industry is the main source of income for the research centre these projects were excluded. For reasons of confidentiality it is difficult to collect data on these projects. Even more importantly, a lot of contract research is based on the results of earlier research at the research laboratories which results in quite low observed information seeking and use in these projects.

In general, it was decided that the projects would be taken from research programmes of VTT. These programmes are aimed at increasing high quality research on certain nationally important fields of technology. They are in-house management tools for developing research capabilities in the areas seen important at VTT for offering research services to Finnish industry in the future. Roughly speaking a programme usually lasts three years, takes three million FIM (includes only main labour-costs centrally financed) and some 30 scientist-working years. In practice a programme is a set of projects on a given area of research completed by several laboratories together. It is usual that in the final phases of the programme the laboratories involved have such research activities that the industry comes to take part in some projects.

Three research programmes were taken into closer consideration for selecting the projects to be studied:

1) Computer aided design and manufacturing (CAD/CAM) in the construction industry,

2) Applications of artificial intelligence (AI), and

3) Optoelectronics.

Each programme aims at developing the research abilities of VTT. The information technology orientation implicates the emphasis of the research programmes of the 80's. The CAD/CAM-programme tries to increase the use of information technology in the building and construction industry which has been quite conservative in this area. During the course of the programme several other national efforts have arisen and VTT plays a major part in most of those efforts. In the VTT's programme the main emphasis has been on building design and manufacturing techniques. Nearly ten laboratories of VTT have taken part but the main responsibility has been on the Concrete and Silicate Laboratory and the Laboratory of Urban Planning and Building Design.

The AI-programme concentrates on knowledge engineering. It is a typical research programme in the sense that the knowledge of AI at VTT was quite low and scattered when the discussions on industrial applications of AI arose in the early eighties. The programme started with a set of preliminary studies and later turned to developing applications. The programme is heavily interconnected with the other simultaneous programmes of the Technology Development Centre of Finland and the Nordic Industrial Fund. There are also interconnections between the research programmes: in the Laboratory of Urban Planning and Building Design AI-programme is closely interconnected with the CAD/CAM-programme. The Medical Engineering Laboratory and the Laboratory for Information Processing have the main responsibility of the AI-programme. Some ten laboratories in all are participating.

The third programme in optoelectronics is more basic research oriented than the others. This compact programme is led by the Semiconductor Laboratory. The Electronics Laboratory and the Electrical Engineering Laboratory are other participants. There is already a ten year tradition of research in this field at VTT. The main interests are in basic technology, measuring techniques and applications of e.g. optical sensors.

The CAD/CAM-programme ended in 1987, the AI-programme has been under way since 1985 and the optoelectronics-programme started in 1987. The idea was to gain experiences both from the projects where the industry already was involved and from 'start-up' projects. Ongoing research was studied in the optoelectronics-programme. The programme consists of up to 20 projects varying in size from a couple of months' work to some 15 man-years' work but large projects are usually divided into several sub-projects. Twelve projects were selected as a representative set of projects with both varying and typical results of the work done at VTT. Table 1 lists the projects studied.

Table 5.1. The projects included in the case-study at VTT

CAD/CAM in construction industry:

1. Computerization of building standards and regulations

Task: To study possibilities of organizing a computerized database of building standards and regulations, and to develop a pilot system.

Labour: 24 research work months

Budget: 350 000,- FIM

2. Computer aided manufacturing of concrete elements

Task: Automatic calculation of early tenacity and

Table 5.1. Continues:

developing the manufacturing process of concrete substances.

Labour: 11 months

Budget: 250 000,- FIM

3. Future development of computer aided urban planning and building design

Task: Present situation and future needs in research on CAD in urban planning and building design.

Labour: 6 months

Budget: 120 000,- FIM

4. ADP of building work

Task: To study the ADP of building work and to model the use of computers for building companies.

Labour: 28 months

Budget: 500 000,- FIM

5. Technical and economic optimizing methods in building design

Task: To study the possibilities of optimizing methods in building design and to develop a pilot model for industrial buildings.

Labour: 15 months

Budget: 500 000,- FIM

Table 5.1 Continues:

Applications of artificial intelligence:

6. Methods and tools for expert systems design

Task: To study methods and tools of knowledge engineering for use in other projects of the research programme.

Labour: 28 months

Budget: 850 000,- FIM

7. Installation of MYCIN

Task: Installation of MYCIN and developing a prototype application in microbiology.

Labour: 25 months

Budget: 700 000,- FIM

8. Machining expert system in CAD/CAM

Task: To develop a prototype machining expert system.

Labour: 35 months

Budget: 1 100 000,- FIM

Optoelectronics:

9. Photonics -research project (a part of Semiconductor Laboratory)

Task: To produce and develop optical fibres, optical measuring techniques, optical integrating and

Table 5.1 Continues:

optical measuring devices.

Labour: 250 months

Budget: 4 300 000,- FIM

10. Hybrid-integrated optoelectronic structures

Task: To develop abilities to design and make hybrid-integrated optical structures.

Labour, planned: 55 months

Budget, planned: 1 800 000,- FIM

11. Technology of optical fibres

Task: To develop optical sensors for various applications

Labour, planned: 44 months

Budget, planned: 1 200 000,- FIM

12. Applications of laserphysics and interferometry

Task: To develop abilities in optical measurement techniques and to build new devices

Labour, planned: 99 months

Budget, planned: 4 300 000,- FIM

The set of projects is representative of the programmes they are taken from. The smallest projects were excluded. As they are usually done by scientists working on other projects as well, aspects of them are difficult to analyse separately. Only two projects of the planned set had to be changed because the key-researchers left VTT.

5.2 Methodology

Interviews provided the main means by which data were collected. In addition, some content analysis of project documents was completed. The first nine projects in Table 1 were studied retrospectively, the final three being studied by following the use of information with interviews while the projects proceeded. The methodology of the retrospective analyses is presented first.

Interviewing was performed in three parts and the project members in each research programme were usually interviewed during the same week. The research programmes were selected after discussions with the representatives of research managers. Preliminary information on the research programmes was gained from documentation and some ideas on the projects to be studied were developed. The leaders and co-ordinaters of the research programmes were then interviewed. In the interviews the main ideas of the study were introduced, comments on the study-plan collected, and the list of projects to be studied was confirmed. Willingness to participate was total. The concentration on studying the use of information and its consequences had to be emphasized, because an overall evaluation of research programmes (as done for every programme at VTT) was the main concern of those interviewed.

In the second phase the heads of the selected projects were interviewed. The preliminary list of questions was sent before the interviews to the respondents along with general information on the study. The interviews could be characterized as deep-interviews with the following main topics (see Appendix 4 for the full list of questions):

1) respondent data,
2) background data of the project (e.g. aim and earlier research in Finland in the area),
3) input to the project (personnel, equipment, information),
4) output of the project (documents, devices, knowledge, new skills, ...),
5) benefits of the project (economic and others), and
6) evaluation of the project (self evaluation and received comments).

In connection with the interviews the basic documentation of the projects was collected. There were some problems here: in spite of established 'project-bureaucracy', documentation varies considerably. Additionally, in the case of one project, documents were not available because of confidentiality (substantial private finance involved in the end of the project). However, revised project-plan, main publications and other such documents, minutes of the project group's meetings (only seldom kept, quite general) and economic reports of the project were collected. Prototypes were also demonstrated and devices introduced. Because of the lack of detailed documentation for our purposes, more emphasis was put on the second interview. Still, even this rough documentation proved to be useful in helping scientists to memorize the course of the project in the third interviews. The gathering of documents seems also useful in a psychological sense: it helps in preventing too selective memorizing.

The third set of interviews followed the approach of the second and this time 1 - 2 scientists working for the project were selected. Those interviewed had central roles in the projects - in smaller projects only the project head was interviewed. The following topics were discussed (see Appendix 5 for the full list of questions):

1) tasks of the project,
2) main changes during the course of the project and the reasons for the changes (background from the project documents),
3) use of information (discussions about project records, amounts of articles, contacts to experts etc.),
4) which types of information were used,
5) nature of the project in relation to new information,
6) levels of use of the collected information,
7) learning in the project, and

8) information needs of the main task of the project
   - how the information was sought
   - experience in information seeking
   - self-evaluation of information seeking and use.

All 30 interviews succeeded in general terms. Nobody refused to answer, but in the case of a few respondents the interview was slightly disturbed by hastiness. The original plan to have an hour's time limit for the interviews was basically adhered to: almost all the interviews were in the range of 50 minutes to 90 minutes, only some interviews in the remote locations and with demonstrations taking longer. The problems arose from the subject of the study: the limited awareness and interest in the economics of information of the research scientists made answering quite hard for the respondents. It proved that without a lot of practical connections to e.g. research records and results there are no ways to characterize the use and economics of information in the research work. The case-study approach was rewarding because it gave possibilities to shift the emphasis in the interviews when deeper understanding of the projects was developed. Still, after some tests, the interview schedule was kept the same for each level of interview in order to make classification of the results possible.

In addition to self-evaluation some experts were interviewed to assess the use of new information in the projects. These interviews were partly connected with the continuing evaluation pattern of the research programmes of VTT. Two experts per project were interviewed and the experts were the same people in each research programme. The experts found it quite difficult to answer the questions concerning information use in the projects. The following topics were discussed in the interviews (the interview schedule is in Appendix 6):

1) importance of the project,
2) the role of the project in creating and transferring new information and knowledge, and
3) the nature of the project in relation to new information.

The problems in retrospective studies were supposed to be eased by supportive data from three ongoing projects (projects 10-12 in Table 5.1). The use of information in the early stages of these three large projects was monitored by interviewing the heads of the projects three times during the first year of the project. The following topics were dealt with in those interviews (for the full list of questions see Appendix 7):

1) nature of the project (background and changes during the early stages),
2) input to the project,
3) information inputs,

4) experience in the use of information, and
5) future of the project.

It was realized quite soon that the projects were so large that the heads of the projects were not able to give detailed data of the information used in the projects. So instead, we concentrated on the information use of the project-heads which was found to be most important for the project in other analyses. Furthermore, interviewing did not seem to be the best way of collecting this kind of data: e.g. the problems of remembering information activities in detail were severe. Diary-keeping would have been better but it was not possible here because it would have burdened the project-heads too much. In addition to the formal interview, discussions of more general issues took place. The opinions on other simultaneous data-collections and analyses were gathered for supporting study-planning.

5.3 Input-Output Characterization of the Research Projects

Twelve research projects, subject to the case-study, are introduced in this section. The main emphasis is on the inputs and the outputs of the projects. Some assessment of the projects is also presented - of course there are no data available on the results of the ongoing projects. The idea is to give basic understanding of the research projects at VTT before the use of information is studied more closely.

In their goal setting the projects fall into four groups: development of abilities (6), basic research oriented (4), practical application (1) and state-of-the-art report (1). In developing abilities, models are built and prototypes produced. In the basic research oriented projects some new 'laboratory demonstrations' have been developed, for instance a new measuring device. Only one project is clear development work though concrete results are emphasized in several other projects as well - this characterizes the attitude of the research scientists at VTT: practical results are almost always mentioned as an ultimate goal for the research.

Half (6) of the projects were seen as a vital part of the research programme they belonged to. Almost the same number (5) were felt to have only loose connections, one project preceded the programme. Earlier knowledge of the subject-area was small or non-existent in six projects whereas in five projects there was a solid basis of up to ten years experience on which the projects were based. In one case preliminary study was undertaken.

The main information inputs into a research project are usually the knowledge and the abilities of the scientists. Research is usually group work at VTT. Of the projects studied only two were mainly done by one person. There were two projects with two, three, four and six scientists, one with five and one with ten scientists. Additionally, there were experts involved in the projects as members of the project - and the steering groups. Also, supportive staff were involved in most of the projects, the maximum being 25 people. Typically a project lasted one year, the range being from eight months to three years. There were few changes in the staffing of the projects: long projects used to take new people ,especially those preparing their dissertations on the projects. Only in two projects did a key-person change but the loss was fairly easily replaced. It seems that in the present employment situation industry is no longer 'buying' scientists as eagerly as before.

There was a certain uniformity in appointing the scientists to the projects. The key-person (or people in some cases) was either the originator of the research idea or had been involved in developing the idea. Naturally then he also had some preliminary knowledge of the subject and even though often this knowledge was quite scanty the senior level basic knowledge of the field was there. In four projects the expertise for the project was clearly collected from several laboratories. In one case the project group was actually formed by recruiting new scientists. Most often the main responsibility was in one laboratory and only some marginal parts were 'bought' from other laboratories. Supportive staff inside the laboratory was usually taken from junior scientists. The pattern was clearer the bigger the project and the longer the research tradition in the laboratory. Whenever possible the projects consisted of pairs of senior and junior scientists. This seems ideal also from the viewpoint of information input into the project.

Although the main information input into a research project is usually provided by scientists working on the project and other experts participating in project work, information is also sought during the project. There were four main groups of source information: national and international contacts (conferences, visits,etc.), continuous reading (especially scientific journals) and retrospective literature search (normally online search). In the projects studied 2 - 3% of the total budget was used for visits abroad (range being 0 - 6.2%; 0 - 20 000,- FIM) and the use of information services was under one per cent (range being 0 - 2.4%; 0 - 6 000,- FIM). Not all information seeking costs are included: circulation of journals within VTT and the use of information services other than those provided by the Information Service of VTT are excluded. Information is also bought in connection with earlier projects and other simultaneous projects. Still, one can confirm the generally acknowledged fact that information acquisition accounts for an insignificant part of the research budget.

Information seeking can be said to have been active and versatile in most (8) of the projects, in three of those the emphasis was on continuing monitoring of new research while in the rest state-of-the-art information was sought. It was noticed that the monitoring of the three ongoing projects stimulated information seeking in them. In the average completed project the scientists attended 1-2 conferences (maximum being 20), made a couple of visits abroad and a couple of foreign experts visited VTT. Contact with international experts were also made by phone and letters. Furthermore, one online search was made (many complaints were made about the results) and scientific journals were continuously scanned. When detailed local data (problem data and domain information) were needed, scientists usually interviewed local experts; for instance, the the adp needs at the building work were examined this way. The size, nature and the topic of the project naturally influenced the information seeking activities but the general pattern was surprisingly homogeneous in these 'information-active' projects (five out of nine).

In two (out of nine completed) projects a somewhat different approach was applied: an online search was completed in the beginning of the projects and journals were scanned. There were no direct international contacts. In two other projects even less attention was paid to information seeking. Information was either available in the laboratory or a client gave it. It would be an exaggeration to say that the latter four projects were worse than the others, they just describe the different nature of those projects. In the case of relying on published information, projects were not yet ready for international contacts and in the case of no information seeking, information was already available and there was no time (or need) for further efforts. In general, it seems that information seeking patterns are quite well established.

One may find some problems in timing and 'overuse' of particular channels. For instance, in one project attendance at a conference was too late to benefit that project. In another project important written material was received late. In two ongoing projects a major forthcoming international conference in the field in Finland clearly delayed some information seeking activities and afterwards generated some new ones. More generally, it seems that the making of new international and national contacts is an important and demanding task of the project-head.

As can be understood from the subjects of the projects studied computers were heavily used in the research work. Some programming was done in ten out of twelve projects. For four projects expert systems development tools (shells and languages) were bought. Some major acquisition of equipment took place only in three projects (e.g. lasers and measuring devices were bought). Naturally there was some smaller procurement in each project (e.g. components were bought for six projects), two projects were purely written accounts. The acquisitions of equipment demonstrate a bias as they are mainly financed from a separate equipment-budget.

The main results of the nine completed projects were prototypes, documents and new knowledge. In two projects measuring devices were developed, their degree of applicability varying from ready-to-use devices to laboratory demonstrations. Software products were among the results in six out of nine projects, four producing different kind of prototypes. One project had six patents among the outputs. Also two ongoing projects applied for a patent during their first year.

Each project group documented its results by producing reports and articles. Typically one or two reports were written in Finnish (published by VTT) and a couple of articles were published in Finnish journals. Only two projects produced major documentation also in English. The results were also delivered through conference papers, presentations in seminars and training courses. Five projects presented their results at foreign conferences. Substantial training was given in Finland in connection with four projects (up to 10 courses). In one project some ten dissertations were also completed. The documentation indicates that most of the projects transferred technology and knowledge to Finland (as already expressed in the goal setting of the projects), only one (or two) clearly exchanging information with international research communities.

The scientists emphasized that new abilities had been developed in the projects, in six projects the ability to produce products or to advise on production was mentioned as a result of the project, one produced devices ready for production. Deepened understanding, organized knowledge and awareness of the subject field were among the descriptions of new knowledge gained.

In fact this new knowledge was already in use in seven out of nine projects in the form new projects which indicates the continuing nature of the research work at VTT. The other two have not managed to get financing for future work. Two projects have already led to some consulting based on the knowledge gained in the projects. In economic terms knowledge and abilities have advanced, and the possibilities of getting follow-up projects for the laboratories involved have improved. Two projects gave results which offer direct income to those applying the results: one in the form of savings in a production process and one in the form of new products (a new company set up). The real economic influence can be seen in succeeding years after the industrial applications are in full use - the main problem being then how to isolate the influence of a particular project from various other sources (e.g. earlier projects and the role of commercial efforts).

The scientists' own estimates of the fulfilment of the goals were good or excellent in five projects, in the other four minor problems were caused by lack of resources, changing goals in the course of a project, technical matters, and working in a previously untouched area. Value for money was said to have been gained in eight cases, it was reported that value had been obtained for 70% of the money spent in one project. The outside experts were more critical: four projects were seen as too expensive and only two projects were seen as really nationally important while the rest were merely increasing the abilities of VTT.

The scientists had received individual positive comments on the projects from outside. International interest has been expressed in two projects. In the case of the Finnish interest, the more practical the results have been, the more interested industry has been. The feedback has been quite scant in most of the cases and clear positive connection to the efforts in disseminating the information of the results was noticed.

The outside experts rated the projects studied in transferring new information and knowledge to Finland quite low: two had hardly any importance, five other projects were merely organizing (translating) and using existing information and knowledge, and only two developed some new information and knowledge in Finland.

5.4 The Use of Information in the Research Projects

When looking at the tasks of the projects studied the following pattern was dominant. The ideas were developed by seeking and using international information, local conditions were studied and prototypes were built. In four projects theoretical issues were dealt with while in one project quite straightforward development work was completed. Two projects were merely state-of-the-art reports while the others were more research oriented.

The preliminary understanding of the use of information in the projects was developed by studying the information needs and seeking patterns in relation to the key-tasks of the projects (only those projects already finished). Those tasks were usually the practical ones probably because the practical results were highly valued. The information needs were naturally variable but the emphasis was on methodological information in five key-tasks. The factual information-oriented tasks were from the projects which generally had lower goals. This indicates that methodological information plays the most important role in the projects.

Information seeking for the key-task was then discussed. In three projects the information was mainly generated within the project. Two projects relied heavily on published information and one had information already available. In the other three the sources were scattered. Other VTT laboratories not participating in the projects had no role in information seeking. On the contrary, colleagues in the laboratory were often consulted. This could mean that there are not many unofficial contacts within the laboratories and in the beginning of the projects the expertise of VTT has been well exploited. Literature was of some importance in all but one task. However, interestingly, only in two tasks had unpublished information some minor role. Foreign and Finnish experts had some role in information-seeking in seven tasks but their importance was rated as fairly marginal. However, they were nearly always mentioned as intermediaries for published information. This suggests that personal contact with experts can compete successfully with the information services (which were also used in all except two of the projects in finding useful information).

It was not possible to find any clear patterns in seeking either factual or methodological information but independent experts and colleagues were often mentioned as sources or intermediaries to literature on methodological issues. Methodological information was also said to be hard to find and to assimilate in several projects. Experts were seen as the best support here also. When factual information was gathered from experts more organized methods (like interview schedules) were used. Co-operation in the project generated new knowledge in a couple of cases. Problems in information seeking were seen as being caused by the new fields of technology or a lack of background knowledge in the projects. It was estimated in three projects that more international direct contacts could have increased the quality of the projects (better information and knowledge could have led to better results) but usually scientists were satisfied with their information seeking.

The project documentation and interviews were then used to study major changes during the course of the projects. The planned budgets were quite well kept. In two cases the budget was exceeded by over 25%: the reasons being added tasks and training of new personnel. In four projects major changes took place in the content of the projects in the course of the research work. In each case the reasons were unique: basic research is full of surprises, changed goals, major new tasks and new approaches found. The remaining five were completed as planned with some minor changes in emphasis. In two cases an individual piece of documented information was recalled as a cause for new direction in the research, but usually the use of new information seems to be an integrated part of the continuing learning process which seldom has 'great discoveries' easily recalled afterwards. Research work seems to advance by continuing iterations of several simultaneous sub-problems of the research project. Where new information is flowing in through various channels - the working patterns of the research groups should be studied more closely to deepen understanding of research work.

As described already in some other studies (Morehead & Rouse 1985) scientists fell clearly into two groups when discussing their attitudes towards their problem-solving patterns: seven out of twelve scientists saw general modelling and searching for several possible solutions as an ideal pattern for the research work (theoretical approach). On the other hand, five supported an idea of straightforward seeking of practical solutions (procedural approach). There were complaints among those supporting the theoretical approach that only seldom are there real possibilities at VTT for applying this approach. Still, the research programmes were seen as an important tool for supporting this when the pressure in contract research does not allow the luxury of general thoughts. Interestingly these attitudes seem to be personal and not so much dependent on the research tasks completed.

The importance of sufficient time was heavily stressed as vital for good research, although in the projects studied there was usually (in seven out of nine) enough time available. This response must be seen in the context of the tightly scheduled contract-research projects which most scientists were simultaneously involved in.

The role of time and learning was then discussed in connection with the use of information in the projects. All except one project were seen as important learning processes. In minor projects it was emphasized that one project is too small for real learning processes. It was seen as essential to have large enough continuing areas of research (in terms of research groups) to reach the level of high-quality research.

Respondents were then asked to compare the project groups' previous knowledge with different types of new information acquired by the projects (Table 5.2). Respondents were asked to assess the extent to which previous knowledge and the newly gained information contributed to the success of

Table 5.2 Use of previous knowledge of the project group and new knowledge acquired during the project

Type of information and knowledge	Range %	Mode %
Previous knowledge	5-70	30
New inf. & Knowledge:		
General technical inf. & know.	0-15	10
Domain info. & knowledge	10-35	30
Problem info. & knowledge	15-40	20
Method info. & knowledge	0-30	20

12 respondents from 9 projects.

a project. Thus previous knowledge contributed, modally, 30% towards the success of a project.

The project groups had always some previous knowledge gained from earlier projects, basic education etc. but new information and knowledge was also always needed. General technical information and knowledge had seldom any real importance. The remaining three groups of information and knowledge in Table 5.2 were quite equal in size. The estimates were found to be hard to give and thus one has to be wary of the interpretations. When methodological knowledge was mentioned earlier in relation to key-tasks it was rated quite high: here the rating is rather low. This may indicate that recognizing the time and efforts for seeking and use of domain information, and producing of problem knowledge is much easier than the use of methodological information and knowledge. The latter is sought and used in various ways which certainly influence the importance-estimates given. There were projects (2 out of 9) where method knowledge was already there but for most of the projects some essential method knowledge was sought.

An attempt was made to describe the nature of the projects by classifying them in relation to information. Thus, a project could create new knowledge, use information from outside, use its own existing knowledge alone, or combine external information with its own knowledge, see Table 5.3.

Creation of new knowledge and use of own knowledge were generally quite low in the projects studied, 20% for both on average. The transfer of technology and knowledge to

Table 5.3 Information and nature of the projects

Information/project	Range %	Mean %
Create new knowledge	0 - 50	20
Use outside information	5 - 90	32
Use own knowledge	0 - 50	20
Combine own and outside	0 - 40	28

12 respondents from 9 projects.

Finland as a main task for VTT is confirmed by this data as the use of outside information and the combining of it with own existing knowledge takes 60% of the total information and knowledge used. The projects seem to differ from each other and also the views of different scientists within the project varied which means that any further interpretation must be done cautiously. The outside expert gave nearly the same distributions but they generally thought that less new knowledge was created.

The nature of the ongoing projects was also studied with the classification in Table 5.3. The same question was put to the project heads in all three interviews during the first year of the projects. The main difference from the results of the retrospective studies was that the creation of new knowledge was much higher here (mean being 32%). These three projects are all working in connection with international research communities and they are producing new research findings which are also supported by other data collected in the interviews. The given estimates changed in those three interviews and these changes clearly followed the information seeking and use phase of the project. In the first interviews the projects were hardly started and that data differed greatly from the data of the other two interviews. Major information seeking activities were also seen in the data. This kind of longitudinal data collection could be used in monitoring information seeking and use activities in the research projects. More data should be collected for more reliable results.

Finally, the use of information was monitored by scanning the records of the key-scientists in each project. It was noticed that in addition to the influence of the nature of the project and other projects in the same field (these could not usually be separated because of the habits of scientists to store records) there are substantial differences in personal patterns as to how to deal with written information. There are clearly the 'information rich' (5 out of 12) and the 'information poor'. Some collect all the information which relates to their work, others try to manage with less effort. Naturally the nature of the project has an influence on the ammount of information needed. There was evidence that the 'information poor' relied heavily on a few experts, while the 'information rich' also had more personal contacts (see for somewhat similar findings, Gralewska-Vickery 1976).

It is interesting to compare the amount of articles collected and the problem-solving patterns of the scientists discussed earlier. One could imagine that those scientists who prefer the theoretical approach would collect more articles (depending also on the project in question) than those prefering the procedural approach. This was not always the case. Only six (out of 12) were in harmony with the hypothesis, two collected a lot of articles but supported procedural approach, and four 'information poor' supported the theoretical approach. The size of the sample does not make generalizations possible but the data indicate that the attitudes of individuals exist among the complex factors influencing their information behaviour.

The scientists had either 2-3 pamphlet trays for documents (half of which were for project bureaucracy) or they had 10-30 pamphlet trays. Journal articles were the main source of published information and there were two groups: collectors of 5 - 40 articles and collectors of 100 - 800 articles. Additionally there were some important books read in the projects (range 3 - 10). All except one project had contacts with experts outside the project-group. In two projects expert data were gathered by interviews, if these are excluded 1-8 Finnish experts were contacted. Seven projects had also international contacts (range 3 - 20). These figures include only the contacts which had major importance for the projects. Discussions with sales people, for instance, were usually excluded. Most of the international contacts were made at conferences but also by means of visits.

The use of documents was divided into four categories: scanned but not useful, read but not useful, partially useful and generally useful, see Table 5.4. The results were quite scattered. Generally useful were only 15% of the material sought, the mean would be under 9% if we exclude the state-of-the-art study from the set of projects. About half of the material was found to be useful. It seems that

Table 5.4 Use of acquired information

Level of information use	Range %	Mean %
Scanned, not useful	0 - 70	20
Read, not useful	0 - 60	24
Partially useful	7 - 100	40
Generally useful	0 - 80	15

12 respondents from 9 projects

one needs to do quite a lot of waste scanning and reading. Surprisingly there was no correlation between the amount of literature gathered and its usefulness. With earlier results this stresses that individuals have firm patterns in their information use which are not much influenced by the nature of the project. It was learned here that the best way to get reliable data from this matter was to take a pamphlet tray of material collected for the project, and scan that through with the respondents by asking what had happened to each individual article, report or whatever.

5.5 Value-In-Use of Information in Research Projects

The thoughts of earlier theoretical analyses are here put against the results of the case-studies. A set of questions was introduced to explain what information was used, how much it was used, how it was used and what consequences the use had. The ultimate goal was to develop ideas as to how the values of different consequences could be monitored and measured and even more importantly which factors should be monitored for effective information use.

Before going into details on the value-in-use of information it is worthwhile to comment on exchange values. Awareness of the economics of information is almost non-existent among scientists and some even emphasized that the economic matters were not their concern. These attitudes are strongest among those not involved in the leadership of the projects where economics is mainly dealt with. One factor influencing the situation, as noted earlier, is that the observed costs of information-seeking form an insignificant share of the total project budget. There seems to be a real case for reminding the scientists of the total costs of information seeking and not least of the costs of information use, especially the time used in information seeking and use. There is little hope for more rational behaviour if the scientists do not see their information seeking and use as a whole entity as being made more effective. In the present situation more data on the costs of information use are necessary (this issue is elaborated on in Section 7.1) and one was convinced that the exchange side of the dual approach of the value of information cannot be studied with scientists. On the other hand, the situation in the U.S.A. seems to be quite different and there the economic data are easier to collect from users of information (see King et al. 1982; Roderer at al. 1983). While our U.S. colleagues managed to collect statistical data of the value of pieces of information (e.g. research reports) our efforts gave only some detached examples.

The expected value-in-use of the information channels was the key-factor when scientists decided on how to seek the information needed. The versatile patterns in information seeking were found. Even in those cases where only a little new information was sought the awareness of possibilities at a general level was there. The junior members of the research groups got most of the new information from senior scientists. They were usually advised on how to manage the information seeking tasks handed to them (usually factual, domain information). It is obvious that senior scientists in their laboratories form general understanding and working patterns in information seeking based on their own personal experiences. This means that the behaviour and attitudes of those scientists are of major importance when one wants to influence information seeking patterns in the laboratories.

Still, the actual value-in-use of information can only be studied by examining the use scientists put the information to in their research work tasks. It was noticed that projects were often too small for the study and that for best results one should follow the research work for several years (e.g. like Allen 1977). Research groups working in particular areas of research could have been a better target for our approach. On the other hand, such an extensive study was not economically possible and detailed enough monitoring of the research work would have burdened the scientists too much (see Bitz & Owen 1981). In our situation the cross section study gave first hand data on largely unknown issues which are later supported by other data.

As already mentioned the research work is clearly a continuing learning process and it needs large enough research groups. Usually the research programmes and the projects in them are economic units of this continuing process, where limited time and other resources stimulate effective work towards practical results. The research programmes of VTT have an important role in supporting and developing research processes whereas the contract research is often transferring knowledge and technology from these processes. Because of the national role of VTT it has to work on a wide range of activities, not least transferring foreign technology and technical information to Finnish industry. However, there also has to be VTT's own qualified research, if for no other reason than for ensuring the continuity of the transferring process.

The value-in-use of information arises from research processes and it is not possible to isolate value-in-use of the pieces of information for that process except in some special situations. Usually different types of information flow into the research processes through varying channels and occasionally one may recall some changes in direction caused by some new information received from a journal article or even more often from a personal contact. An ideal situation from the viewpoint of the scientists is that VTT offers versatile support to information seeking and so builds an information rich environment for the research work.

In the projects studied, information was sought generally quite broadly, although a fairly low use of information services was revealed by the interviews. The efforts involved in information-seeking seem to provide the basis for assessing the importance of information channels. In the interviews the importance of foreign contacts was over-emphasized and information services under-emphasized although, for example, continuous reading of scientific journals was usually a vital part of information seeking for the research projects. The scientists use the nearest and easiest-to-use information services (not only the services of VTT). They do not seem to think enough about whether they could save some time (and money) by using the information services available more selectively. The issue is important enough to be a subject for debate within VTT.

To the Information Service of VTT the research results can be summarized as follows. The circulation of scientific journals is the most important service. Online searching has to be available whenever needed but it seldom has a vital role in the projects. Document delivery services have to function well. Information services should provide more support to the scientists and the research groups when they build their personal contact networks internationally and nationally.

There are three main factors influencing the value-in-use of information in our research settings: (1) users, (2) research tasks, and (3) types of information used. The information-seeking behaviour of individuals seems to be quite stable but individuals differ one from another. The working patterns have developed through personal experience and the environments in which scientists have worked. The nature of research tasks is obviously important: for instance, in some fields, international co-operation is vital for the research, as in the case of optoelectronics. In another case, building research, local conditions are of major importance.

The level of quality in research also influences information seeking and use. State-of-the-art reports can be based on published information. Development work can be done by using one's own knowledge but more sophisticated research needs versatile information-seeking and use. The types of information are also of importance. The clearest sign of this was the observation that the methodological information was sought in the most variable ways and personal contacts were considered most important in seeking that information. The use of this information is quite hard to monitor because it is used continuously in the research process. It is much easier to monitor the use of domain and problem information and knowledge because it is often sought and used in certain data-collection phases of the project. Although the earlier knowledge of the scientists performing the research tasks was often of great importance there was substantial seeking, use and producing of new information and knowledge in the projects studied.

The value-in-use of information is a complex issue. The economics of information is even more difficult to assess in connection with research projects when one realizes that the costs and benefits of different types of information do not often have any correlations. It may happen that one gets vital advice from a foreign colleague free of charge by just being in the right place at the right moment, the only expenses being the costs of getting there (this has happened especially with methodological information). On the other hand, several years of empirical research in the laboratory may give no results.

To summarize, an information rich environment for research gives the best possibilities of maximizing the value-in-use of information and so the sophisticated research is warranted. If this is not the case with a particular research project or more generally with a certain research area it is a task of the research managers to know why. From time-to-time a piece of research can be performed without new information but this cannot be generally acceptable behaviour. Additionally, another task of research managers ought to be the monitoring of information use.

6. EFFECTIVENESS OF INFORMATION SEKING AND USE AT THE TECHNICAL RESEARCH CENTRE OF FINLAND (VTT)

6.1 General

The case-studies gave detailed data of the use and seeking of information of a particular group of scientists at VTT but for generalizing the results to the VTT-level a questionnaire was prepared. In this Chapter the results of this questionnaire are documented.

6.2 Methods and Analysis Techniques of the Study

A questionnaire issued to a systematic sample of 100 scientists at VTT was used for data gathering. It was supposed to give statistical data on the information seeking and use habits of the scientists. There were four groups of questions (see Appendix 8 for the full list of questions):

1) background data of the respondents (name, laboratory, education, age, working experience as a scientist and at VTT),
2) information seeking and use profile of the respondent (24 statements for agreement or disagreement. Data was also collected on the amounts of use of some means in information seeking and use),

3) sources of information (the usage of 30 documentary and non-documentary sources in four categories: not used, seldom, sometimes and often used), and

4) open-ended part

   - problems in present information seeking patterns
   - ideas for further development
   - costs and benefits of information seeking and use.

The statements of information seeking and use profile were based on the preliminary understanding of the behavior at VTT, also some earlier studies of the engineers using information were consulted (e.g. Allen 1977; Bitz & Owen 1981; Gralewska-Vickery 1976; see Chapter 4 for additional references). The idea was to find interrelations between varying forms of behavior. The data on the sources of information were collected quite traditionally by giving respondents a list of sources and asking how often they use each source(see e.g. Shuchman 1981). It was hoped to improve reliability by asking when each source was last used. Even though the respondents found it hard to recall and almost 30% of the respondents ignored the question, it partly directed the respondents to think of their responses more carefully. The respondents were also asked to rank their five most important sources of information.

The open questions were intended to give respondents the possibility of presenting their problems in information-seeking and use as well as their ideas for further developments. Being aware of the problems in getting data on the economic issues the questions were presented with background information and with examples. Certain questions concerning the value of information could not be used due to the fact that the scientists were not accustomed to valuing their information seeking and use patterns (as was noticed in the case-studies). Consequently these questions were replaced by indirect questions. The questionnaire was tested by seven senior scientists at VTT.

The analyses of the data were done using Reflex, The Analytic Database System (TM) by Borland Analytica Incorporated on an Amstrad PC1512 microcomputer. Reflex is a reasonably priced piece of software which provides a flexible tool for analyzing relatively small data-sets. There are five 'views' to the data: the Form View (each record in the database), the List View (records shown as a spread sheet), the Graph View (visual summaries of particular data), the Crosstab View (a numeric summary table for pinpointing trends and relationships in a field of the records), and the Report View (customized printouts). The 'views' give a lot of possibilities to 'play' with the data for finding interesting relationships. The Graph View proved especially useful with the summary attributes (SUM, COUNT, AVG, MAX, MIN, STD and VAR) - other statistical functions were not available. The Crosstab View, although interesting, was not of much use to us. The whole data-set is in the CPU (minimum 384 kb RAM required) which makes the program quick but also means restrictions exist: e.g. maximum of 128 fields, each field max. 254 characters, max. of a record 32 512 char. and max. 65 534 records (Reflex 1985).

An effort was also made to use cluster analysis of the data. The software BMDP2M (BMDP Statistical Software, Inc.) was used in Cyber 180/840 (Dixon 1983). This clustering software forms clusters of cases (observations) based on one of the four distance measures. (1) The Euclidean distance (the square root of the sum of squares of the distances between the values of the variables for two cases). (2) The distance calculated using the sum of the pth power of the absolute difference. (3) The chi-square statistic and (4) phi-square (the last two measure the difference in frequencies between two cases and are used when the data are counts). We used chi-square in our analysis. Initially each case is considered a separate cluster, joined in a stepwise process until all cases are combined into one cluster. The algorithm uses the distance between centroid clusters or the kth nearest neighbour density estimator as a criterion for joining clusters. Output includes a tree diagram describing the sequence of cluster formation, a Table that lists the amalgamation distance and the mean for each variable as each new cluster is formed.

6.3 Sample

A systematic sample of one hundred people was taken from the project management system of VTT. The sample was intended to be all the scientists, planners and managers. The managers and planners were removed from the sample leaving 81 people to whom the questionnaire was sent. Due to various reasons (mistakes in the register, some people had left VTT and managers with the title of scientists) the final sample dropped to 69 scientists. The response rate was 84% (58 responses). This result was achieved by two reminders: a reminding letter and a phone call to those who had not answered (the latter was needed also to find out the actual size of the sample). The reasons for not answering were hastiness, low motivation and troublesome questions, about half of those who did not answer were senior scientists.

Thus, the analysis is based on 58 responses which came from 29 laboratories (out of 32), 1-5 responses from each. There is unlikely to be any bias here because the laboratories which have not taken part are small units. In the open ended part also seven test questionnaires are added to the data. The age distribution is given below in Table 6.1 which shows that our set represents well the scientists at VTT except for the higher age groups.

Table 6.1 The distribution of the respondents.

Age	Number	%	Whole VTT 1986 %
<30	11	19	21
30-39	36	63	58
40-49	6	11	18
>49	4	7	3
In total	57	100 %	100 %

Average 35 years; standard deviation 6.5.

The following Figure 6.1 gives the education distribution.

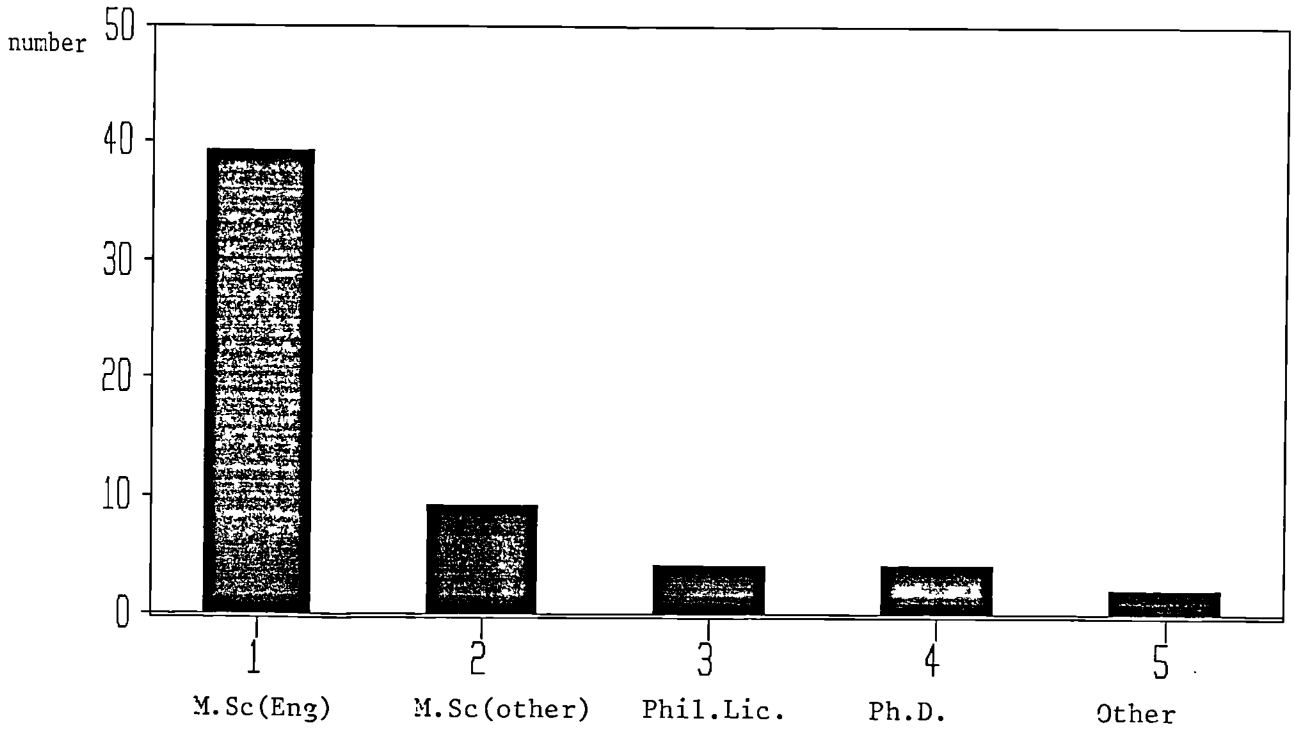

Figure 6.1 Education distribution of the respondents.

Naturally the majority consists of engineers; most of the licentiates and doctors are also engineers.

Figure 6.2 describes education in relation to average age, average work experience and average VTT-experience. It is quite understandable that higher degrees and work experience show in the averages but still the VTT staff can be characterized as young and moderately experienced. Most of the work experience is gained at VTT - only Ph.D.'s had substantial experience outside VTT. The total average experience is 7.7 years (STD 6.2; range 1-29) and the VTT experience is 6.1 years (STD 4.9; range 1-21).

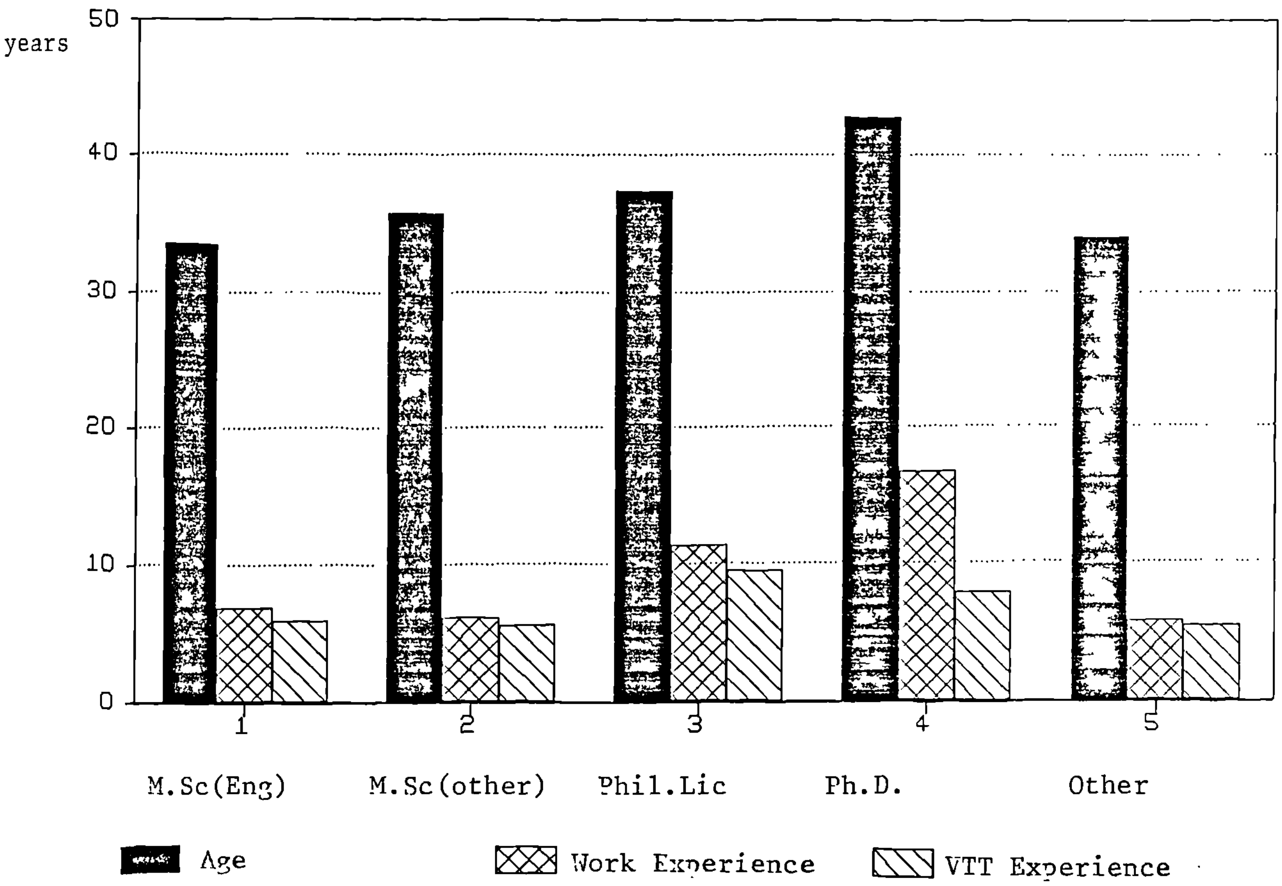

Figure 6.2 Education, average age, work experience and VTT experience

6.4 Sources of Information

The sources of information were studied by identifying how often given sources were used. The response rate to these questions was very high (97-100%, except where other libraries were used 71%). In addition, the five most important sources were asked for (here the response rate was somewhat lower, 69%). The main results are presented in Table 6.2. The answer 'no' was defined as not used in two months.

Table 6.2 The use of different sources of information at VTT

	Most important for scientists%		How often used %			
Source	Among 5 most important %	The most important %	Often %	Some-times %	Seld-om %	No %
1. Periodicals	70	30	79	16	2	3
2. Colleagues (VTT)	68	15	76	12	10	2
3. Res. reports	43	18	41	35	19	5
4. Books	30	3	41	38	16	5
5. Library/own lab.	25	0	48	28	14	10
6. Int. contacts	23	3	9	28	13	16
7. Pers. res. notes	20	8	60	22	9	9
8. Industry	20	5	21	22	22	35
9. Colleagues (Fin)	20	0	39	32	13	16

Table 6.2 Continues:

	%	%	%	%	%	%
10.Internal reports	18	3	25	27	16	32
11.Inf. serv. (VTT)	18	3	9	22	34	35
12.Res. libraries	18	0	12	32	17	39
13.Abstr. journals	18	0	31	19	16	34
14.Clients	15	5	29	29	19	23
15.Personal indexes	15	0	30	16	7	47
16.Software	13	3	36	14	16	34
17.Handbooks	10	0	26	38	26	10
18.Universities	10	0	12	14	34	40
19.Trade literature	8	0	14	34	30	22
20.Online search	8	0	6	10	31	53
21.Textbooks	8	0	10	36	28	26
22.Other res. org.	5	5	7	28	26	39
23.Standards	5	3	22	12	33	33
24.Theses & Dissert.	5	0	7	42	23	28
25.Consultants	5	0	0	12	17	71
26.Government dep.	3	0	7	9	25	59
27.Drawings	3	0	19	12	18	51
28.Patents	3	0	0	7	19	74
29.Prof. societies	3	0	0	14	17	69
30.Correspondence	0	0	12	23	30	35

The main message from the table is very clear: the two most often used and most important sources of information are Periodicals and Colleagues at VTT. According to our earlier studies the latter means colleagues in the same laboratory. The third most used source is Personal research notes but it is rated as the 7th in importance. The Library of a laboratory is the 4th most often used and is rated as the 5th in importance which suggests that the physical vicinity for a library is important (relatively low use of information service of VTT and higher use of research libraries can also partly be explained similarly) - it is also worth noticing here that there are several laboratories which have made little effort to organize their own library. Research reports and Books are the 3rd and the 4th in rating and they share the 5th place in use. It is natural that use corresponds closely to importance but the exception is International contacts which are used only occasionally (International contacts were rated very highly in the case studies also). This, together with low use and rating of Correspondence indicates that travelling is the means whereby foreign contacts are made. Letters, telephones, telex and electronic mail do not seem to be very important in international contacts even though there are individuals using them a lot - those individuals usually travel a lot also.

The sources rated least important were Professional societies, Patents, Drawings and Government departments. The five least used are Patents, Consultants, Professional societies, Government departments and Online searching. Online searching is rated higher in importance (20th) than in use (27th) while in the case of the others these two figures correspond closely. e low use of Online searching is partly explained by the fact that although an online search is done for most projects (see the case studies) individual scientists are not so often involved with the searches. Interestingly, Abstract journals are used and rated much higher than Online searches which could be explained by financial factors. The low rating of Consultants can be due to consultants being seen as rivals and the low use is caused by their cost. The Information Service of VTT was rated as the 11th in importance but only 21st in use. This can be explained by the geographical scatteredness of VTT and closeness of the library of the Helsinki University of Technology which means that library sources other than VTT's Information Service are used instead. In view of these facts the information service has also concentrated on services other than local collections. Personal indexes are kept by about half of the scientists and over one third of the scientists use software products.

Comparisons with other studies must be made with caution because of the different objectives, methods and target groups of the studies. Colleagues and in-house reports were seen as most important in Shuchman's study of U.S. engineers in general (Shuchman 1981). Dissertations and patents from our list were the least used in Shuchman's study. The research and technology transfer orientation of VTT probably explains the emphasis on periodicals, research reports and books. Allen (1977) who found personal contacts most important in his case-studies of a set of engineering research projects discovered that the most used literature sources were textbooks and various kinds of journals.

6.5 Information Seeking Profile of an Engineer at VTT

Information seeking profiles of the scientists at VTT were studied by presenting a set of statements for agreement (True) or disagreement (False). Data on the use of certain means of information seeking were also collected. The basic results are presented in the Table 6.3.

Table 6.3 About information seeking profile at VTT

Statement	Responses	True %	False %
Working hours are not enough for reading needed for the projects.	56	73	27
I am satisfied with my knowledge of new research in my field	55	51	49
The continuous following of important journals in the field is essential.	57	93	7
In the beginning of my career I read more journals.	56	41	59

Table 6.3 continues:

		%	%
Literature is essential when going into new fields of research.	58	97	3
I am satisfied with the results of online searches	43	70	30
Abstract journals are a good means of following fields of interest	52	56	44
I occasionally get reviews which are important for my projects from my colleagues.	58	69	31
I receive too much information which does not have relevance to my work.	58	29	71
New information is over-emphasized, everything not known previously, is new.	58	28	72
Personal contacts are the best means for gathering the latest research information.	58	95	5
I often use personal contacts outside VTT for my research.	58	84	16

Table 6.3 continues:

		%	%
International contacts are essential in following the latest developments in my research field.	58	83	17
Information can be received from the experts only if one has a high level of knowledge.	57	70	30
Conferences abroad should be attended regularly for following the latest developments	53	87	13
National conferences are seldom useful.	55	17	83
Colleagues at VTT transfer information they have adopted efficiently to others.	57	19	81
Joint efforts in the research groups are important for information seeking and use.	58	83	17
The use of information is a learning process which takes time.	57	89	11
I am satisfied with my library usage	52	56	44

Table 6.3 continues:

	%	%	
The information service should analyse information for project needs.	53	42	58
I use my own reference files for my ongoing research projects.	57	35	65
I am satisfied with the efforts made at VTT for supporting my information seeking.	50	40	60

The importance of personal contacts and literature, especially periodicals, is clearly emphasized in these results also. International conferences as well as national ones are seen as crucial in information seeking. Interestingly information overload is not seen as a problem and in the case studies and the open-ended questions (Table 6.5) most were satisfied with online searching. The problems in transferring knowledge between laboratories was proved here as on other occasions earlier. The research groups were seen to be important in information seeking and use, and information use is a time-consuming, learning process.

The satisfaction over the efforts made in supporting information seeking, own library-use and importance of abstract journals were split: one half were satisfied/ agreed, the other not/disagreed. Only half of the respondents thought they were well aware of the new research in their field which means that there is room for new efforts in supporting information seeking.

The scientists travelled abroad 2.1 times on average last year (Standard Deviation, STD 2.1, range 0-12) while the overall average at VTT was 1.7 (includes all staff with an academic degree). Libraries were visited 2.0 times per month on average (STD 2.8, range 0-15), 13% did not use a library at all. The number of periodicals followed were from 1 to 50 (average 12.9, STD 9.3), 65% of the scientists followed ten or less journals. On average 3 abstract journals were followed (STD 3.0, range 0-33) but there were 23% who did not use them at all. Annually 1.4 online searches were made on average (STD 1.7, range 0-10); 22% had not used this service last year. See Figure 6.3 for distributions of travelling, library use and online searches.

In Figure 6.4 travelling, library use, periodicals, abstract journals and online searches are grouped according to educational background. It seems reasonable that average travelling increases with higher academic degrees because these indicate progress in one's career. The amount of periodicals followed seems to be a little higher with the engineers (M.Sc.), except with the group 'Others' (includes

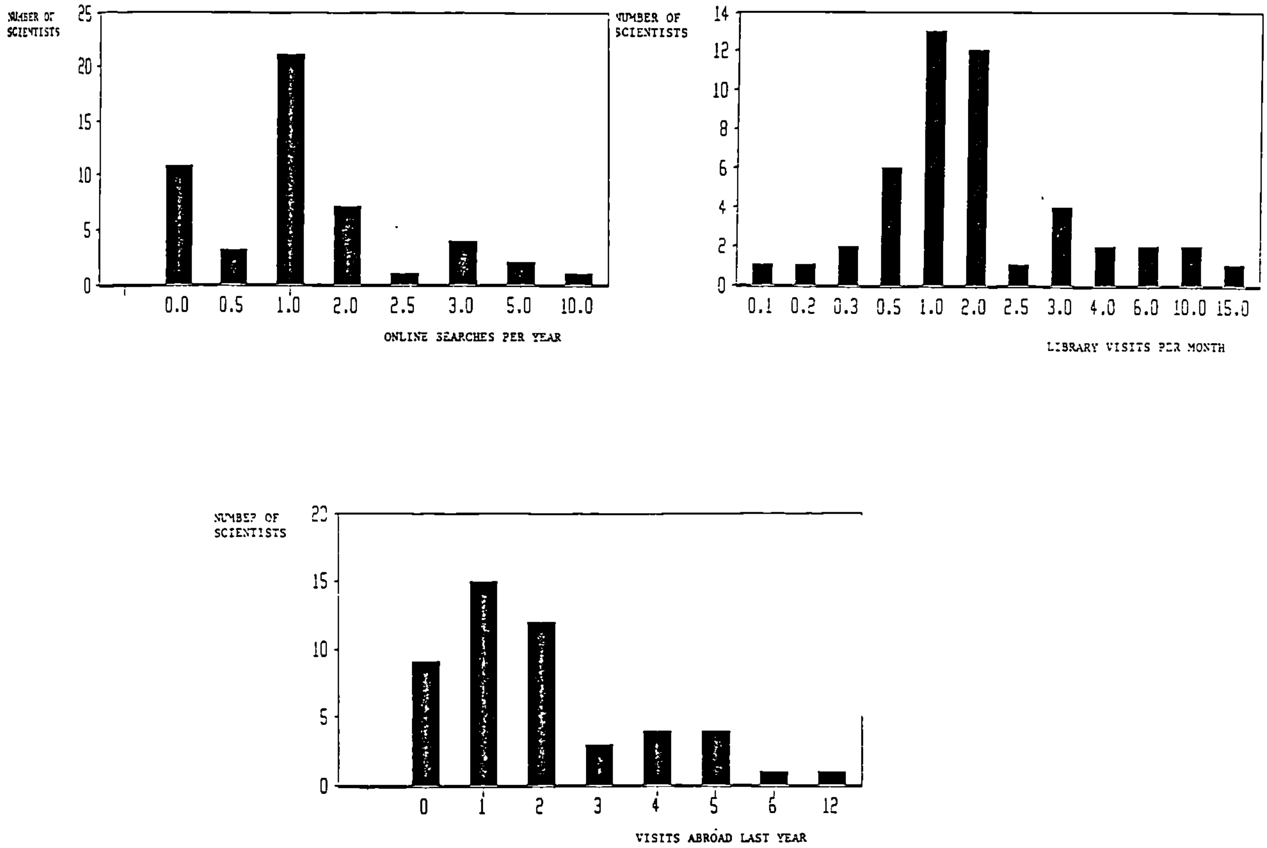

Figure 6.3 Number of online searches per year, number of library visits per month, and number of visits abroad last year.

only 2 scientists). Abstract journals again are most often used by the other M.Sc's.

Similarly the relationships with work experience are described in the Figures 6.5 of monthly library use and 6.6 of use of periodicals and abstract journals. Library use does not seem to alter work experience:there are low users and non-users in all experience groups. Following of

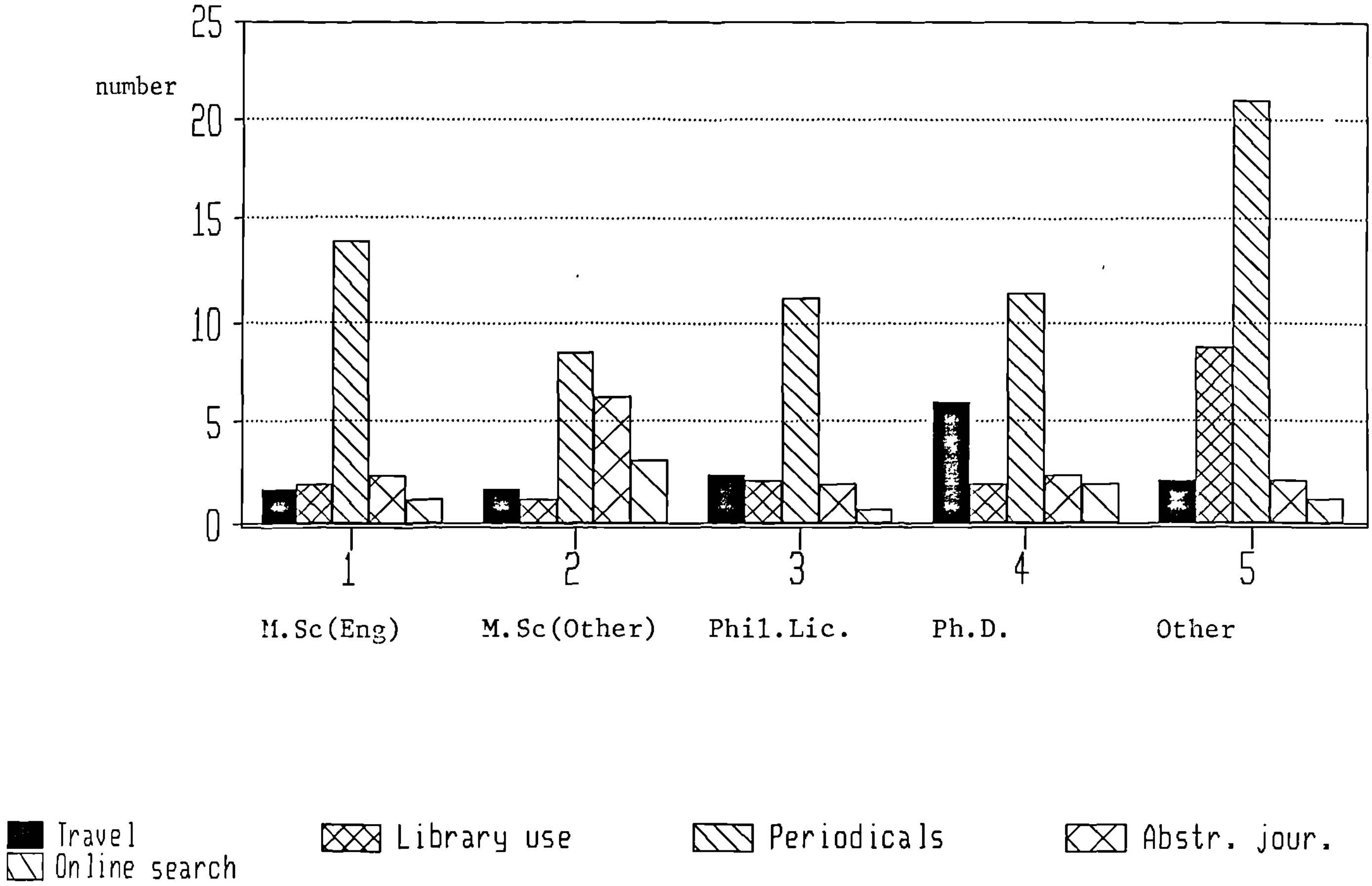

Figure 6.4 Education, Travelling, Library use, Periodicals Use, Use of abstract journals and Use of online searching.

periodicals is well scattered and, interestingly, experience does not seem to be any influencing factor in the number of periodicals followed. Abstract journals are used equally in all experience groups. Similarly work experience does not have any clear influence on online searching or travelling.

The correlation between travelling, library use, periodicals, abstract journals and online searches were also analysed with scatter graphs. No clear correlations were found. Travelling and online searches were associated with slightly lower levels of library use. The correlation

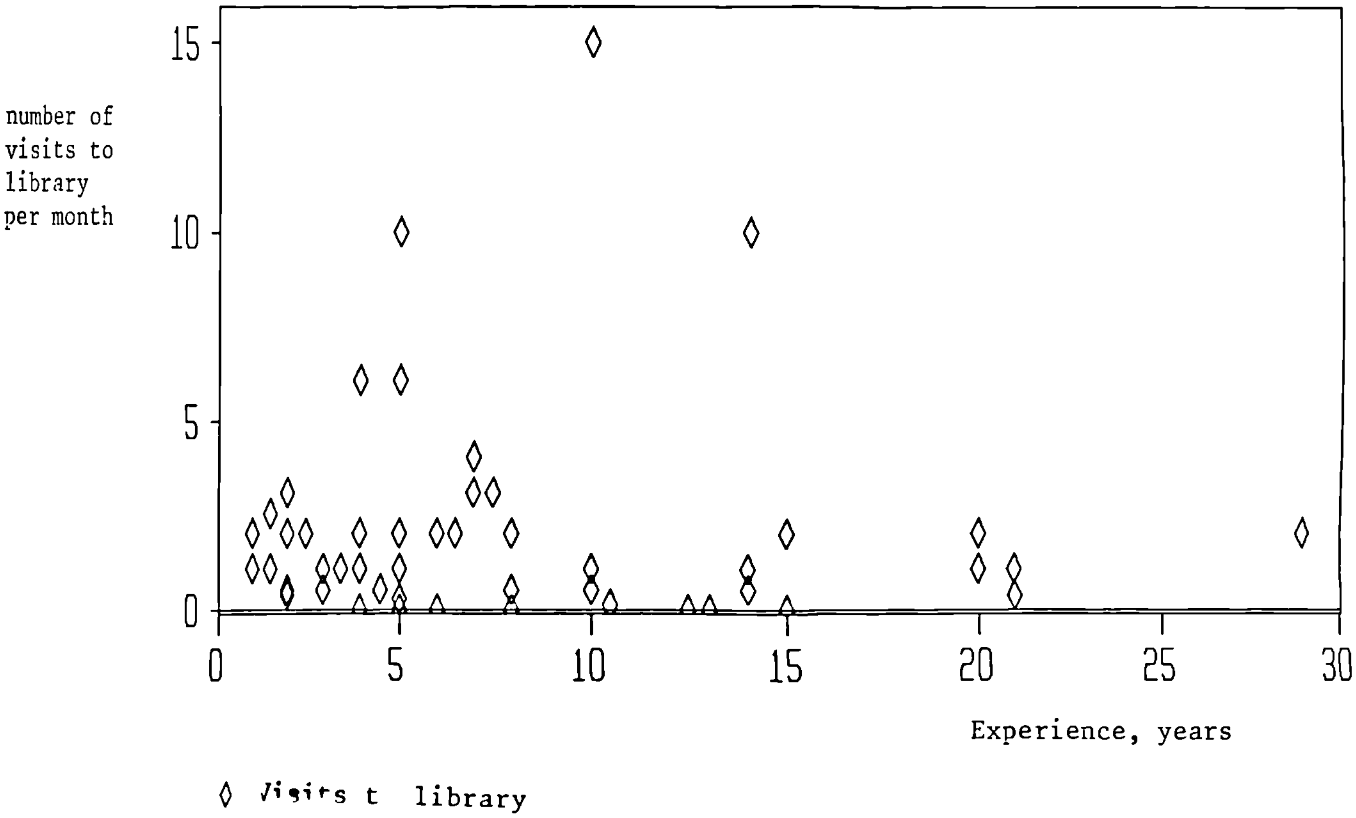

Figure 6.5 Work experience and library use

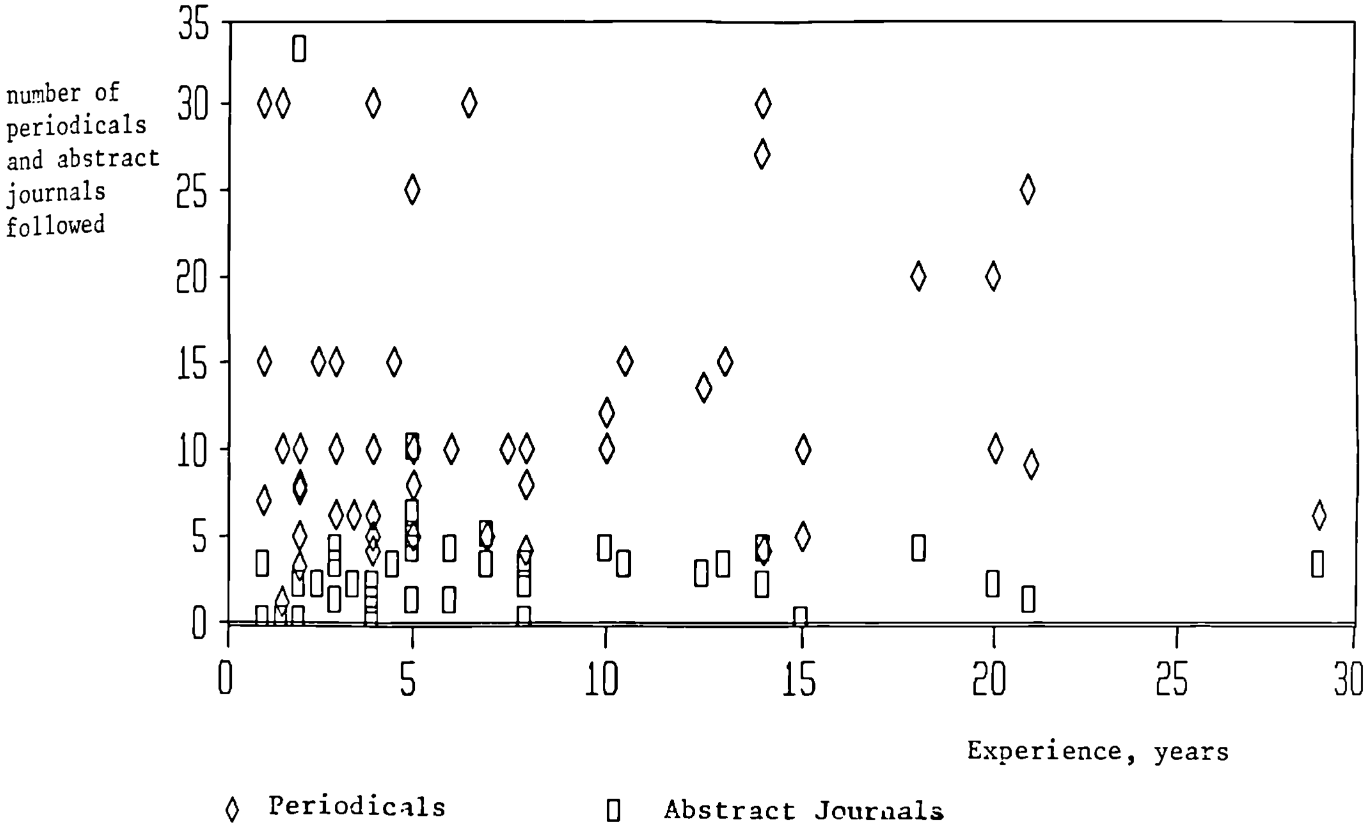

Figure 6.6 Work experience and number of Periodicals and Abstract journals followed.

of periodical use and online searches are described in Figure 6.7. Those who make many online searches do not seem to be among the heavy scanners of journals, but again, there are no clear correlations.

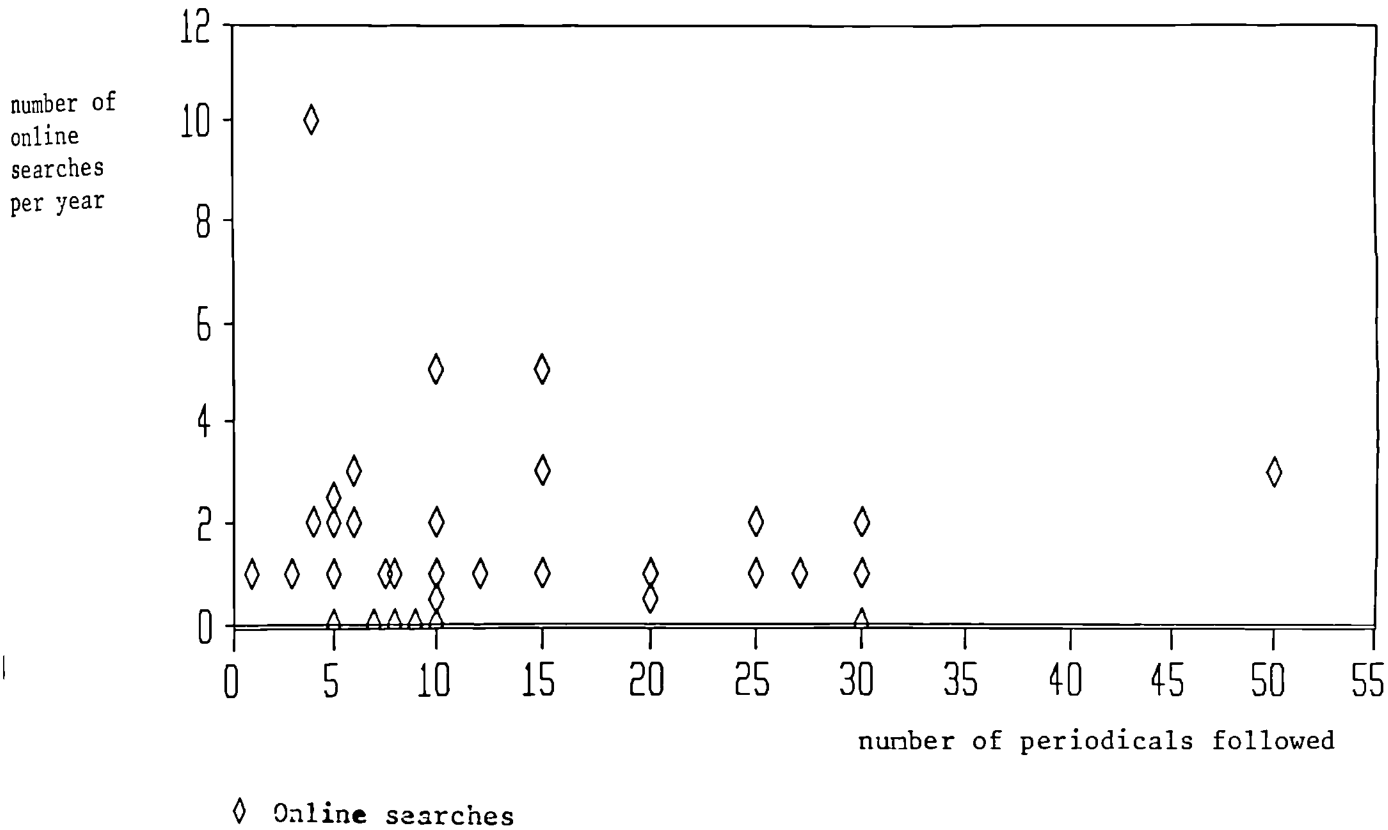

Figure 6.7 Periodical use in relation to online searching

Clustering analysis was used in looking for more complex relationships in the data. The data on information seeking profile and the sources of information were analysed. The general result was that the scientists seem to be rather individualistic in their information seeking. There were no clear groupings in relation to the area of research (laboratory) and similar work experience, VTT experience or age did not group the scientists either.

In Figure 6.8 there is a typical example of the results: VTT-experience is clustered based on the data of the information seeking profile statements. There are no clear clusters in any experience-group (see LABEL in Figure 6.8) and most scientists join the main group one-by-one. This means that the differences in information seeking behaviour of the scientists cannot be explained by the different VTT-experience.

6.6 Problems and Development Needs in Information Seeking and Use at VTT

The awareness of the problems in assessing the value of information directed us to seek indirect indicators to the economic issues of information seeking and use. This part of the questionnaire was handled with open questions which were introduced quite broadly to the respondents. In the results also the test respondents (7) are included which means that the total set of responses in this part is 65.

In Table 6.4 the most important factors influencing the decisions as to how information is sought are presented. The respondents were asked to mention the factors and rank them according to their importance. 2.2 factors on an average were given (range being 0-5) and the response rate to this question was 66%. The factors are grouped from the

BMDP2M CLUSTERING ANALYSIS, LABEL=VTT EXPERIENCE

IN YEARS

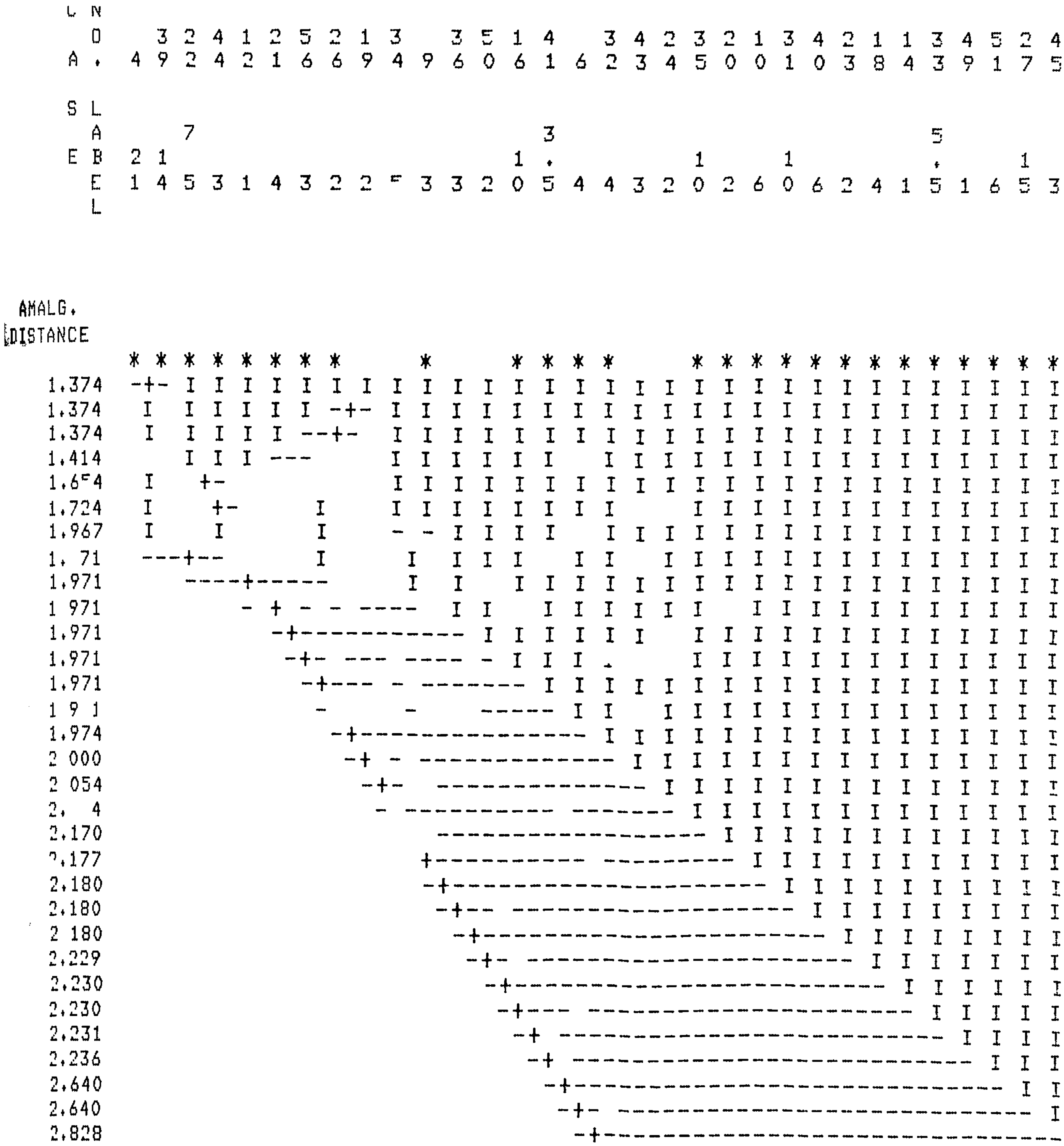

Figure 6.8 A cluster analysis of VTT-experience based on the information seeking profile data.

Table 6.4 Factors influencing to information seeking behaviour

Influencing factor	Most important	Important
1. Urgency	11	19
2. Earlier experience	9	15
3. Nature of the need	8	14
4. Availability	7	15
5. Price	5	17
6. Personal contacts	1	4
7. Reliability	1	3
8. Planning	1	3
9. User	0	3
10. Expected benefits	0	2
11. Hazard	0	1
In total	43	96

Response rate 66% (43 scientists).

answers. The number one rating is a better main indicator because many respondents gave only one indicator.

There are five important factors: urgency, earlier experience, nature of the need, availability and price. The speed of an information service is clearly the most important to the users of the service. Although the price is often mentioned as an important factor it is only the fifth most important in the ranking. Benefits were mentioned only twice among important factors.

The respondents were then asked about recent mistakes in information seeking. Only 31% responded (20 scientists) reporting 22 cases, see Table 6.5. Online searches were clearly at the top of the list of mistakes. The biggest problem being the precision of the search and some doubts were also cast on the abilities of the intermediaries (see also King et al 1984 for somewhat similar results). There were several areas in which information seeking was neglected: information available at VTT had not been

Table 6.5 Problems in information seeking at VTT.

Mistake	Number of occasions
1. Online search	10
2. Neglecting of information seeking	4
3. Problems in document delivery	2
3. Money not available for information seeking	2
5. Useless current awareness service ordered	1
5. Use of information service	1
5. Useless efforts	1
5. Information came too late	1
In total (20 respondents)	22

sought, national information had not been scanned, national and/or foreign experts had not been contacted and literature had not been used.

The scientists were then asked to name the needs to develop information services at VTT, for the results see Table 6.6. The fact that own online searching is proved to be the most important development object is probably due to ongoing discussions about it. - It is interesting to note that hardly anyone of the respondents had done their own searching. Of the services provided by VTT's Information Service, slowness in document delivery irritates the scientists most.

There are nearly 50 SDI-profiles used at VTT (through its own information service) but there seem to be more people (roughly 200) in need of such a service. The importance of international contacts and also periodicals came up here as well, as earlier. Internal information services at VTT are quite high in the list of the most important development targets. There are some who would like to have more intermediaries located in the laboratories (about half a dozen laboratories are already in that position). Interestingly, some would like to solve the problems of the costs of information seeking by taking the expenses away from the projects to be paid from general budgets. There are still laboratories where information seeking costs are

Table 6.6 Development of information services at VTT.

Development target	Mentioned	Most important
1. Own online searching	9	4
2. Effectiveness of the information service (VTT)	7	3
3. Current awareness (SDI) services	6	3
4. More money for international contacts	5	4
5. Effectiveness of the circulation of periodicals	5	3
5. Better service of the internal information of VTT	5	3
7. More training abroad	4	2
8. Specialized information intermediaries into the laboratories	3	2
9. Expenses of information seeking to be held centrally	3	2
10. International experts to VTT	3	1

(12 other development targets mentioned 1-2 times)

paid from a 'general budget' but the tendency during the past few years has been towards putting also these expenses into the project budget.

The question about economic issues of information seeking in the laboratories was answered by only 54% (35 scientists) of the respondents. Nearly half reported that there were discussions and economic thinking behind the decisions on information seeking in the laboratories. One quarter answered that there are no economic discussions, 14% answered that no systematic discussions took place, and another 14% said that such discussions are not necessary because when the information need occurs it is always fulfilled. Nearly half felt that the issue should be further discussed while 22% answered that enough had been done. It seems that although there are often detailed cost-benefit considerations associated with, e.g. travelling abroad, the comprehensive analysis of various information seeking methods is lacking. The reasons for this are probably the unequal costs of complementary means in information seeking.

The respondents were also asked to give examples of beneficial information service. Only 15 scientists out of 65 (23%) answered and the answers were mostly quite general. Seven reported savings which originated from online searching. For instance, a search was used in preparation for the trip abroad and another search was used to assure the financing bodies of the importance of a planned research project. Three indicated time savings in their research from travelling abroad (especially visits to research institutes) and three had time savings from personal contacts. SDI service had once brought an important piece of information which saved some 60% in research time and once one definition of a concept given from the information service of VTT was the key to important research findings.

6.7 More Focussed View of the Value of Information at VTT

The questionnaire was set up for generalizing the results of the case studies and in this respect the results were mainly supportive. Some bias due to the fact that the cases were from the research programmes can be corrected. The main reason for this was that the research programmes the scientists seem to be a little more active in information seeking than usually. It also seems that the scientists tend to emphasize the importance of personal contacts in the interviews. This meant that they neglected almost totally literary sources other than periodicals. Thus the questionnaire confirmed even more clearly that a rich information environment (varying set of channels and support) was desired. It also became clearer that the scientists' view towards new information is usually uncertain: the majority feel they have not done enough. This provides a good basis for developing new and better support.

The value of information was explored indirectly. The result of the case studies was confirmed: economy of information seeking and use is not an issue among the scientists at VTT. Only some activities, e.g. travelling abroad, are under careful consideration. Awareness of the expenses of these activities must be increased before one can really use our dual approach to the value of information. Another relevant factor is that it seems to be quite impossible to collect statistically useful data on the benefits of information use. Somewhat contrary to some U.S. studies (e.g. King et al. 1982) only a quarter of the respondents to the questionnaire were able to give recent examples of the measurable benefits from the use of a piece of information. This means that examples can only be used for arguing for or against some information seeking channels but not in valuing information for research work more generally.

The value-in-use of information could not be measured directly even though we have now quite a detailed description of information seeking and use at VTT. However, information seeking and use activities play an important role in the success or failure of the research work. The areas worth looking at in the research work for a manager are:

1) information environment of the research project,
2) joint efforts in information seeking,
3) how methodological information is sought, and
4) how the sought information is used.

Optimizing these areas provides possibilities of finding the highest value-in-use of information for the research project and, furthermore, optimizes information seeking and use for effective research.

7. ECONOMICS OF INFORMATION SEEKING AND USE AT VTT

7.1 Time and Money Used for Information Activities in Research Work

There is little knowledge available at VTT of how scientists use the time allocated for particular research projects although there is a well established general information system for collecting daily data about time used for each project and other activities. The scientists are accustomed to monitoring their activities, which gives a good basis for further data collection. This part of the study produces data about the distribution of particular activities within the research project. The study is motivated by the need for VTT-level data to prove the importance of information activities in the projects.

When collecting VTT-level data the basic set was again those approximately 1000 projects under way at VTT. After learning from the case studies that more reliable data can be obtained if the projects studied are the main tasks for the scientists studied, we decided to take our sample of one hundred projects and study the heads of those projects. Another reason for selecting project heads was that clearly, they are in the central position in transferring new information and knowledge into a project. When the project head had only an administrative role in the project he was asked to forward the questionnaire to the key-scientist in the project. The scientists were then asked to monitor their activities on a given project daily for one particular week using a form which had seven categories: information seeking, reading, communication within VTT, other communication, actual research work (experimenting, analysis, etc.), project bureaucracy and documentation. The form used was tested and advice was given for completing the form (see Appendix 9).

The sample of one hundred projects was taken from a register of the project management system - the sample included also contract research for the private sector. For the sample, the projects were divided into three groups depending of the phase of the project at the time the sample was taken (at the end of the year 1986): 1-33%, 34-65% and 66-100% of the allocated time already used for the project. From these groups the projects were taken randomly. In practice only about 80% of the ongoing projects could be used for the sample because the rest of the projects did not have detailed enough data in the register. This is unlikely to bias the sample because there seemed to be individuals in most of the laboratories who neglected their duty to give full data to the register from which the sample was taken. Twelve projects were excluded from the sample because they were not research projects (mainly projects dealing with the new buildings for VTT).

The response rate was 92%. Four projects had not actually started and there was no work done for 15 projects which means that the actual analysis is based on data of 62 projects. These projects represent quite equally those three groups of projects in varying phases. The result was gained with one follow-up around three weeks after the actual response week with those who did not answer on the first round.

Before going to the actual results some general comments on the nature of the data are given. There were 1-5 projects from 26 (out of 32) laboratories. There were a lot of zeros in the categories (no work was done for the project during the monitoring week). This shows that the project heads at VTT have often several projects to work with. Also the ranges in tha data were quite large, see Table 7.1 below.

Table 7.1 Some features of the time-allocation data

Function	Zeroes %	Range h	Median h
	%		
Information seeking	58	0 - 12	0
Reading	58	0 - 19	0
Communication, VTT	42	0 - 6.5	0.5
Communication, other	42	0 - 21	1
Actual research	53	0 - 35	0
Project bureaucracy	48	0 - 9	1
Documentation	55	0 - 18	0

Figure 7.1 describes the total time spent for each project and how the projects did scatter according to their phases.

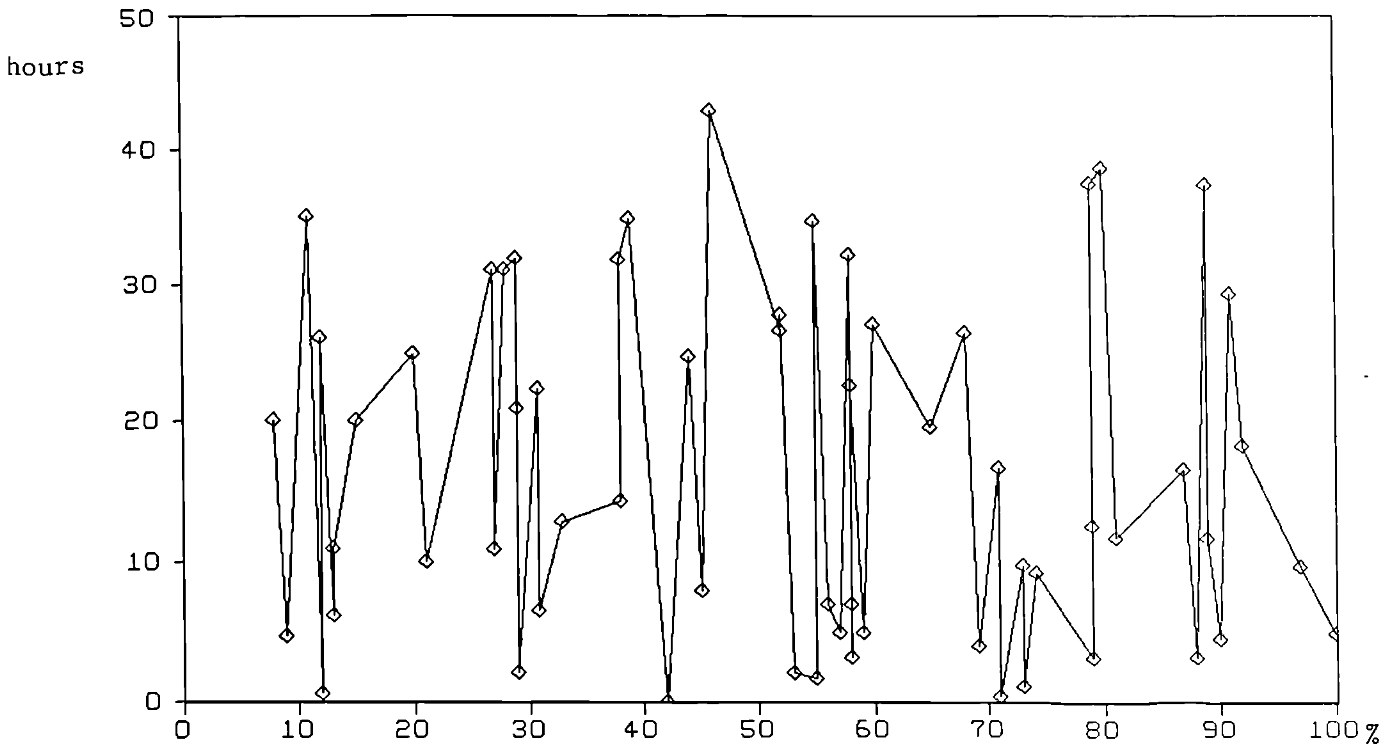

Figure 7.1 Total time spent for each project and their phases

The scatter diagrams were used to study how much the phase of the projects shows in each activity. Information seeking and particularly reading were most active in the first half of the projects but generally these activities were quite equally scattered. Communication seems to take place evenly throughout the projects, the time used for internal communication was substantially lower. Actual research was also evenly scattered from the beginning to the end of the projects. Project bureaucracy, which was of only minor importance, burdened the scientists a bit more in the second half of the projects. Documentation is also made evenly throughout the projects and it is surprising that there is only a small increase of documentation at the very end of the projects.

The distribution of the time spent for each activity is summarized below in Table 7.2.

Table 7.2 Time spent for different activities in projects

Activity	Total h	% of all %	Mean	Std. dev.
Inf. seeking	96.75	9	1.6	2.7
Reading	120.50	12	1.9	3.8
Communication/VTT	82.30	8	1.3	1.7
Communication/other	190.25	18	3.1	4.7
Research	285.50	28	4.6	5.5
Bureaucracy	79.00	8	1.3	1.8
Documentation	180.00	17	2.9	4.5
Total (62 projects)	1034.30	100	16.7	12.2

The biggest share of 28% goes to actual research while outside communication (18%) and documentation (17%) take the next biggest shares. Information seeking, reading, communication within VTT and project bureaucracy take each

8-12% of the scientists' time in the projects studied. Literary information use (information seeking and reading) takes 21% and communication 26% which means that the scientists use almost half of their time for gathering and exchanging information. Project bureaucracy does not seem to burden the project heads very much even though low motivation has given rise to many complaints against it. The large standard deviations in comparison with the average figures show how scattered the data are. Allen (1977) studied 33 project teams working with arduous research projects and got the following time allocation: 77% research, 8% literature use, 17% communication and 6% other activities. The categories are varied and their interpretation is varied. We only studied the heads of the projects (e.g. most of the project bureaucracy and documentation goes to research in Allen's study) but it must be emphasized that research at VTT is different from that in Allen's studies. VTT's projects are much more information seeking and use oriented: Allen calculated for written sources and for communication about 8% each while the figures at VTT are 21% for written sources and 26% for communication. This means that, for instance, Allen's conclusion about low importance of written material for engineers does not necessarily apply at VTT.

The data can then be transformed to monetary values. From various internal sources we can find out that an hour of a scientist's time at VTT costs about 210 FIM. There were about 940 substantial research projects under way in the end of the year 1986 and each project takes approximately 16.4 month's work. The following Table 7.3 can be produced from these facts.

Table 7.3 Project work and resources

Activity	Share %	Costs per project
	%	
Information seeking	9	45 000
Reading	12	60 000
Communication/VTT	8	40 000
Communication/other	18	90 000
Research	28	140 000
Bureaucracy	8	40 000
Documentation	17	85 000
In total	100 %	500 000 FIM

(1 FIM was equal 0.14 GBP in January 1988).

Some care must be taken when reading these data. It is likely that the project heads use more time in communication, project bureaucracy and documentation than project personnel in general which means that especially the share of actual research is bigger in overall context. However, the figures clearly show that information activities take time worth tens of millions FIM and thus form a substantial share of the costs of the project-portfolio.

It is interesting to compare these data against the data of the case studies. Information seeking and reading takes about 100 million FIM in used time while direct information seeking expenses are 1-2 million FIM (1000-2000 FIM per project). Communication with experts outside VTT takes over 80 million while over 10 million is used for visits abroad. The latter naturally includes also the foreign presentations of the research results. Thus it is clear that direct costs of information seeking are insignificant in comparison with the cost of time usage. There is room for the provision of an even richer information environment if, and only if, the scientists are able to direct their information seeking, reading and communication optimally. It is better to seek more information and then read selectively than to acquire only a small amount of information. For instance, it is possible by using online searching at the beginning of a project to collect an extensive list of references and read reviews first to make more effective further reading possible. (see also King et al. 1982).

It is even more difficult to interpret communication data. The time used for communication within VTT was low in comparison with outside communication but it can be explained by the fact that internal communication takes less time and is partly done through social contacts. The research is also quite widely scattered and so there are not many colleagues within VTT to communicate with. The scientists emphasized earlier the importance of contacts within their own research group and with international experts. Especially the latter can be seen in the time usage. Allen (1977) has also proved the effectiveness of internal contacts in comparison with external whenever the solution to the problem at hand can be found this way. Allen emphasizes the need for a diversified set of contacts with colleagues within and outside one's own organization. Our data support his view.

7.2 More Effective Information Use at VTT - Research Managers' Viewpoint

7.2.1 General

We have so far produced data on information seeking and use from the viewpoint of the scientists at VTT. The economics of information seeking and use is naturally a management issue, and in this section the value of information is studied by interviewing research managers who make decisions about how the information seeking and use conditions are organized.

The general director, research directors and administrative director (heads of the divisions) form the board where the important VTT decisions are mainly made. However, the responsibility for research in each field of technology represented rests with the directors of the laboratories because each laboratory is an economic unit to a certain extent at VTT. Most laboratories are organized into sections where the actual project work is done, with senior scientists as the heads of projects.

The heads of the projects were in central positions in the earlier studies, and directors of the laboratories were selected as subjects of the management interviews. It was decided that either the director or the deputy director of all 32 laboratories should be interviewed. The interviews consisted of three groups of questions (for details see Appendix 10):

1) economics of information seeking and use in the laboratory,
2) comments on a model which presents key-areas in developing the effectiveness of information seeking and use (the model was developed from the experiences of the earlier data collections), and
3) practical problems and development targets in information seeking and use at VTT.

The directors of the laboratories were approached with a letter which included a brief (5 pages) summary of the results of the earlier data collections. The appointments for the interviews were made by phone and the actual interviews were made during a month in autumn 1987. Our study was generally accepted and 29 directors and 3 deputy directors were interviewed. The interviews took from 45 minutes to nearly two hours, the average time being 73 minutes.

7.2.2 Economics of Information Seeking and Use in the Laboratory

The increasing ammount of information available on the international information market is reshaping the information seeking patterns of the laboratories at VTT. Most of the laboratories (63%, 20 out of 32) have experienced an information deluge in their field, mainly due to the developments in information technology which have, in fact, broadly influenced almost all fields of technology represented at VTT. The rest of the laboratories have concentrated their research in such special areas where new information is still fairly easy to handle or there are special tools, like databanks, for information distribution and use. Examples of this kind of area are in mining, nuclear technology, shipping technology, textile technology and some areas of building and construction technology. Also within each laboratory there are 'information rich' and specialized areas of research.

In specialized areas of research the laboratories are, or try to be, on a high international level having contacts with other leading scientists in the field. Increasing complexity and interconnections of the research areas and new demands of Finnish industry mean challenges to the laboratories where both high level research in particular areas and wide awareness and abilities in broader areas must be handled simultaneuosly.

The rich information environment with all the possible channels to new information has been realized as essential, but this means also that the effective use of channels becomes increasingly important. Over one third of research managers explicitly emphasize that networks of personal contacts ('invisible colleges') become more and more important in handling the information deluge and in getting timely information whenever needed. Public information is often not enough. When personal contact is made valuable information is exchanged. Part of the information needs have to be fulfilled by special efforts which range from enquiries by phone, online searches or bought market analyses, to the use of scientific attaches or visits to and joint projects with various research organizations abroad. While transfer of international information is of the greatest importance, the effective search for information already in Finland also has to be organized.

There is more and more international information available on the information market. However, when this point was put to the research managers they started to speak about contacts and joint projects. One manager emphasized strongly that "if we would have relied on information available on the information market we would have been out of this business already long ago" and several others listed here their international joint projects and future plans. The majority tend to believe that public information, especially printed information, is loosing its position in transferring important technological information. So, the development of an information market does not seem to offer solutions to the problems in information seeking in the laboratories. The most important information is not there or arrives too late. High level research needs direct contacts. Although new services such as online services as well as traditional services like circulation of periodicals are said to be needed, they provide only part of the picture. This means, among other things, that the analysis of information products and services for the laboratories is not useful - too much of the information flow to the research in the laboratories comes outside the established markets now and very likely in the future also.

The research managers were asked about planning information seeking and use in the research projects. There are three different approaches:

1) planning in detail (one third, 11 managers),

2) reservations in the budget (nearly half, 15 managers), and

3) not planned (one fifth, 6 managers).

The amount of money needed for information seeking was considered to be of little importance and planning depended heavily on the projects. However, the majority of research managers (over 80%) emphasized the importance of effective seeking and use of information at the beginning of projects. The arguments for not including information seeking costs in the project budgets were that (1) the projects were small, (2) the costs were low and (3) information seeking is generalized behaviour. There were no correlations between research divisions and behaviour of the laboratories. The behaviour seems to be heavily dependent on working patterns used by key-individuals (which was the same result as in the interviews of the scientists earlier).

In the past few years planning of information seeking and use has started to be a part of project-planning - if not yet in monetary terms then in terms of effective sources sought. Cost-benefit analysis is not used in valuing information channels. Only a few (5, under one fifth of the managers) mentioned that occasionally implicit analysis of some channels (e.g. travelling) has been behind the decisions on how information was to be sought for an important project.

The main responsibility in information seeking for research projects was generally seen to lie with the head of the project (22 managers, over two thirds), the individual scientist was said to have the main responsibility in eight (a quarter), and head of the laboratory and managers were said to have the main responsibility in two laboratories. All those levels have some role. Heads of the laboratory look after large projects, approve important information seeking efforts, and co-ordinate effective behaviour; heads of the projects behave as gatekeepers in their projects and approve the proposals of the scientists. Scientists make suggestions on information seeking channels and methods and make decisions about details in information seeking. It was realized that information seeking and use from literature was more often left to the scientists while personal contacts and travelling were mainly handled by the heads of the projects and the managers. It is worth mentioning here that the typical size of the project is such that quite often the head of the project is also the main resource for that project.

The research managers rate the present state of information seeking and use in the laboratories quite highly. The average grade was 7.2 (scale given was 0-10 and range of the responses was 4-9.5). The managers were usually pleased with the level of information seeking and use in the special areas of research of the laboratory, and credit was also given to the active scientists. However, the managers saw that improvements were also needed. The common examples were:

- each scientist should be active in information seeking and use,
- joint efforts and more systematic approaches should be applied in information seeking and use,
- there was the need for increasing direct international contacts (language problems and a lack of ambition in international projects were mentioned as obstacles here),
- screening and scanning of information should be more effective in the laboratory,
- a more scientific approach to the work was needed,
- general awareness of developments outside the scientist's own expertise is too low,
- timely information should be sought in a more effective ways, and
- information about general trends should be easier to get.

The fairly good grades for information seeking and use were partly due to the fact that only a few respondents had thought about these activities as a whole earlier. The effectiveness of information seeking and use is still often left to the individual scientists and it is only seldom seen as a management issue. The interview served as a reminder to several managers that information seeking and use are important parts of a research project and that they should be monitored by the research managers. At the end of the interview some managers mentioned that they may have assigned higher grades than were justified.

In addition to general ideas for the improvements needed, many more practical suggestions were made during the interviews. The following main areas of interest were noted:

1) New information technology should be used more broadly in supporting information seeking and use at VTT. Electronic mail was the most immediate development target here. It may be worth noting that although, or because, the scientists of VTT have been involved in developing several electronic messaging and computer conferencing systems, several pilot systems are in use and many scientists use various systems in their national and international contacts, and the efforts to put up a general e-mail system for VTT and its clients have failed. The comments of the the laboratory heads in these interviews have had a stimulating influence on the developments which will take place in 1988.

2) Education in information seeking and use should be an integrated part of the in-house training programmes. Even though some efforts have been made in this area during the past few years the heads of the laboratories

were not aware of them or they thought that the efforts were not sufficient.

3) The information service should develop services and 'advertise' services in the laboratories. Online searching in the laboratories, new ideas on circulation of periodicals, news information services, better information on VTT's own research, support in developing databanks in laboratories, and codes of practice for information seeking and use were among the concrete suggestions.

The managers agreed with most of the suggestions of the scientists. Only the suggestion that the costs of information seeking should be taken away from the projects was generally disagreed with. One important issue arose: almost all suggestions made had met with resistance. For instance, although the circulation of periodicals was mentioned by many respondents as the most important development target for the Information Service of VTT, some respondents said that it is now functioning perfectly and they do not want any alterations because of the efforts they had made to reach the present state of affairs. This means that it is seldom possible to find VTT-level practices and new approaches which please every laboratory, because there are always those who are happy with the present state of the service. Thus, the developments have to follow the idea of offering a wider variety of information services and behaviour suitable to each laboratory and each individual scientist.

Several factors influencing information seeking and use patterns in the laboratories emerged from the interviews with managers. Some of them were specific to the field of technology as noticed earlier. An additional example is the Fire Technology Laboratory where the newness of the field means that there are no established information seeking channels available for the present. The age of the laboratory (which was a new one) was mentioned by three laboratory heads as a reason for the still quite vague information seeking patterns. The age structure of the personnel has some bearing on the results. When there is a substantial proportion of young scientists in laboratories there can be a lack of senior scientists to support information seeking. On the other hand, two heads of the laboratories mentioned that the number of senior scientists has increased too much and that it is therefore difficult to form dynamic research groups. The size of the projects was mentioned especially by the heads of the small laboratories as having caused problems. One manager said that there should be at least 30 scientists in a laboratory in order to build continuity for research (information seeking and use were seen as important aspects here). Working patterns, tradition in the laboratory, the field of research, nature and goals of the projects and earlier knowledge in the laboratory are among other related factors influencing information seeking and use patterns. This means that the VTT-level efforts can only support the more effective information seeking and use practices. The main efforts have to take place in the laboratories and even further in the research groups actually working on the research projects. The role of the information service is a consulting one, not so much intermediary.

7.2.3 A Model for More Effective Information Seeking and Use

The information seeking and use patterns of the scientists at VTT and the earlier data from this investigation were the basis for the model of effective behaviour in research work. This model was presented to the research managers for comments and alterations (see Figure 7.2).

In the model the basic input/output model of a research project is expanded and elaborated upon by the important factors for effective information seeking and use. The above six actions are most important if the value-in-use of information for the research projects is to be maximized. This model was also presented to the managers as a means to increase the quality of research.

The managers were asked to comment upon the model, suggest alterations and new areas for it. Before going into details on the comments we present data on the importance of each

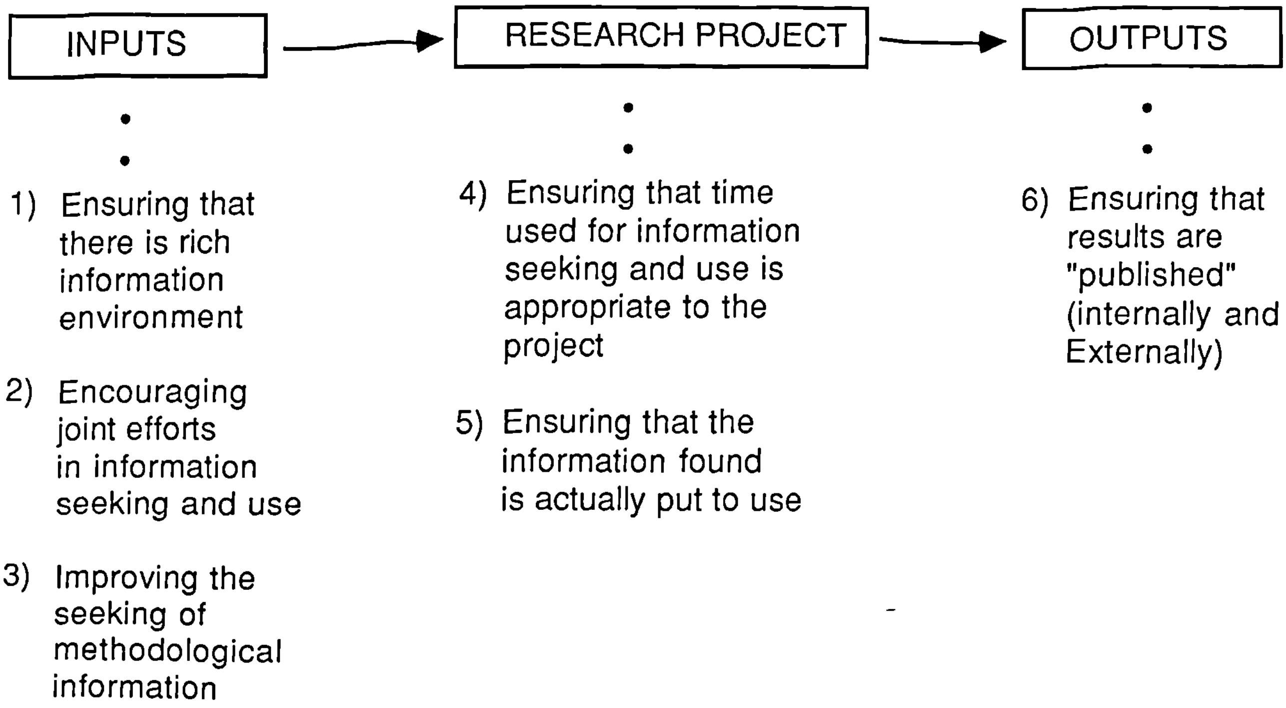

Figure 7.2 A model of the actions to be taken in research work for effective information seeking and use

part of the model as given by the managers interviewed (see Table 7.4).

It was realized in the interviews that the managers rate these actions according to the management patterns they use. This means that the higher the ranking the more attention the action has gained. The low rating of the factor "Time used for information seeking and use" was perhaps due to the difficulty of knowing what should be the effective use of time. As already mentioned, this interview was the first stimulus for many managers to think about information seeking and use as a whole and as an important part of management. The positive attitude towards the

Table 7.4 Ranking of the actions in information seeking/use

Area	Among 3 most important %	n	Most important %	n
Publishing	28	(27)	38	(12)
Info. environment	24	(23)	31	(10)
Joint efforts	16	(15)	13	(4)
Use of information	17	(16)	6	(2)
Method information	9	(9)	9	(3)
Time used	6	(6)	3	(1)
In total (amounts)	100	(96)	100	(32)

interviews was perhaps due to the favourable reaction towards these issues.

Ensuring that results are 'published' (internally and externally)

The publishing of research results has been a common issue at VTT during the past few years. Many laboratories have invested a lot in this area but even more efforts should be made. The documents produced from the research project vary but generally the following levels were seen as all important:

1) international article,
2) international presentation,
3) presentations and demonstrations in Finland,
4) articles in Finland, and
5) research reports (VTT and others)

A sixth level was often added in the interviews:

6) confidential research reports for the clients.

Thus, whenever appropriate the project should produce publications at these levels. It has to be emphasized that this ranking of levels is only made for analyzing information activities in the project. Many managers also emphasized that the role of different documents varied. Generally speaking the international articles and presentations have an essential role in the exchange of information with foreign scientists, research institutes etc. They are important 'business cards' in foreign contacts but they also indicate afterwards the level of the research project or projects they are based on. Four managers pointed out that international publication should not be over-emphasized because the advancement of the career's of individual scientists is not the main goal of the research at VTT. Nevertheless, the majority of the managers saw international articles and presentations as an important part of the internationalizing process at VTT.

Presentations and articles in Finland are important in relations with the clients of the laboratory. They have an important role in marketing the knowledge and know-how of VTT. Demonstrations and seminars etc. of the recent research results were seen as the most useful means here by five managers. Different situations in the laboratories were experienced: three managers mentioned that some senior scientists even use too much time for giving presentations in Finland, and two others thought that Finnish articles are not worth the trouble.

Research reports are often the first documents of the research results. In the case of confidential research these reports are not published. However, when important research results have been attained the main results are published, though often delayed. In the case of public research, research reports are most often published by VTT. However, it was stressed by one third of the managers that the reports for the clients are the most important documents to be produced in a research project. The past efforts to increase publishing in the VTT's publication series had seemingly provoked some managers. As one put it: "paper is not the result of research at VTT, as it may be of the university".

In the management sense, the publishing of research results seems to be quite well thought out in the case of the most important and large projects: there are often publishing plans and they usually hold. The major problem experienced is lack of project-money, time and "running out of steam" (the comment of a rather depressed manager) for all necessary publications. More generally, documentation is not yet an integrated and conscious part of the research projects.

Ensuring that there is rich information environment

A rich information environment was generally recognized as being important for a good research project. As one manager said: "All channels to new information and knowledge must be kept open". Several comments and alterations were made to the ranking of the scientists as follows:

SCIENTISTS:

1) Important contacts in Finland,
2) International contacts,
3) Business travelling abroad,
4) Periodicals,
5) Visits to library,
6) Abstract journals, and
7) Online searches.

MANAGERS:

1) International contacts (including business travelling),
2) Important cont./Finl.
3) Online searches,
4) Periodicals,
5) Abstract journals, and
6) Visits to library.

The majority of the managers considered contacts most important although six managers mentioned that it is essential for a young scientist to use literature at first. International contacts were put first by 25% of the managers mainly because they are the most important for transferring technology and technical information. It was also mentioned by four managers that the role of travelling is diminishing in international contacts. New information technology offers new support. In addition to telephone, mail and telex, such tools as electronic mail, international information networks (e.g. EARN and UUCP), teletex and telefax are becoming widely used which makes it possible to have even better and more continuous contacts with foreign experts and the scientists of one's own laboratory working abroad. The amount of foreign scientists working in the laboratories is also increasing.

Contacts and communications in Finland have a different role as they include contacts with the clients. It is also very important to start information-seeking from colleagues in one's own laboratory and in VTT, as well as from Finnish colleagues outside VTT. An example of difficulties was given here: young scientists do not always study carefully enough what has been done even in the laboratory but give preference to international information.

The managers trust online searching much more than the scientists even though many managers were disappointed with the results. The debate for and against online searching is continuing in the laboratories of VTT. The managers' views can perhaps best be summarized by a quote from one manager "Online has an all too bad reputation - it should be used more and the intermediaries should be able to support searching in the laboratories better". Over 80% of the managers wanted to put online searching next to the contacts or beside the journals in importance. Three managers stressed strongly that it is no longer economically viable to follow research areas generally by scanning journals, reports etc., but the information must be sought by online methods whenever needed and continuous needs must be fulfilled by current awareness services. The situation varies in laboratories so much that it is not possible to find any single understanding of this issue. However, generally speaking, the managers clearly emphasize more new media in information seeking than the scientists. They hope that online services will increase productivity in information seeking.

On the other hand there are also managers (some 20%) who believe in following scientific journals as a main tool in seeking international information. Many of these also prefer abstract journals as they are more economic than online searching. These managers could be characterized as older than average or coming from a basic sciences oriented laboratory.

The use of libraries was generally rated the lowest. The importance of the library in the laboratory was recognized but many thought that the use of big libraries is too time consuming. Still, one manager said that scanning in a library is essential for him in developing new ideas and wanted to have the reading room reinstated in the Information Service of VTT.

The managers (as well as scientists as seen in Chapter 6) have strong opinions about the use of different information channels but all accepted the need for a variety of channels. For some laboratories there are special sources of information, the use of which strongly characterizes their working patterns. For instance, the Laboratory of Nuclear Energy Technology uses certain databanks and computer programs. In the near future the role of databanks will probably increase in several laboratories.

The managers did not have many comments on the VTT level averages in the use of channels as established from the data concerning the scientists. The situation varies so much in each project that the averages per project were not seen as useful. The statistics of the individual scientists did not surprise the managers much. Two managers clearly did not have any knowledge of this kind of data in their laboratories and they even said they are not interested in it. Foreign travelling was seen as lower than 2 per scientist per year by seven managers and the number of journals scanned was seen as greater than 13 per scientist by the other four managers. It seems necessary to collect project data by grouping the projects according to their size and nature in order to get meaningful data for the laboratory level.

Encouraging joint efforts in information seeking and use

Small projects are much discussed at VTT and a lot of efforts have been made to get larger orders from the clients. Nearly one fifth of the managers said that there has been considerable success here, but even more still saw the situation as a major problem. The special Research Group approach is used in about half of the laboratories to help the exchange of information and advance the updating and the development of know-how. The managers reported problems here. It takes a lot of time and effort to build good research groups and they do not always function well. Other related problems were those caused by young and/or small laboratories (see also the list of factors influencing the information seeking patterns generally the end of Section 7.2.2), and the data were also derived from scientists with little experience and those no longer productive.

The idea of working in pairs, senior and junior scientists together, was generally supported by the managers. Many laboratories have experienced a lack of senior scientists which has meant that some of the senior scientists have too many projects. This easily leads to a situation where the senior scientist is merely a bureaucratic head of a project. This is generally seen as a negative development, as one manager said "I keep on saying that every scientist should spend his time in the laboratory with experiments". Thus, working in pairs is a clearly acknowledged idea in most of the laboratories but it is often hard to put into practice.

Many managers have also noticed that scientists are either active gatekeepers or, more or less, introverts who are keen on experiments. Also some 'sinks of information' have been noticed, that is those scientists who are known to be well informed but who rarely give any information to others. Five managers mentioned that the ideal scientist at VTT is a gatekeeper type and that they try to remember this in recruiting new personnel. About as many said that there is a need for a mix of both gatekeepers and 'workers'. 'Sinks' must naturally be avoided.

Joint effort in the research projects is one of the key issues in successful research work. Education and inhouse training (which was mentioned by five managers) have been and are still important tools. Inhouse seminars, meetings of the scientists, social contacts etc. play a vital role. The normal career of a scientist at VTT is that he or she comes from university and leaves after 5-10 years to enter industry. Thus joint efforts are even more important than in other more stable environments. It is the research group that provides stability, rather than the individual scientist.

Ensuring that the information found is actually put to use

The managers are very concerned about the effectiveness of information use. The problem lies in the difficulty of getting data on the situation. The managers were given the results of the case study on the usefulness of articles collected during the project. The case study indicated that about half of the articles proved not to be useful to a particular project and only a few were generally useful. Over half of the managers found the data appropriate. One third felt that the result is usually even worse. Only three managers felt that one should avoid such waste copying. It seemed that the personal experience of the managers as information searchers was behind these comments, rather than their observation in the course of managing scientists.

As one manager put it "Research is information seeking and only a small amount of the efforts gives any result". Copying was seen as a cheap means of making sure that the area of interest has been covered. Scanning photocopies is especially useful in developing ideas and following methodological information. In practice, only part of the material found useful at first glance proved to be so after more careful reading. The use of online searching and abstract journals even increased the material scanned. They also increase the proportion of not useful readings. The main concern here was that one should not "copy and forget". It was emphasized that copies should be scanned several times during and after the work.

The value of information service here lies in giving a broad set of potentially interesting information or merely citations to information. One can then decide on the order of reading. This, in certain cases, can be very effective. For instance a good review article or report when starting a research project in a new area can save a lot of time and effort. There remains the problem, however, of how to make sure that these good reviews are found.

Also discussed was the major problem of how to handle all the collected articles. When personal computers become tools for all scientists these problems could be reduced. The problem is the time one has to spend in keeping these personal files updated. Two managers also noted that articles contain old information and, especially in the area of information technology, information must be received before it gets into the scientific journals. Here again is a reference to the importance of personal contacts.

Improving the seeking and use of methodological information

The majority of the managers (over 90%) said that seeking and use of methodological information in the research projects are important success-factors although only three put this matter among the three most important areas to follow in information seeking and use. In comparison with factual information, information about methods was seen as more demanding to seek and handle. Over 60% of the managers agreed that colleagues, contacts in Finland and abroad, and literature are important for finding the right methods for research. It was noted by three managers that less experienced scientists should use literature and consult colleagues in their own laboratory before using international contacts. There were cases where the methodological knowledge already in the laboratory was not fully exploited. When looking for the best methodological information in a research project 20% of the managers put contacts outside VTT (especially foreign contacts) before colleagues because senior scientists cannot usually find help from their own colleagues. Over 15% of the managers emphasized the role of literature above other channels.

Development of research methods was seen as an important in-house training matter by nine managers. Some said that this area is the key-issue at present in developing the quality of research in the laboratory. It was often mentioned that even though learning from colleagues is often an effective way of getting good research methods into the projects one should develop in-house programmes for the scientists to advance their methodological know-how. Because of the lack of senior scientists as project heads two laboratories use 'kummisetä', literally translated as godfathers, for the projects. This means that every project which is led by a less experienced scientist has a kummisetä who supports the project, for instance, in information seeking. The size of the laboratory was also mentioned by three managers. The laboratory must be large enough to make it possible to maintain methodological skills when individuals come and go. These were the mainstreams of the thoughts but one manager said a little sarcastically that "everyone does what he is able to do and new staff are recruited when methodological abilities are not found in the laboratory."

Ensuring that time used for information seeking and use is appropriate to the project

Although the managers rated time allocation studies as the lowest in our list of areas to be followed by the manager, the results raised a lot of interest and discussion. One of the main comments on the statistics was that they show how VTT does a lot of surveys and "paper-research". A quotation from a manager: "In small projects one can only seek information and then it is time to write a report - there is no time for actual research".

It was possibly due to the lack of this kind of data earlier that many conflicting thoughts arose:

Time is an appropriate measure for analysing the situation. It must be remembered, however, that creative work takes 20% of the time and provides 80% of the most important results (2 managers).	vs.	Time is an inappropriate means for monitoring scientists. Research needs "free space" (2 managers).
The 'information statistics' - information seeking 9% - reading 12% - communication/VTT 8% - communication/outside 18% - documentation 17% of the time use of a project-head sounds right (38% of the managers).	vs.	Use of time depends on the size of the project (25% of the managers), The results are true only in large projects. The rest of the managers had no idea of the distribution in their laboratories.
Individual reactions A: "Quite understandable". "I wish the statistics were true".	vs.	Individual reactions B: "Alarming". "Shocking" "Informing - the use of time must be discussed in the laboratory".

The comments on each area were as follows:

Seeking of information from the literature: 9% of the project head's time was considered high by two managers.

Reading: 12% of the project head's time was thought to be high by four managers and low by five managers. Arguing for the latter opinion one manager said: "Understanding takes time, not reading as such".

Communication within VTT: 8% of the project head's time was seen low by seven managers and high by two managers.

Communications outside VTT: 18% of the project head's time was seen as high by 11 managers. The comments were made that scientists do not prepare well enough for the contacts, and that new media are not used as much as they should be.

Documentation: 17% of the project head's time was said to be high by four managers, and low by five managers. It was said that efforts have been made recently to improve this area.

Project bureaucracy: 8% of the project head's time was seen to be about right, but complaints were made that all the bureaucracy at VTT takes some 20-30% of the time of the key-scientists.

Empirical research, 28% of the project head's time was generally said to be too low (60% of the managers). They believed it ought to be 50-70%.

There were more questions raised than answers given here. It was generally acknowledged that the effective use of time should be consciously monitored by each individual, and that almost all that managers can do is to discuss the matter. The awareness of time distribution provided some managers with a stimulus to consider information activities more carefully in the context of project planning. Also several pleas were made for developing new means of communication. Electronic mail and international networks were mentioned most often.

The managers were also asked to name any missing areas of interest from the given model. The majority (78%, 25 managers) did not suggest any new areas to monitor. Four managers named a new area: documentation and filing of the research results in the laboratory which should be done so that the results are readily available for future work. This suggestion could be taken into the model by broadening the action 'Ensuring that results are 'published' (internally and externally)' to 'Ensuring adequate documentation'. Three managers also mentioned that one should pay attention to how the research results are used and whether they are useful to the clients or not. This takes us to broader views than the effectiveness of information seeking and use in the research projects. These questions refer to the evaluation of research work as such but as already noticed in connection with the interviews with the scientists, the results of the research and their influence are also connected with the issues concerning information seeking and use in the research.

Finally, the managers were asked if they are interested in using the developed model in their own laboratory. Over 40% of the managers (13) answered yes and nearly 60% (19) no. The reasons for saying no were that there is no time for such studies, enough data were already collected in the VTT-level study, there were doubts over the usefulness of such a study and more practical help was needed than developing working patterns as such in the laboratories.

Those who said yes were interested in slightly different matters. Three managers said that they want a time allocation study to be done in their laboratories and to have a discussion with the staff about the results. Another three were interested in a brief questionnaire to all scientists and a seminar about the results. Two managers wanted to have a more detailed study on the heads of projects. The remaining five did not describe their interests in detail.

Part IV: Conclusions

8. THE VALUE OF INFORMATION IN ORGANIZATIONAL SETTINGS: A FRAMEWORK FOR MANAGING INFORMATION USE

8.1 Starting Points

We have developed a dual approach to the value of information where exchange values and value-in-use are studied (Chapter 3). An organizational setting, a technical research centre, was assumed to provide ideal surroundings for testing the approach. A set of case-studies and other data collections were set up for developing a comprehensive understanding of the economics and the value of information seeking and use at the Technical Research Centre of Finland (VTT). The practical management questions to be answered were: How can one make the use of information optimal, and what kind of methods can be developed for monitoring the use of information?

The empirical study was based on a literature review of the studies on information need and use in engineering (Chapter 4). The case-studies by Allen (1977) and Bitz & Owen (1981) largely influenced the settings for the studies. The U.S. studies of the value of information by King Research Inc. (King et al. 1982; Roderer et al. 1983) encouraged the collecting of empirical measures of the exchange values of information. In addition, several surveys on engineering research had an impact on our triangulation oriented studies. However, our interest in the use of information in research work meant that the common surveys on the use of information systems, channels and services were not of much help.

The value-in-use of information for the research projects was the main point of interest in our study. We found evidence to suggest that it is not possible to collect statistical data on the value-in-use of information inputs and find their influence in the results of the research. Although there were some individual examples they were not generally useful. Obviously the European research tradition is quite different from that in the United States. This meant that we were forced to neglect the approach mentioned earlier which had been successfully applied by King Research Inc.

Instead, we collected descriptive data on the use of information in the research projects and more generally on information seeking and use at VTT. The summary of these studies is presented in Section 8.2 of this Chapter. With the data concerning the success of the research projects studied we developed a model of important management actions for maximizing the value-in-use of information for the research projects (see Section 8.3, this Chapter).

Our dual approach meant that we were also looking for evidence of the exchange values of the information services and information products used. These efforts failed. We consider our dual approach valuable in the light of the several reasons for the failure:

1) The scientists and even research managers are not used to thinking about information products and services in monetary terms. The main reason for this is that the costs of using these products and services - they think - are of minor importance and that usually they are so specialized that the comparison of different products and services is difficult. The scientists have also accustomed to 'free' information services from teachers and university libraries when they were students.

2) Information markets are developing but they are not yet developed enough. Top level research groups have to get into the situations where the information and knowledge is exchanged with other (international) research organizations. This means that the scientists get the information and knowledge before it enters the market. This may be the case even in the future in spite of the developing information market because of the new means to perform co-operative research and also because of increasing international co-operation in technical research. In other words, much of the important information exchange takes place outside the information market and thus the research managers do

not see the exchange value considerations as being important.

3) The earlier mentioned European tradition in research probably hinders thinking in terms of exchange values when considering information products and services. This situation is bound to change when there are more comparable information products and services available on the market.

The problems on the market side of the exchange value studies meant that we concentrated upon collecting data on the costs of information use. This proved rewarding in providing interesting data and also in motivating the research managers to start thinking of information seeking and use as an important part of their management practices.

8.2 Information Use in a Research Organization

In this section the findings of the VTT study are summarized. The views of scientists and managers are put together. The idea is to give a reader the frame of reference for the model in the next Section. The model describes the management actions needed to ensure effective information use in research work.

8.2.1 Costs of Information Seeking and Use

The scientists and managers tend to underestimate the importance of the costs of information seeking and use. The main reason for this is that only seldom are the costs of a project shown in the project budget. The accounting practice at VTT is that only foreign travelling and some services acquired from the Information Service (for instance, online services included but circulation of periodicals excluded) are clearly seen in the project-account. At present these 'direct' costs of information use at VTT are a few thousand Finmarks, under 5% of the project budget on average.

The often omitted labour expenses constitute the biggest share of the costs. The time study of the project heads at VTT showed that information seeking from literature took 9% of the total time used for the project and reading took 12%. Communication took 26%. This means that nearly half of the time is used for information seeking and use. Thus, when research work is made more effective the time used for information activities has to occupy the central role. Better information services and better support in communication could easily offset the costs of the investments in the form of saved time. Still, the key to this problem area is how to make scientists work more effectively and use all the support available whenever needed.

The time usage statistics raised mixed feelings among the heads of the laboratories. For the majority the statistics came as a surprise and their main concern was the small proportion of actual research (under one third of the total time used). Nearly one fifth received ideas for further studies and actions in their laboratories but another fifth doubted whether the research work could be made more effective by rationalizing time usage.

8.2.2 Benefits from the Use of Information

After counting the costs one would like to see the benefits gained. Unfortunately only seldom can one find clear-cut connections between information use and the results of the research. Sometimes a new piece of information gives a clearly noticeable new and 'better' direction for the research but usually the new information flows continuously to the research process in the form of documents, advice from the experts and colleagues etc. The new information and knowledge joins the earlier knowledge and it is afterwards hard to isolate the role an individual piece of information has had in the research work.

Some scientists gave examples where the piece of information had had a central role in the research process. The benefits from the use of information could be measured, for instance, in the following cases:

- an online search saved time in planning a visit to a research organization and also in planning a project,
- a visit to a foreign research organization gave new information which saved time in an ongoing project,
- a personal contact with an expert saved time (several responses), and
- a current awareness service picked out a piece of information which improved the result of a project substantially.

The examples of the benefits gained from a piece of information are important in describing the value of an individual information channel.These few examples are not of much help in developing the information seeking and use practice for research work. The use of information as a part of research work must be studied more thoroughly.

8.2.3 Information Seeking and Use

Information and knowledge comes to a research project with the scientists appointed to work in the project. New information is acquired during the project. To a certain extent new information comes also with new equipment and software used. In the twelve projects studied thoroughly at VTT the results were thirdly based on the earlier knowledge of the project groups. A senior scientist, usually a project leader, has often taken part in the planning and development of its idea. His responsibility has been the seeking and use of new information. Less experienced scientists work as assistants in the projects. This general working pattern means that senior scientists generate and direct information behaviour in the research groups and the laboratories.

Personal contacts and periodicals are the most frequently used and the most important sources of new information. Research reports, books and other documents are also much used, contrary to the impression given by some U.S. studies (e.g. Allen 1977). Online searching is less often used. It is also rated quite low in spite of a lot of efforts the Information Service has made to promote it. The senior scientists emphasized how the best documents for the research are often found through personal contacts. The scientists rated the main channels of information in the following order. The average numbers of use are shown in parantheses:

1) International and national contacts (10 important international and 10 important national contacts per project, 2 international business trips per scientist per year),
2) Scanning and reading of periodicals (13 periodicals per scientist),
3) Visits to library (24 visits per scientist per year),
4) Abstract journals (3 journals per scientist), and
5) Online searches (1.4 searches per scientist per year).

The heads of the laboratories generally emphasized that online searching should be used more and thought that it should be second in rating to contacts. The managers would also like to put the libraries at the end of the list as their use was considered time-consuming. (Meaning large special libraries here. Most managers acknowledged the need for a small reference library in the laboratory).

There are three major factors influencing the use of information in a research project: scientists, tasks and the types of information needed.

The scientists fall into groups ranging from 'information rich' (or gatekeepers) to 'information poor'. The gatekeepers frequently use various channels and sources whereas the 'information poor' use few sources only occasionally. These scientists are more interested in such work as laboratory experimenting and programming. In the case-studies at VTT we found a fairly even number of scientists in both groups. Another related phenomenon was also observed: some scientists prefer the procedural approach to their problem solving while others are theoretically oriented. There was much evidence that information seeking and use patterns are heavily dependent on the attitudes and working practices of individuals (for discussions on the attitudes of engineers see Nagus 1982). The nature of the project, laboratory or working experience had less influence on the behaviour. It looks as though the optimum research group consists of the most heterogeneous set of individuals. This was also emphasized by the heads of the laboratories. Although the lack of gatekeepers in a research group is likely to cause problems there is also a need for 'workers' and these abilities are not always found in one person.

The case studies of twelve research projects demonstrated that the use of external information is essential in the research projects of VTT and less effort goes into generating new knowledge and information. This is probably a true observation (supported by the time usage data) although the research programmes, from which the projects come, emphasize the new areas of research at VTT. In these circumstances effective information seeking and use is vital.

The seeking and use of factual information differs from seeking and use of methodological information. The seeking and use of factual information seems to be quite straightforward although often cumbersome: for instance, by the series of laboratory tests or already documented test-results. The seeking and use of methodological information is much more demanding: it is often a time-consuming learning process. It seems to be especially important to use rich channels and sources here. Personal contacts proved to be competing successfully with 'official' intermediaries. It is far more useful to get a list of readings from a colleague than through, *for instance*, an online search. The former list includes an expert's knowledge of the useful readings while the latter is a more random selection of readings available in a set of databases. Additionally, experts and colleagues were useful in teaching the use of methods, and in supporting the selection of methods for the research project.

The information deluge is much talked about in the private sector and within governmental organizations also. However, in the research organization the problem seems to exist in finding good and detailed enough information. The scientists and the research managers have become used to the situation where only half of the acquired information proves to be partially useful and only a small percentage of them is generally useful. 'Waste' scanning and screening is a part of the research process if there are no clear solutions for the research tasks at hand in one's range of vision.

8.3 Action to Be Taken for Effective Information Seeking and Use

We used the input-output model of a research process as a basic frame in our analyses of the research work. The 'black box' of the research process is opened by monitoring information seeking and use for the process. When it became clear that only cost-data of the use of information can be produced for statistical analysis, the cost-benefit analysis of information use had to be discarded. By collecting descriptive data about the use of information in the research processes and data on the quality of research results we developed an elaborate input-output model of the management actions for promoting effective information behaviour. These actions optimize the value-in-use of information for research tasks.

The model was developed for the the benefit of management. For this reason, only the most important actions are included. The model was submitted to VTT laboratory heads for comments and alterations and is presented in Figure 8.1. All the actions were seen as useful in monitoring the effectiveness of information seeking and use. The actions are rated in Figure 8.1 according to the importance the managers placed on them.

The most important and also the most common way of ensuring the effective use of information in the research process is to monitor the documentation of research. The quality and variety of the documents produced were the major concern of the research managers. However, it was emphasized that publications are only one result of the research and usually equipment, software etc. are more important results.

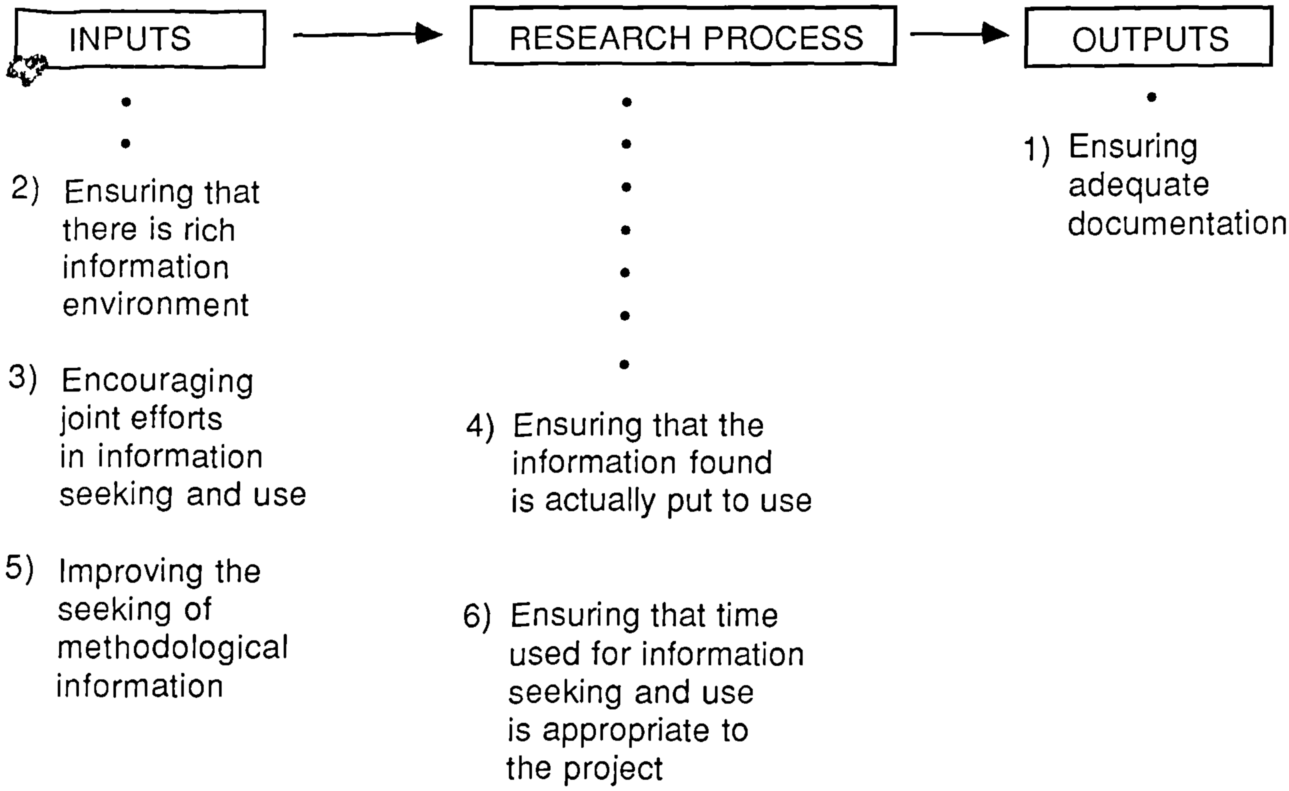

Figure 8.1 Management actions for optimizing the value-in-use of information for research work

Ensuring that there is a rich information environment for the research groups was thought to be the second most important action in managing the use of information. A variety of information channels, information systems, information services and information products should be available, and the scientists should have the abilities to use them efficiently. New effective means should be adopted quickly. In this respect the scientists do not seem to be as progressive as the managers.

Thirdly, one should encourage joint efforts in information seeking and use. The idea of working in pairs (senior and junior scientists working together) and, more generally, heterogeneous research groups were considered worth aiming for. There are two demands ensuing from this: the research groups must be big enough (this presupposes that the research tasks are large enough) and there must be enough time for appropriate communication.

Ensuring that the information is put to use is the fourth in importance of the management actions. The personal filing practices should be developed for effective use of collected documents, notes etc. The fact that the scientist has to screen and scan a lot of documents for his research work was acknowledged by the managers but the use of acquired information was generally seen to be too low.

Improvement of the seeking and use of methodological information comes next in importance for the managers. The rich channels were seen as important. Colleagues and outside experts are essential in advising the projects in methodological problems. It was considered vital for the development of research groups that sufficient effort be put into the seeking and use of new methodological information.

Sixthly, the manager has to ensure that time used for information seeking and use is appropriate for the project. There is a clear need for producing time-allocation data on the work of the research groups for management purposes.

These data are useful in convincing the managers of the importance of information activities in research work. They are also needed as a background information when rationalizing efforts to support the working patterns of scientists are made.

The model can be used in developing the effectiveness of information seeking and use in research groups and research laboratories. Detailed data have to be collected about the information seeking and use patterns of the scientists. Table 8.1 summarizes the data collection methods suitable for a research laboratory. It is a modification of the data collection of this study.

In practice the methods have to be modified according to local needs and interests. The heads of the laboratories at VTT were interested in different things, some in time-usage and others in the facts about information seeking and use in the projects. The majority felt that it is not necessary to collect all the data listed in Table 8.1 when VTT level data are already available. It was generally emphasized that after data collection the results must be discussed in a seminar for the managers and the scientists of the laboratory. It is also important that the representatives of the information service and other units supporting the information seeking and use should participate in the development.

Table 8.1 Data collection for the action model for effective information seeking and use in research

Data collection	Indicator
All/sample of the projects ended	Contacts in the projects
in a certain year, an interview/	Size and nature of the
questionnaire to the heads of	project staff
the projects.	How method information
	is sought
	Use of article copies
	Documentation data
All/sample of the ongoing	Time used in
projects in the laboratory,	-information seeking
a time-allocation study to the	-reading
scientists working in the	-communication/VTT
projects.	-communication/other
	-research
	-project-bureaucracy
	-documentation
All/sample of the scientists	Foreign travelling
in the laboratory,	Periodicals reading
a questionnaire.	Online searches done
	Abstract journals read
	Visits to library made

Table 8.1 continues:

All/sample of the scientists in the laboratory, an interview/ questionnaire.	Ideas for developing information seeking and use

At an organizational level the following actions are needed for more effective information seeking and use (a research organization, recommendations based on VTT data):

1) Research has to be developed in large enough units and the time scale of research has to be 5-10 years. This provides the possibility of building information seeking and use practices in the research group that are not totally dependent on the abilities of certain scientists but the responsibilities can be shared by group members. Issues of information seeking and use need to have a more recognized role in the development of research groups.

2) The research units (laboratories) have to monitor and develop their information seeking and use patterns and abilities more consciously as an important part of the management practice. Local data collections and discussions are needed from time to time to remind the scientists and managers of the importance of these issues.

3) The parent organization needs to give good support to communication between the research units in the organization and to their national and international contacts. Electronic mail and international networks are the most important development targets at present. Although progressive research organizations use these systems already their broader use is just beginning.

4) The information service unit has to offer scientists a variety of services the use of which is flexible. Instead of general services one should develop more tailored services for the research units and even for the individual scientists. In order to be able to offer cost-justified services the information service unit has develope systems which broaden self-service.

8.4 Concluding Remarks

Information seeking and use practices vary. The behaviour of the scientists and the working patterns in the laboratories are the result of a complex set of influencing factors. These include the field of research, the personnel structure, the age and the size of a research unit, the nature and the size of a research projects etc. Thus, the generalizations from the VTT data at this level of detail must be made with caution. However, the earlier studies on engineering research support the findings at the general level although because of somewhat different approaches closer comparisons are not possible (Allen 1977; Bitz & Owen 1981; Gralewska-Vickery 1976; Shuchman 1981).

We developed a model for use in management. This meant that we had to do without Allen's (1977) longitudinal studies as well as without 'laboratory tests' of the information use proposed by Bitz and Owen (1981) because, in management, to use those studies would burden the scientists too much. On the other hand, the surveys of the use of information channels, like Shuchman (1981) did, are not useful alone.

9. SUMMARY AND CONCLUSIONS

The economics and value of information have been analysed in this study. Efforts have been made to deepen our understanding of the phenomenon. Our approach could be characterized as a phenomenological or hermeneutic approach where by means of the case studies and the analysis of the literature, the nature of the practical value of information is identified. It is our belief, also supported by empirical findings, that practical information use situations give the best starting point for the analysis. This is somewhat different from most of the recent studies which have often been motivated by the need to argue for the importance of some particular information systems, information services, information products and even information professionals. The Special Libraries Association study, President's Task Force on the Value of Information Professional (1987), provides a good summary of the latest approaches in the field of information science. Although such studies as those collecting examples of the usefulness of certain information services are undoubtedly necessary and useful for the providers of those services they still leave rather a vague picture of value analyses in general.

9.1 Summary of the study

There were two research tasks in this study. The first looked at methods and techniques which research managers might use to measure the value of information in practical situations. The literature of information science and economics was analysed. In spite of the quite extensive literature reviews, ready-to-use methods were not found. Instead, useful background information for our study was collected.

There are three paradigms 'ruling' research on the value of information: the economic paradigm, the cognitive paradigm, and the information theory paradigm. Interestingly, economists have concentrated their recent interest around the information theory paradigm and the economic paradigm is only used in some empirical studies. Information scientists mainly use the cognitive or economic paradigms. Although there have been a few attempts to cross the boundaries of the paradigms the main part of the research is completed under one paradigm. For instance, those information scientists who are studying information markets and information management clearly emphasize basic economic approach. Other information scientists who study, say, the use of information and information systems usually stress the cognitive paradigm.

While economists have failed to introduce useful practical means to measure the value of information in spite of research based on information theory, the research in information science seems to split into two groups. There are those who believe strongly in economics. After the failed attempts in using cost-benefit analysis there is the information accounting and budgeting boom at the organizational level, better known as Information Resource(s) Management (IRM) approach. On the other hand, there has been much research on the use of information, which, at best, applies a cognitive approach.

We arrived at the conclusion from the literature review that it is necessary to organize research on the value of information by using the economic and cognitive approaches simultaneously. Neither of them describes the phenomenon fully alone. By simplifying, one can introduce a dual approach to the value of information for practical studies:

1) The exchange value of information products,services, channels and systems should be studied using economic methods.

2) The value-in-use of information should be studied using the cognitive approach which takes the user, the use and the effects of use of information into consideration.

The second research task was to study the value of information in organizational settings by developing means for the research managers to optimize the use of information in research tasks. Then the value-in-use of information is also maximized. We developed a management model for organizing the assessment of the value of information. The model is composed of six management actions for monitoring information seeking and use in research work (see Figure 8.1 in Chapter 8).

The model can be used in developing the effectiveness of information seeking and use in research groups and laboratories. Data for the model needs to be collected on the present state of affairs concerning each action in a set of research projects or tasks. The analysis of the differences and similarities in the tasks and the behaviour of the scientists are then discussed in joint seminars and meetings of scientists and research managers.

9.2 Future Studies

In future research on the value of information we suggest more specific goal setting and definitions of what values are actually being studied and measured. Research in the area is certainly needed, but in order to gain more reliable and more easily comparable results the basic approach has to be clearer.

Information is acquired in the form of information products and services. The value of information is fully explicated in its use. This means that the cognitive processes of individuals involved in information tasks, and such issues as time for learning about the use of different types of information, and time for actual use have to be studied.

It seems that in practice a case study approach is the only means at present available for studying the value of information deeply enough. Data have to be collected from information work and individuals performing the work using several collection techniques (interviews, questionnaires, diaries, content analysis etc.). The model developed in this study has to be applied to other areas, such as company research units and other research organizations. Furthermore, it would be interesting to see how useful the dual approach and the model would be in analysing the economics and value of information seeking and use in other areas, such as planning, marketing etc. in the private sector. Success in these areas would mean that we would then be able to give better tools for the managers to monitor the economics and value of information seeking and use than those occasional studies of the economics of individual services which have provided the best results until now. But at first the managers need to be 'awakened' to the importance of these activities and here time allocation studies such as those reported in this thesis are surely needed.

Two research ideas have been developed from our studies. The first one deals with the seeking and use of international information in a set of Finnish high tech companies. The basic interest is supposed to focus on the information concerning both marketing and innovations because they both are essential for the success of the companies. The approch developed in our studies at VTT is planned to be used in a modified form: case studies should burden the participating organizations as little as possible. On the other hand, there are needs to deepen our analysis. One particular point for this is in studying more thoroughly the types of information sought and used, and the corresponding time needed. So, the role of time allocation study would be an integrated part of other data collections.

Another idea is to apply our approach in analysing the information work in public administration. The idea here is to study the information seeking and use behaviour of civil servants. The key-tasks of a set of civil servants are planned to be analysed for developing more effective information seeking and use behaviour.

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APPENDIX 1

ECONOMICS OF INFORMATION

1 Economics of Information

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INTRODUCTION

General Background

This review describes the past 20 years of research on the economics of information and has been written from the viewpoint of library and information services. The literature covered has been published mostly in the United States and in Great Britain.

Research into the economics of information is conceptually vague and even though much research has been done, the results are still vague. Even though this report presents empirical research, it is necessary to introduce the basic concepts and ideas of the economics of information. Opinions are included among definitions because even the important concepts are somewhat hazy and there is disagreement even about the starting points of the research. A brief glossary of terms used in the economics of information is given by ROBERTS and includes valuable examples of the definitions used in the literature.

ARIST has reviewed this subject in four previous chapters (GRIFFITHS; HINDLE & RAPER; LAMBERTON; MICK). Economists who have studied the economics of information include MACHLUP (1962; 1980) and FLOWERDEW & WHITEHEAD. In information science the subject has been treated recently by KING ET AL. (1982; 1984), TAYLOR (1982a; 1982b; 1984a), CRONIN (1986), and CRONIN & GUDIM. LANCASTER (1977) evaluated the research done as of 1977 and BLAGDEN (1980a) reviewed research in the United Kingdom.

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The review of earlier studies on cost-benefit analysis in information science by FLOWERDEW & WHITEHEAD is recommended. It has now been supplemented by the seminal report of MARTYN & FLOWERDEW. WILLS & OLDMAN supplement the previously mentioned British viewpoints from the perspective of special libraries (see also BLAGDEN, 1980a).

For the U.S. studies, the collection of articles in KING ET AL. (1983) contains the latest writings about the costs and pricing of information products and services and the value of information. VAN HOUSE recently surveyed the research on the economics of information within libraries, and VARLEJS has covered this topic as it concerns public libraries.

Economics and Information

The phrase "economics of information" began to appear in the terminology of economists in the 1960s. In information science it appeared primarily in connection with evaluation studies. After the discussions on the costs and the effectiveness of information services, the value of information for the user and the productivity of information work have become issues of the 1980s. The economics of information can best be described by naming the central areas of interest in the information market (CASPER; VAN HOUSE): 1) information supply (economy of information production, pricing information products), 2) information demand (acquisition and use of information), 3) special problems of information as a product or resource (e.g., pricing of use, public funding of information production).

A study of the economics of information presupposes a definition of information itself. Many information scientists define information in terms of its method of presentation. For example, "information is stored knowledge," according to MARTYN & FLOWERDEW. Others define it as a process in which data become information, knowledge, and even wisdom (CLEVELAND; HORTON, 1979; TAYLOR, 1986). Data are raw material of information collected from nature or tradition (historical information), which is transformed, processed, collected, transferred, made available, and so forth. Information becomes knowledge when someone applies it to something useful. Wisdom can be seen as processed, integrated information (e.g., CLEVELAND). Information is thus seen as a kind of product, even as a resource (HORTON, 1979), but information is a unique resource (CLEVELAND; CRONIN, 1985; FLOWERDEW & WHITEHEAD; HORTON, 1982). The special features of information are now examined separately from the theoretical and practical viewpoint.

Recent discussion has focused on information in the context of a profit-oriented market. This, of course, makes the whole concept structure very shaky. CLEVELAND, who is a political scientist, characterizes information in the following way: 1) information is human- there is information only through human observation; 2) information is expandable; "The more we use it the more profitable it becomes"; one basic limit is the biological age of human individuals and groups; 3) information is compressible; the increasing amount of information can be controlled by centralization and integration and by compressing it so that it is useful in different surroundings; 4) information is substitutable—it can replace other resources like money, manpower, and raw materials; for instance, the accumulation of information related to automation replaces several million workers annually; 5) information is transferrable; the speed and facility of information transfer are a considerable factor in developing and shaping communities; 6) information is diffusive—it tends to leak out and spread despite our efforts to protect individuals and innovations; 7) information is shareable; goods can be exchanged, but in information exchange the giver still "retains" what he has given away.

At this point the above features of information must be left only as comments criticizing simple resource thinking. The study of the economics of information, in concrete investigations, has often used classical economic theories. Some special features of information have, however, emerged during empirical measurements and studies: 1) information products cannot be replaced with other information products if the information contents are not identical; 2) information products add value, but their benefit also depends on the ability of the user to exploit them; 3) information does not deteriorate by use; only time makes information similar to consumer goods in some cases (e.g., information on stock exchange rates; otherwise information is more like an investment good); 4) information is not a constant- i.e., generally it cannot be quantified. The model of SHANNON & WEAVER is only suitable for examining the amounts of information transferred, not for defining the value of the information content; 5) information is an abstraction- i.e., it is produced, disseminated, stored, and used through different devices and services. This feature causes plenty of confusion, for example, when one estimates the value of information indirectly by what someone is willing to pay for it; 6) new information is produced mainly with public funds (especially basic research), but the total production costs are rarely included in its market price; and 7) the real benefit of information is difficult to measure because it is tied to its use, which is unpredictable. These characteristics of information make studies of the economics of information problematic. The economics of information is, however, becoming an important research object in information science with expanding information investments and information work and economic pressures for effectiveness of information activities.

Research on the value of information is one of the key areas in the economics of information. These studies must be connected closely with the studies of how information is used. However, recent articles that criticize user studies suggest that such studies are not very common (see, for example, CAPLAN, DERR, and JARVELIN & REPO).

On the other hand, some have tried to define information products. While WILLS & OLDMAN argue strongly against an idea of information as a product, others like TAYLOR (1982b; 1984a) try to characterize information products. According to Taylor an information product (or service) must meet the following conditions: 1) it must have a noticeable role in the activity studied; it has to be measurable and comparable with other information products; 2) it has to be stable enough so that its production costs can be measured; 3) it must have such a form that it can be identified for other uses.

Such a definition of an information product (and service) ought to be available because it allows us to examine information in a general and situation-independent way. The definition also includes information content as part of the definition of information product. In the production and processing of pieces of information in an abstract information system the definition seems usable, but it does not offer a way to study the use of information. In practice, we are forced to examine separately, information products, information services and information systems on the one hand, and the use of information and its benefit and value, on the other.

Approaches and Methods

As previously stated, questions concerning the economics of information are closely connected to the evaluation of information services and libraries. The basic evaluation theory is simple: the goals are described, and then we measure how well the particular activity (or activities) helps us to realize the goals. Economic analysis has a central position in this evaluation. Cost-benefit analysis is needed in decision making in general as well as in the evaluation of previous decisions and in seeking the partial systems important for the activity. Cost-benefit analysis aids decision making when we seek answers to the following questions (FLOWERDEW & WHITEHEAD; WILKINSON): 1) how much should the organization invest in information products and services (e.g., compared with competitors); 2) how much of the organization's running costs should be invested in information services and how much in other activities; 3) is the size of the present information budget adequate, or should it be changed; 4) how are the resources allocated among different information services; 5) are the investments in particular information services successful, or should they be changed; 6) how useful are the individual information service projects; 7) how are the information services priced; 8) how should information production and dissemination be supported or taxed; 9) is pricing suitable for management and investment plans; 10) what kind of measures are needed to monitor the performance of the information services.

Flowerdew and Whitehead restrict themselves to cost-benefit analysis of the measures in terms of money. This approach, which is characteristic of economics, has been criticized because benefits cannot always be measured in terms of money. Thus, some researchers (e.g., OLDMAN, WHITE) deny the usefulness of cost-benefit analysis in measuring the value of information in the library environment. Stronger but questionable criticism is presented by Machlup (in VARLEJS) who notes that it is futile to try to measure the influence of information services on the users, the value of information or its social benefit. LANCASTER (1971), too, presents similar thoughts. Although these latter thoughts have been picked from connections, where the writers have criticized badly made and faulty generalizations in cost-benefit analyses of information, they indicate that some leading scientists both in information science and economics doubt the possibility of measuring the value-in-use of information. But we can at least name those benefits that cannot be measured with money. This view is used here because the difficulty of explaining the benefits of information in terms of money has led the analyses in practice toward this extended view of cost-benefit analysis. Perhaps one should speak of the value of information rather than the cost-benefit of information to avoid confusion. In presenting the empirical studies we further specify costs, effectiveness, and benefit. By combining these concepts we get five levels on which to examine the economics of information (FLOWERDEW & WHITEHEAD; LANCASTER, 1977; WILKINSON).

Costs. The definition of costs is often the first task in valuing an information activity. In defining the costs for information production, dissemination, and so forth, time has to be included as a cost. Allocating overhead costs to the service or product evaluated also can cause problems. The empirical studies of costs have often been too vague and sketchy to be of much benefit for decision making in practice. The calculations of costs have usually been limited to those associated with the production of information products. Less study has been devoted to the costs of information use, and the few studies made are limited to the costs of the use of certain information-acquisition channels.

In connection with the costs of information and its dissemination, the public expenditure connected to the production of information has often been discussed. Comparison of public expenditure with private costs in acquiring information is difficult and has not been studied much (for a broader presentation of costs see ROBERTS).

Effectiveness. An evaluation of the effectiveness of a service or product presupposes a comparison of the goals with the results. In most evaluations of information services and products, large sets of data must be handled and measured—i.e., both "hard" data (amounts, costs) and "soft" (opinions, views).

Examination of cost/effectiveness gives, in principle, good possibilities for evaluation of the effectiveness of alternative plans and allocation of resources. For the ideal evaluation of effectiveness we need a measurement of the value of each product and service, and then the possible sets are compared. The benefits and costs that cannot be directly given in monetary terms can be assigned relative weight coefficients. In proper comparisons, statistical data are collected from the users on standpoints, use, etc., as a background for evaluating weight coefficients, but still weighting is a problem.

Efficiency. While effectiveness studies compare goals and results, efficiency studies concentrate on how well the activities as such are performed. These studies have been very popular in evaluations of library and information services.

In measuring the efficiency of work processes, alternative processes and their costs are studied. Although this type of investigation is important (e.g., for the management of information services), when effectiveness and benefit studies are missing, interpretation of results continuously causes problems. This is evident in the compilation of national statistics. When it has been difficult to get statistics on the actual use of libraries, the performance of a library has been described in terms of circulation statistics and interpreted as a measure of the library's effectiveness. Naturally those statistics only tell us how busy some librarians have been and not much about how well the library has served its clients.

Benefits. The benefits from the use of information and the measurement difficulties have always been priority areas in the economics of information. Recently, these investigations on benefits have often been called studies of the value of information (e.g., GRIFFITHS). There is much speculative literature on the definition of information value. Still, the definitions converge at least in that information value has to be defined from the viewpoint of use or users.

To trace the benefit of information services and products, TAYLOR (1984a) has suggested: 1) statistical methods to collect user experiences, and 2) the so-called critical success factors approach (CSF), wherein the most important tasks (of the managers) and the related information needs are clarified by interviews. Previously, user interviews and surveys (e.g., on willingness to pay and time savings) and demand analyses have been used to determine the benefits. "Hard" data have been produced by calculating the actual payments for information products and by costing the time spent in identifying, acquiring, and reading (KING ET AL., 1982; 1984). There are many measurement problems and even problems connected to the basic approaches applied in the studies, which are mainly due to the special characteristics of information discussed earlier.

Value (or cost-benefit analysis). Cost-benefit analysis examines the benefits and costs of an activity. All the previously described levels can thus be used to describe the prevailing situation or alternative plans. A thorough analysis records entities that can be measured monetarily as well as those that can't. ROTHENBERG, for instance, writes about the starting points and the methodical basis of cost-benefit analysis.

Although cost-benefit analysis has been much criticized in evaluating information systems and services, analyses have been made and certainly will be made. The need for cost-benefit analysis is due to emphasis on the economic significance of information in organizations and communities. A good cost-benefit analysis should consider problems arising from the fact that it is often easier to measure the cost than the benefit; otherwise the cheapest solutions (and probably the most useless) are wrongly emphasized in the analyses.

The methods of research into the economics of information and associated problems have also been analyzed (BLAGDEN, 1980b; CRONIN, 1982; FLOWERDEW & WHITEHEAD; LANCASTER, 1977; MARTYN & FLOWERDEW). The problems of defining information have led the appraisers to stress concrete approaches (particularly Lancaster) and a more accurate definition of information markets (e.g., MARTYN & FLOWERDEW).

MARTYN & FLOWERDEW criticize studies performed on the following grounds: 1) the goals of the studies are vague; few investigations have concrete goals; 2) the goals are sometimes "impossible"; Martyn refers here particularly to efforts to define the value of information, and he suggests case studies in this regard; 3) the studies are based on inadequate data; 4) unfamiliarity with the field; the economists do not know the special problems of information science and vice-versa, *especially; a possible improvement* would be cooperation between economists and information scientists; 5) too much emphasis is given to the "scientific" quality of the research results at the expense of the practical benefit of the studies; 6) the methodological defects are obvious--they are to a large extent due to the special characteristics of information; 7) the field is artificially restricted to the information services of science and technology. Even though similar lists can be made from several fields of research, the problems of a new research field are clearly emphasized here as well as the special characteristics of information as an economic entity.

All the methodological approaches typical to social sciences—experimental, statistical, case study, comparative, and descriptive study—are available to study the economics of information. The most important data-collecting modes are collection of facts and user interviews and questionnaires. In research performed all the above approaches have been used, but because exact descriptions and definitions in the field cause problems, the best results are achieved by an analysis of case studies (see, e.g., MARTYN & FLOWERDEW).

EMPIRICAL STUDIES OF THE ECONOMICS OF INFORMATION

General

This section presents the main research topics of the economics of information and studies completed in each field. The review is based on the literature of information science. Several studies contain material that makes it possible to present them in several contexts. However, each study is presented in the one category thought most appropriate for its main focus.

The studies are grouped according to the research material available. They do not necessarily indicate the activity in the whole field. We try only to specify presentation and, to some degree, to specify the development of the research in the economics of information during the past two decades. It has not been possible to acquire all research reports. Thus, most of the material consists of articles.

Costs of Information Products and Services

Information products and services incur costs. The costs are generally stated in monetary terms, but in some cases certain disadvantages are considered as costs. Such costs can then be defined as a lost benefit. The costs of information products and services have been treated in many review articles (HINDLE & RAPER; KING ET AL., 1983; LANDAU, 1969; MICK). Some textbooks also treat the topic (ATHERTON; LANCASTER, 1977; ROBERTS).

All the reviews and textbooks worry about the quality of the cost measurements and research. Research methodology is considered particularly inadequate as well as documentation. Research has concentrated on costs of individual services and information services as units. Comparability of the results of badly documented *investigations is rather poor. Even some of the* reviews are only vaguely organized (e.g., MICK) or collect isolated examples of studies done (e.g., in KING ET AL., 1983). It is also interesting to notice that Landau, nearly 20 years ago, cited the above-mentioned problems associated with performing cost measurements that still prevail today.

LANCASTER (1977) analyzed research of the costs of libraries and information services thoroughly. The priority fields in which cost analyses have been made are acquisition, cataloging, online information search and information production. In acquisition the influence of literature prices and the costs of handling have been studied. In cataloging, most of the studies done have compared manual and automated cataloging; for instance, Pierce and Taylor (in KING ET AL., 1983) measured the costs of one manual and two computerized cataloging systems (OCLC and BALLOTS).

One popular research topic during the past decade has been the costs of information searching (also discussed later). Shirley (in MICK) cites many different costs arising from an information search. However, in several investigations the scope of the costs is limited so that the research results are of limited value. For instance, Bement (in MICK) compares the costs of the results of two information searches from three online services (BRS, DIALOG, and SDC) by calculating only the connect time and the costs arising from the number of references retrieved. Thus, the costs for the preparation of the search and for offline output are not considered, and the causes for the significant differences in cost among systems are not understood.

The costs of producing information have also been studied. For instance, Senders et al. (in MICK) justify electronic solutions by presenting in detail the costs of a scientific publishing scheme. In 1976 King (in MICK) collected statistical data of production costs of information. Altogether, research in this field has been scanty because it is difficult to collect data about the costs of producing information.

It is also instructive to look at cost analyses from the viewpoint of their purposes. From the articles collected by KING ET AL. (1983) we can pick five different types of analyses.

Direct cost analyses. In direct cost analyses the costs of the activity are collected once or at regular intervals. As an example of one-time collection of costs we can take the 1973 study of Vickers (in KING ET AL., 1983). This investigation collected cost data from 18 European online systems. The aim was to study how automation affects costs. The investigation showed that costs are affected by the arrangements of information system management, salaries and productivity of the personnel more than by automation. Talavage et al. (in MICK) collected similar descriptive data about costs, appropriations reserved for the activity, etc., of approximately 500 information services.

Cost data are collected at regular intervals mostly for management. Helmkamp (in KING ET AL., 1983) planned an automated cost calculation system for a technical information service. The costs were specified per service, and the overhead costs were allocated among different services. The calculation system produced cost reports at regular intervals. MOISSE presents the cost calculation system of information activities at the Battelle's Geneva research center, which also includes the information services required for research. Costs for time spent in reading and using the information are considered along with information acquisition and seeking costs.

Theoretical models. Cooper (in KING ET AL., 1983) provides an example of a theoretical model for cost definition. In 1972 he created a mathematical model for minimizing the costs of an online information service. The model is based on minimizing the system costs plus user costs. The article, however, does not include data on how the model could be applied to studying concrete systems.

Planning cost analyses. In cost analyses done to support planning, data on the cost of alternative solutions are generally produced. For instance in 1979 Kraft and Liesener (in KING ET AL., 1983) described an operations-research approach connected to planning a school library. Cost data are produced to support the evaluation of alternatives in planning. (The researchers claim that they are making cost-benefit analyses although they are only recording the costs of alternatives.)

Independent cost comparisons. Cost comparisons can also be done separately from the planning process. Pierce and Taylor (in KING ET AL., 1983) built a model for comparison of manual and automated cataloging. Data on the one-time, fixed, operating and use-independent costs of the different alternatives were collected for the model. The average costs of cataloging a single item were calculated for each alternative. This study is a good example of modeling, in which the key variables are first collected and their interactions and relations with the environment are then defined for comparisons.

Prognostication cost analyses. In 1979 Barwise (in KING ET AL., 1983) predicted, with the aid of cost analysis, the price development of an online information service to the year 1985. The prognosis is based on an inquiry sent to the providers of databases. It is essential to the model that it consider the variable external factors; for example, computers and communications become cheaper all the time, but the use costs of databases obviously do not decrease because when the significance of online use of databases increases in the profit formulation compared with printed services for the database providers, the use costs will probably increase considerably at the end of the prognosis period. Now we can see that the prognosis somewhat exaggerated the increase in use costs, but the basic idea of the prognosis was appropriate.

The possibilities of using cost analyses are thus wide. The criticism of the quality of research can be rejected in part by recognizing that the most important research has been done to support practical management. The reporting of the research methods has been of secondary interest. Lately interest has shifted from mere cost analyses to other, wider questions. Nevertheless, we should remember that cost definition is an important part of these more comprehensive and, as such, more important studies.

Price of Information

Information has a price because its production, storage, dissemination, and use incur costs. The question is, who pays. The production and dissemination of information are usually subsidiary activities, whose costs are not always charged to the user. This information has not been priced and is sometimes considered to be free.

With more emphasis on the economics of information, librarians, especially those in public libraries, have started to talk about the price of information and fees for some services. The pricing of information is also being studied (KING ET AL., 1983; MICK), even though the literature reports it much less than the general studies mentioned above.

The price of information hardly ever arises from information itself and its value-in-use but from transfer or equipment costs and sometimes also from commercial profit. For instance, it is rather comical to pay for the references from an information search according to how long one has been in contact with a computer. The partial public-good character of information makes pricing difficult, though its dissemination is to a great extent commercial. In principle, pricing can have two bases: average costs + profit or marginal costs + profit.

The use of average costs and profit as a basis for pricing is hampered by the problems of calculation of total costs and prediction of demand. Several economists have therefore considered the best solution to be the calculation of the price of information from the marginal costs of dissemination. It is said that in this way also the use of information can be maximized. In research on the pricing of information we can find at least three areas of interest, enumerated below.

Economic examination of charging. McKenzie (in KING ET AL., 1983) presented in 1979 the economists' basic ideas on library services. According to him, more effective library services require the pricing of services and competition between libraries. Gell (in KING ET AL., 1983) presented similar thoughts; she considers that the services should be at least partly charged for if they are to become effective and because public funding for information activities is likely to decrease (CASPER (in KING ET AL., 1983) used regression analysis when she tested changes in the demand for library services when prices change. Her most important observation was that the influence of price depended strongly on user income. Other variables affecting use included knowledge about services, their accessibility, and competitive services.

Examination of the relationship between the price and use of information. The previously mentioned study by Casper could also be included in this group. Cooper and DeWath (in KING ET AL., 1983) studied information searches before and after invoicing was introduced. They noted that invoicing improved the quality of searches, and that the number of searches dropped only by a little more than ten percent. When King (in KING ET AL., 1983) talked about the necessity of marketing information, he stated that price is only one factor influencing the decision on information acquisition. According to him information providers will have a problem when the same information is disseminated in paper form as well as in electronic form and these products compete with each other. He emphasizes the need to monitor the situation to find a suitable (and necessary) mix in product supply. HUNTER, too, considers the pricing problems of online databanks by emphasizing co-operation between the libraries and system producers in the sensible development of pricing.

Pricing from the perspective of the information producer. Berg and Braunstein (both in KING ET AL., 1983) have studied the pricing problems of a publisher of a scientific journal. Berg drafted a model that named the factors that influence the demand and supply of the journal, including functions (e.g., between costs and sales, number of pages, and production costs). Braunstein considered particularly the simultaneous maximization of the publisher's profit and public benefit. Both studies include empirical tests of the models presented. BAUMOL ET AL. have drafted a guide for the definition of prices and costs for organizations disseminating information. It is based on several empirical studies on the costs and pricing of publishing activity. It states that it is impossible to include in the journal price the total costs of information production and that pricing according to the customer groups is needed; also the author page price and subscription prices must be optimized simultaneously.

Effectiveness and Efficiency of Information Services

Research on the effectiveness of an information service is typical evaluation research and has been the subject of several studies in the library and information service field. LANCASTER (1977) presents a number of such studies. Only some recent articles that explicitly deal with cost-effectiveness analysis are reviewed here. The investigation by WOLFE ET AL., however, is deferred until later because its problems are primarily connected to cost-benefit analysis.

The effectiveness (and efficiency) of an information service can be studied in several different ways. Approaches used often include collection of statistics about the use of all or some services provided and analysis of the statistics, as well as comparison between alternative services (for instance, own service vs. service bought from outside the company from the viewpoint of the information service of the organization) and market studies of the services (BLICK, 1977a).

Aslib has been performing these studies in British organizations. VICKERS suggests the following approach for improving the effectiveness of an organization: 1) the information needs in the organization are clarified with personnel interviews; 2) the information sources are then examined; 3) the goals for the information service are formulated with the management; 4) the services needed and changes in existing services are planned; and 5) the services are effectively organized. Here one should pay special attention to the results of the services. Too often stress is laid on the efficiency factors and so the focus has been on information acquisition and processing.

Another somewhat different approach to evaluating effectiveness within an organization has been inspired by "programmed budgeting" (D. MASON). The five phases of this "planning-programming-budgeting system" are: 1) clarification of the goals of information service; 2) description of activities;

3) analysis of activity modes; 4) cost calculation (to clarify the unit costs of each service); and 5) evaluation of cost-effectiveness.

These and similar approaches give general frames for the studies, but they seldom offer any special tool for measuring information. It is essential to the adoption of different approaches in information service that the special features of this activity are recognized. It can be catastrophic if outsiders begin to improve an information service on the basis of plain cost data. Thus, those who run information services must do the effectiveness analysis themselves or at least participate in these studies.

The development of the effectiveness of a library has recently been subject to an extensive study of the use of the library (BREMBER & LEGGATE). Considerable versatility in collecting basic data is demonstrated in this study. Data were collected with structured user interviews, questionnaires, feedback forms connected to the services, observations, follow-up of disseminated references. and loan files.

Also the effectiveness of the individual services of information units has been subject to several studies. BLICK (1977a; 1977b) has collected comparison data for decision making on organizing a current-awareness service in the drug industry. Three different service modes were examined: 1) current-awareness service as general follow-up: "Do we do it ourselves or do we buy it as a service", 2) arrangement of the current-awareness service on a certain topic; 3) "Do we use our own data base or outside services in information searches."

The different measures of each service (time, costs, availability, etc.) were collected, and weight coefficients were given to the alternatives. The best alternative was obtained by calculating the sums of the weighted characteristics.

Several studies have also been devoted to the effectiveness of information search systems. For instance, WILLIAMS collected empirical data about the effectiveness of an information search when the search is done by those who need the information, when an information scientist seeks it for a user, or when both search it together. The best result was obtained by searching together, but the searches made by an information scientist were the cheapest. The weights on the relations between benefit and costs remained open in this study.

Cost-Benefit Analysis of the Dissemination of Information

Much has been written about cost-benefit analysis in the library and information service area during the past decades. In reading the articles one gets the feeling that almost everything associated with the economics of information has sometimes been called cost-benefit analysis. There are also many interesting empirical studies. Some are discussed below.

This type of research has a long tradition, and there are several good review studies available. For instance, FLOWERDEW & WHITEHEAD and later MARTYN & FLOWERDEW have presented economic evaluations criticizing the knowledge of and skill in cost-benefit analysis in information science. GRIFFITHS reviews several studies on the value of information.

WILLS & OLDMAN analyze the studies more strongly from a library perspective. In addition, several collections of articles and papers repeat the contents of the publications mentioned: for instance BLAGDEN (1980a; 1980b) and HANNABUSS stress cost-benefit analysis from the point of view of the information user.

These studies are presented in five groups. The grouping does not necessarily do justice to the full extent of the research. The studies by King Research, Inc. are presented at the end because they summarize previous knowledge in the field.

Pseudo-cost-benefit analyses. Several studies claim to have used cost-benefit analysis but in truth did not. Often what has really been measured is some cost savings. Another issue that makes the grouping of cost-benefit studies difficult is that some reviewers (e.g., FLOWERDEW & WHITEHEAD) include in their analysis only those benefits and costs that can be measured in monetary terms. However, here we are including non-monetary benefits and costs in the measurements.

An example of pseudo-cost-benefit analyses is the type of study done to compare the costs of alternatives when an organization is planning a new information system. In Finland such (cost) analyses have been made, e.g., in administration when information systems have been designed. Such investigations, at their worst, are little more than after-the-event calculations which are intended to support decisions already taken.

Studies on resource allocation. WILLS & OLDMAN evaluated certain studies done in the late 1960s, in which library budgets were studied by operations-research methods. The basic idea was that past decisions on resource allocation showed the value of each library service (see, for example, HAWGOOD & MORLEY). The weakness of these studies is that they imagine that the resource allocations that were made really provided the best services. Wills and Oldman also studied this question of resource allocation, but their most important analyses were based on the viewpoint of the library users.

Demand analyses. An example of demand analyses comes from public libraries. Newhouse and Alexander (in WILLS & OLDMAN) asked library users how willing they were to lend or buy books when the prices increased. The aim was to determine the levels at which the borrowing of books would benefit the library users most. The problem of the study was that demand was also influenced by variables other than price change (e.g., location of the library, knowledge about services). Still, this kind of study offers significant practical information for library acquisitions. MASON & SASSONE and WOLFE ET AL. have also used demand analysis as part of their studies. Because of their broader scope, these studies are reviewed below.

"Direct" CBAs. The "direct" cost-benefit analyses (CBAs) of information are most often based on time savings or willingness to pay or a combination of both. An often cited "classic" study is the comprehensive one by WOLFE ET AL. on the effectiveness of scientific information services. This study, based on "classical" economic theories and questions, was proposed to both the suppliers and users of information services concerning: 1) time savings when secondary sources are used in seeking information, 2) additional time, if no

secondary sources are available, 3) need for extra salary in this case, and 4) dependence on secondary services.

FLOWERDEW & WHITEHEAD, who considered the study important and interesting, thought that the definition of the optimality of scientist's time use presented a problem. The interests of scientist and employer can conflict; for example, an extensive current-awareness service in one's research area is important for the career of the scientist, but it may hamper the productivity of the work from the point of view of the employer at least in the short term. This is just one point where cost-benefit analyses are powerless because of problems in defining the value of information. The analysis does give information on direct benefits and direct costs to individuals, but another, broader level—the information environment and its "social" ramifications- is essential in evaluating information services.

WILLS & OLDMAN, too, doubt the ability of scientists to read only what is of prime importance for ongoing research. They brought the investigation of WOLFE ET AL. back to an examination of the effectiveness of secondary services. FLOWERDEW & WHITEHEAD refer also to several other studies on time savings, where monetary values for time savings are calculated. These studies do not seem to provide enough versatile data about the benefit gained from information.

An example of time-saving studies in practical surroundings can be taken from KRAMER. According to him, a librarian has to be able to answer questions about the benefit of library services. In Kramer's investigation library users were asked: "how much money or time did the information search save you or your research group," and "how long would it have taken you to acquire the information without the aid of the library." The replies yielded concrete data about the importance of libraries to be presented to management.

Another much-used use indicator has been willingness to pay. FLOWERDEW & WHITEHEAD and WILLS & OLDMAN present several such studies. For instance, DAMMERS studied current-awareness service such that, in addition to follow-up of time use, users were asked what they were willing to pay for the service. The problem with such a survey is to know how realistic the replies of the users are when they do not pay for the services themselves, and even if they do have to pay, the question becomes hypothetical.

HAWGOOD & MORLEY asked the users of a current-awareness service both about their own willingness to pay and about how much they thought their university would be willing to pay. Then the benefit of the information both for the individual and the organization was taken into account but only as evaluated by the individual users. It was also interesting to observe that data about the willingness to pay given by the individuals and organizations were not interdependent. FLOWERDEW & WHITEHEAD estimate, however, that such investigations, when carefully made, can be applied to a definition of the value of information services.

ANDERSON & MEADE, at the National Oceanic and Atmospheric Administration (NOAA), have done cost-benefit analyses to evaluate the information services of NOAA's development programs. The cost data were gathered from development projects and formed the basis for the in-house pricing of information services. The benefit was calculated from data on willingness to pay, which were considered to give the lower limit for benefit. In connection with willingness to pay, data on the present charges were also collected by inquiries and telephone interviews. The conclusion was that even in this restricted form, with regard to measurement of benefit, the analyses were useful in comparing between alternative information services. Still, the study was considered to be too arduous for continuous use.

Besides the investigation of WOLFE ET AL., another study based on the classical ideas of economics is that of MASON & SASSONE. They analyzed the supply-and-demand situation for a service of the Information Analysis Center. The costs were calculated from invested resources and the benefit came from the users' willingness to pay, which was plotted as a demand curve (social demand is estimated to be somewhat greater). The information user could either do his own search (own supply, no handbook) or reduce his costs by using the service (own supply, handbook). The total benefit of the information service is described graphically by the area below the demand curve up to the maximum amount of service acquisition. The area below the supply curve describes the total costs. The net benefit is the difference between these two.

Further, the value of a service is obtained as a difference between the net benefit of self-service and the net benefit of information service. The quantitative benefit is the saving in time when an information service instead of self-service is used. When the cost of time is known, the value of the service can be measured, and this value can be used to put a price on the service. The model suggests information about the benefits of using an information service when the user has two alternatives and when he works economically (i.e., effectively). The model does not consider the costs connected to information use. An additional problem is the collection of the empirical data needed for the model.

Braunstein (in KING ET AL., 1983) correspondingly used an economic approach when he analyzed the benefit and costs of library use from the user's viewpoint. The analysis was very rough because Braunstein included only the costs the user incurred in going into the library and the costs the library paid to supply the desired reading. He also examined the delay that other borrowers suffered when the book was out and the benefit the borrower gained when he did not have to buy the book.

CBAs based on the need and use of information. In several of the above analyses the use of information or information services was seen as a starting point for research. In the studies presented here the information needs and use have a more central role. A Swedish medical company has made an interesting study of information needs and cost-benefit analysis, which is supposed to support management in practice. (Unfortunately, only a short presentation of the research is available (LJUNGBERG & TULLGREN)).

WILLS & CHRISTOPHER studied the acquisition of information in connection with market research. They used cost-benefit analysis to define the optimum method for seeking information. This theoretical article predicted significant empirical applications for the approach, but the model has not been used since, which must be due to problems in data collection. The frequently mentioned analyses of *WILLS & OLDMAN were library-use* oriented. They studied, for instance, how often the customers visited the library, their information-acquisition habits, the use of a library, and influences of use. The analyses were qualitative, and Wills and Oldman saw them as a preliminary study for quantitative studies. This comprehensive inquiry, primarily of student use of libraries, has, however, remained only a criticism of rough cost-benefit analysis; it did not produce any significant new results.

Perhaps the most interesting of the latest empirical studies are those made at King Research, Inc. These researchers have completed comprehensive investigations on the value of information: "Value of the Energy Data Base" (KING ET AL., 1982), "The Use and Value of Defense Technical Information Center Products and Services" (RODERER ET AL.), and "The Value of Libraries as an Intermediary Information Service" (KING ET AL., 1984). All the reports are interesting, but perhaps the most significant is the first, which has the best description of starting points and methods. It also includes a broad review of earlier research in the area. Here we present the approach, research methods, and some results of the studies.

In these studies the value of information is defined in terms of willingness to pay (measured by what has actually been paid for the information, both in terms of time spent and monies paid), the added cost of using alternative sources for the information, and the benefits derived from using the information. In connection with the energy database, the following information was obtained: the price (in time, salaries and money) paid for information searches, articles and reports; the price (in time and salaries) paid for reading the materials; and the consequences of reading in terms of time and other savings associated with the readers' work. In addition to this user perspective on the value of information, the benefit or value of the database and certain primary information was calculated from the viewpoint of information intermediaries, organizations and funders.

The report discusses the problems of measuring value. Perhaps the most significant observation is that the value of information must be kept separate from the value of the information product or service. The value of information (content) is related to its use; whereas the value of the information product (or service) is measured in terms of the contribution it makes to the amount of use. The ultimate value of a product is determined by amount of use, the benefits derived from that use, and the benefits that would be lost if the product (or service) were not available.

Data from several sources were used in the study: information on database use, on previous investigations, and from two new inquiries. The questions included writing activity, journal-reading habits, use of articles, mode of ordering copies, and the use of bibliographic and source databases. Questions on the use of the Department of Energy's own reports included how the reports were acquired (from distribution, by asking from own information service, through the National Technical Information Service (NTIS), etc.). Further, using telephone inquiries some of those who used reports were traced from the libraries and were asked: the report in question; the form of the report; how much time was spent in acquisition and reading; how the report was found; how was it acquired; for what use; the time and other savings. More general questions were also asked about information acquisition and use. The questions were tested by sampling, and altogether thousands of inquiry and interview forms were handled.

In the investigation, total savings were calculated for the 60,000 scientists at the Department of Energy, where the annual savings in research time from reading was $13 billion. The creation of information required $5.3 billion, and dissemination and use, $500 million. These figures show the importance of exploiting research done elsewhere, and the investigation produced, in addition, much interesting material, e.g., data about the relations between information acquisition and reading. The average price paid for reading an article was $33.50. Of this $9.40 was used in acquisition and handling, $4.50 in search, $2.80 in acquisition for use, and $16.80 in reading. Reading thus represents 50% of the costs (in reports about 70%). So, if reading can be even slightly better directed by a better search, resulting in more optimal selection of readings, the benefit gained can far exceed the relatively large costs incurred by the search itself.

A similar investigation was made for the Department of Defense (RODERER ET AL). Using the approaches and methods reported above, it clarified the use and value of the information services of the department's technical information service. For instance, they studied the use of technical reports through on-demand use of the report database, through systematic distribution of reports, and through the use of some external (primarily economic) databases.

The aim of the third investigation (KING ET AL., 1984) was to clarify the contribution that libraries and information analysis services have on the value of information again from the user's viewpoint. The study yielded data about library effectiveness (speed and quality of the service), efficiency (how much certain services were used), and cost-effectiveness (cost per use). It looked at two performance attributes of online searching- turnaround time of the search and relevance of the output. These were studied relative to the value of the search to the user (in terms of the user's time) through a conjoint measurement technique. Publication delays, updating of the database and delays in receiving references were also studied.

Most users were very satisfied with the library services. The costs for online services caused most of the dissatisfaction. Interesting data were obtained when the purposes of reading were explored. Scientists at the Department of Energy's research institutes listed, in order of importance, the following purposes: professional self-education, ensuring ongoing research, developing the methods of ongoing research, supporting reporting, research proposals, preparation of lectures, and planning, budgeting, and management. The investigation gave measures similar to those used in the previous studies. The result of the conjoint measurement was that relevance was found to be more important to the user than turnaround time.

Although the studies of King Research, Inc. obviously are the most interesting of the empirical investigations, they are hampered by a certain difficulty with measuring higher order effects. KING ET AL. (1982; 1984) defend their approach with references to the special nature of information and with the claim that their analyses give concrete evidence for decision making in practice, for determining how best to configure information service alternatives. CRONIN (1985) has presented a more detailed critique on the results of the study on the energy database.

The Value of Information in Light of Examples

Every use of information is unique; one can't measure the absolute value of a chunk of information. It is necessary to measure value through samples. In practice, whoever is responsible for an information service should always have examples on hand to describe its benefits. It may be profitable to show examples, for instance, to the manager of the organization when he wonders about the increasing costs of information activities.

Only a few studies on the value of information use examples. This may be explained by the fact that it is difficult to generalize from examples and that it is difficult to acquire reliable information about the benefits even in specific situations. In the following studies, examples have been analyzed, or they have at least been used to support other analysis. LJUNGBERG also stated that it is difficult to find investigations about the monetary value of information. He found three examples from the Canadian Institute of Scientific and Technical Information. In these examples, information that was acquired considerably reduced the heating costs and rationalized the work processes, introducing 50% savings. The advice given by the institute increased the profits of its clients by over $500,000 in one year. In Astra Ab (LJUNGBERG) the value of information was analyzed by using the same methods and principles as those used to evaluate new products (the article does not specify the methods).

The studies by King Research, Inc. (KING ET AL., 1982; 1984; RODERER ET AL.) also give examples of the value of information, which are described as follows (RODERER ET AL.): 1) considered from the perspective of scientists and engineers, value is measured in terms of what the users actually paid in their time and money to acquire and read the information; 2) another perspective is how the reading and use of information affect the users' work; 3) a third perspective involves how the work of scientists and engineers affects the objectives of their organizations. It is speculated that ultimately information has some effect on the operational effectiveness of the users' organizations, the balance of payments, quality of life, training and research in the future, and so on.

In practice several variables are difficult to describe even with examples. However, in the study by KING ET AL. (1982) monetary savings in reading and acquiring information was recorded: 75% of the 148 readers of technical reports in the field of energy saved time and/or money by reading a certain report. The average saving from reading the reports was $1,280; the variation was $0 to $1.5 million. The most common reasons for the savings were the avoidance of repeated investigations and of the trouble of seeking information.

In the investigation for the Department of Defense (RODERER ET AL.) scientists and engineers funded by the agency were surveyed. Information was obtained on specific readings of reports. These data provided estimates of the value of information in reports. They were also asked whether the report acquired was beneficial in terms of their objective and how much research time did reading it save. A 19-page enclosure to the research report lists the detailed replies, but the main points are:

- The information service alerted them to other scientists operating in the field and prompted them to begin international contacts.
- Owing to the character of the data some information could be acquired only through the department's own information service. It was hard to put a dollar value on such information.
- A comprehensive information search of the subject opened new viewpoints for the scientist and deepened an understanding of the problem.
- The information service gave the cooperative partners an idea of what the Department of Defense was interested in.
- Time was saved in writing and research because the tests needed and other procedures had already been done by other workers.

The scientists at the Department of Defense reported time and/or money savings for reports read, and the average savings (in the scientist's time as a result of having read a report) was $4,700. Although these reported consequences of readings in the investigations of King Research are rather difficult to use, it seems that only with them can the appraiser of an information service get a practical touch to his evaluations. The special benefit of such a broad set of examples is that they give quantified data of the evaluations of the service users. Still, caution is needed when using examples of monetary values for purposes of generalization, especially when the data vary widely.

The above studies are based on the information users' own evaluations of benefit. Hyami and Peterson (in FLOWERDEW & WHITEHEAD) give an example of a more objective analysis. They use two models used in agriculture to optimize the production and stocking of products. It was stated that the authorities who collect U.S. agricultural statistics can, with some cost additions, extend the samples of production and stocking statistics. The models showed that when the errors in the statistics could be decreased from 2.5% to 2.0% by enlarging the sample size, the cost-benefit ratio of the information obtained increased to 600:1.

Even though such an investigation is possible only in some special cases, it demonstrates that sometimes information can be defined by a very accurate and monetary value. CRONIN (1984) represents the other extreme. He speculated on the costs, benefit, and value of presenting his paper at a conference. Even though this speculation may easily be interpreted as a joke designed to ease the conference atmosphere, it shows the problems we face when we try to measure the value of information with money in more complex surroundings. The value of information was studied indirectly by MARTYN using questionnaires about late-discovered information in connection with research projects. A more extensive use of information services at the beginning of research could decrease the amount of overlapping research, but Martyn warned against making conclusions that were too far-reaching based on data collected by questionnaires from 266 scientists.

One viewpoint about the value of information is the negative value of missing information or ignorance. BRITTAIN has made an interesting investigation in the field of medicine that touches on this problem. This theoretical study speculates, for instance, on the possibility of defining ignorance in different fields. The definition shall be the starting point for the evaluation of the consequences of ignorance. Brittain explains that, for instance, on exotic diseases and their care there is in Great Britain enough agreement to define ignorance, but that, on the other hand, agreement on the care of cancer is too scanty for us to talk about ignorance accurately enough.

BARRET also gives many examples of the costs of not having information—e.g., in connection with savings in a tower-building program and the costs of a manufacturing failure. He emphasizes the importance of examples and case studies in demonstrating the value of information. Still, it is not just historical examples we need, but dynamic, situation-oriented, up-to-date examples that will help decision makers understand the value of information.

A familiar example of the consequences of a lack of information is the chemical accident, where the right measurements require a knowledge of information about the properties of the chemicals. Not even in these cases, or, for instance in poisonings, can we talk in terms of money only. There is the question, for instance, of the safety or even lives of people. MOISSE gives an example of monetary value: a five-year successful product development was wasted when a significant patent was not found when research began. The patent was missed because it had been indexed incorrectly. The company doing the development work lost $500,000, the cost of the research work. Another of Moisse's examples cites the negligence in following up new patent applications that caused a loss of $400,000. Similar examples have been collected by BLAGDEN (1980a).

INFORMATION SERVICE AS A VALUE-ADDED PROCESS

The value-added process approach is an interesting approach to the examination of the benefit and effectiveness of information services. The approach has been used in evaluation of office work (MITCHELL) and more widely in evaluation of the productivity of information work (STRASSMANN). TAYLOR (1982a; 1984b; 1986) has used the approach particularly in evaluating information services.

Mitchell defines the value-added process or system as any process supporting the results of the employee's work in the office. He points out that this approach is better, in rationalizing office work, than the old approach, which is based on avoidance of costs. Value-added thinking examines the costs and benefit of the operation simultaneously in order to direct resources to the most productive operations.

TAYLOR (1982a) stresses that the value-added process approach also provides an efficient opportunity for evaluating information systems. The systems are examined from a user viewpoint to counterbalance the much-used information production-oriented approaches.

Not much empirical research has been done that uses the above-described approach. The most significant is probably a study led by TAYLOR (1984b) into the evaluation of indexing and abstracting systems. The writing of abstracts and indexes was analyzed in 13 organizations with the aim of defining the activities that benefit the users in information searching. It was found that the services increased 20 of 23 defined values, which include availability (elimination of unnecessary information), scanning (easy use), coverage, cost savings, and physical availability. Though the study gave interesting data on indexing functions, some of the recorded values seemed somewhat academic.

The scientists themselves considered the analysis beneficial in the organization of information gathering, analysis, and interpretation of abstracts. For those who were indexing and writing abstracts the results are certainly beneficial because they describe the factors in the process that are important for the user. The investigation stated that indexers often do not know where or how the results of their work are used. This is, of course, a considerable problem in large indexing and abstracting organizations.

Scientists encountered problems when they tried to combine individual added values to the costs incurred by their production. In addition to those causes that are due to the general nature or starting points of the model, the problems were found to be caused, for instance, by large size differences between the processes investigated. Some of those responsible for the systems claimed also that it is impossible to define the individual costs because the interconnections between subprocesses are so complex.

CRONIN (1984) also refers to value-added services when he examines the pricing of information services; the value added can be a basis for pricing. Cronin refers to a study in which the lack of a database caused scientists' work to be worth an average £5,000. On the other hand, the input of one complete record in the database cost also about £5,000. According to the number of users and the size of the database, we can now calculate the value of the database.

Too few empirical studies have been done to make the significance of the approach for the evaluation of the benefit of information services clear. The strength of the value-added thinking seems, however, to be in that there is at least preliminary emphasis on information use, which is not the case with many production-oriented approaches.

Economics of Online Searching

We have already mentioned a few studies of information seeking. Then we presented the influences of information search fees, pricing of information searches, and the effectiveness of the information search systems. A separate presentation is justified by the extent of the research in this central interest area in information science during the past decade. Basic textbooks of information searching also often refer to economic questions and more widely to evaluation of the systems. For instance, HALL refers to the costs of information searching and to analyzing the differences between manual and automated searches. HENRY ET AL. again present some effectiveness studies of the role of an intermediary in online searching.

LANCASTER (1971; 1977) has possibly had the most effect on the research methods in this field. According to him, the effectiveness of an information search can be described by coverage, recall, precision, access time, and user time. As examples of benefits, Lancaster mentions money and time saving, increased productivity, elimination of double work, and improved operation. His empirical studies are connected to the MEDLARS database. Lancaster's thoughts have been exploited, for instance, by KABI, in his studies of the effectiveness and costs of Britain's Chemical Information Service's searches.

The cost-effectiveness of online and manual searches was compared by ELCHESEN, who studied 40 searches from seven abstract publications and corresponding SDC (System Development Corp.) databases. In this study, the searching process, information sources, and the behavior of intermediaries were also compared. The online searches proved to be the fastest, cheapest, and most effective. In some cases, the old-fashioned, manual search was more accurate and yielded the most recent references.

From cost comparisons and studies on transfer to online use, studies have proceeded to an examination of search benefits as such. MARKEE reports on time savings obtained from university library searches. The users were asked to roughly indicate the savings from search results. Markee admits that time savings is rough in benefit measurement, but it gives, however, additional information for evaluation besides mere cost data.

COLLETTE & PRICE gathered earlier cost-benefit information on information searches from the user viewpoint. The investigations gathered cost data, but benefit data rested on the users' rough (classified in advance) information on time and money saving. The cost-benefit ratio of information searches was 2.8 1. Despite the scientists' assurances, the results seem quite abstract. The abundant analyses of the economy and benefit of information searches do not seem very convincing. Too many investigations describe single variables only. No one, except perhaps Lancaster, has had the patience to present the results in sufficient detail so that generalizations could be made.

MOREHEAD ET AL. offer an interesting approach. Their studies on the information search start with a description of information value. From a statistical, multidimensional concept of information value, the scientists get a common research framework for evaluating information searching and the resulting information. The value of information is determined through definition of need (subject, framework, the writer's aim, and availability are the dimensions studied).

Macroeconomic Studies on Information and Productivity

In information science, macroeconomic questions have not been discussed much. MARTYN & FLOWERDEW present some studies that try to clarify the macroeconomic picture. The approach of Machlup to the economy of scientific publication of tens of man-years is considered problematic by MARTYN & FLOWERDEW because of the lack of basic statistical data. On the other hand, they consider that Porat extended the scope of information to include all the information activities of a society. His calculations have raised much discussion about the definitions used. Despite criticisms, however, these economists have often been referred to when "information society," information professions, and so forth have been discussed.

On the basis of Machlup's and Porat's statistics, COOPER presents estimates of the continuous growth of the information economy. He sees libraries as small partial factors in this growth but stresses that the knowledge developed in librarianship can be used in this widening field. Productivity studies of information activities are reviewed by CRONIN & GUDIM.

An interesting empirical example of macroeconomic studies in information science is provided in the broad U.S. investigation on mathematical modeling of the use of information systems (HAYES & BORKO; HAYES & ERICKSON). One partial study used the Cobb-Douglas econometric model. This model describes production as a function of labor and capital. The scientists divided the capital investments into capital, information (information investments), and other outside acquisitions of resources, and the model was used to see if there was an optimum for information investments.

Fifty industries in the United States were tested for the years 1967 and 1972 using the model. The model tested information purchases as a function of production. Porat's broad definition of information activities (information production, dissemination that includes training, insurance, advertising, information products, and some public services, like post) was used in defining information investments. It was found that information is used much less than would be optimal. This study has generated interest, but the use of econometric theories does not seem convincing, and some doubts can be cast on the interpretation of the results.

The above investigation is also hampered by the problems typical of the macroeconomy—viz., the reliability of the basic data, difficulties in separating information services from other acquisitions, and the connections of the acquisition of information services to labor (for example, recruiting of personnel is also information acquisition).

Over the past 20 years both the character and state of information services as an enterprise have also been examined. For instance, the economic potential of disseminating information electronically (particularly databases) has been widely discussed. The EUROPEAN INFORMATION PROVIDERS' ASSOCIATION (EURIPA) (1981; 1983) has sponsored two conferences on this topic: "The Electronic Information Marketplace" (1981) and "Making Money Out of Information" (1983). Statistics on activity in this field in Europe were presented and the potential for market research, the pricing of information, and particularly the responsibilities of the private and public sectors in disseminating information were covered.

The business side of database production has been studied by LANDAU (1985). He concludes that database production is a growing business and is already influencing the development of a country's economy. Landau and others involved in providing information seem to emphasize that information is a product. This can be explained by the requirements of selling, but then we easily focus on certain "product-like" groups of information (e.g., current facts). However, much information is sold at marginal prices and often the profits of the information providers are based on the free or almost free acquisition of information produced earlier, in many cases at the expense of taxpayers.

The Economics of Information and Automated Data Processing

In writing this review, we came across some articles that treat the economics of information in the field of automated data processing (ADP). Since the investigation presented here is based on publications in information science, the survey is not at all complete for this part. This marginal area is discussed here because of the similarities between information systems and ADP and because the information systems that form the research target of information science have become increasingly computerized (AGRAWAL & ZUNDE).

Some theoretical articles have appeared recently that treat the economics of information for ADP systems. YOVITS & FOULK model the use and value of information in decision making on the basis of extensive theoretical discussions. The simulation models they developed are based on problematic hypotheses. For example, they consider decision making to be comprised of distinct phases, where only directly exploitable information is defined as valuable.

KING & EPSTEIN analyzed the value of information connected to management information systems (MIS). They present statistical multidimensional definitions of the value of information. Models are created for alternative modes of operation in decision making, where the values are described with concepts such as profitability, relevance, understandability, significance, sufficiency, and practicality. CHRISTIE presents corresponding discussions on the multidimensionality of the value of information. A particular problem with these models is the gathering of reliable empirical information in practice. Their real significance remains a mere general description of the value of information.

Theoretical speculations on the costs and pricing of information have also been presented in connection with computer services. Cotton (in KING ET AL., 1983) examined in detail different pricing strategies (profit maximization, cost covering, value-based, client prioritizing, etc.) for computer services. Similar thoughts, emanating from the market situation, have also been presented by KLEIJNEN. These studies are almost analogous to the studies in information science.

A practical example of a cost-benefit analysis in ADP is given by DRAPER, who analyzed the costs and benefits of database management in the U.S. federal administration. The information control systems did not directly save money at first, so the benefit was primarily obtained from improved activity and productivity. Savings came later, for example, in programming and maintenance.

A brief idea of how to handle economic questions in ADP is given in the collection of papers on the economics of information processing by GOLDBERG & LORIN (1982a; 1982b). The introduction states that economic studies are new to this field and speculates about definition problems associated with the use, value, costs, and so forth, of information. This two-volume work consists of seven parts: 1) organization and data processing, 2) company economic models for the data-processing industry, 4) economics in evaluation of information systems, 5) economy of data-processing management, 6) systems and development of applications, and 7) measurement of software projects.

The first two topics are connected to the use and organization of ADP services in companies. The third discusses the character of service demand and the product properties of the services. The fourth is connected to the methods for defining costs and particularly benefits of ADP. Identification of planning, maintenance, and operation costs are examined in connection with management of information services. The two last parts are devoted to measuring application costs.

These studies correspond closely to similar ones in information science (cf., for example, KING ET AL., 1983). In ADP studies, however, the emphasis is more clearly on production and techniques, and cost calculations are dominant. In the articles collected by GOLDBERG & LORIN (1982a; 1982b), the emphasis is on the fact that the studies have practical significance for the management of companies.

FUTURE RESEARCH

Discussions about the direction of future studies have yielded interesting findings in Britain. As a conclusion to their analysis of research thus far, FLOWERDEW & WHITEHEAD presented several researchable topics. The ideas they presented have not been realized, although the British Library Research & Development Department actively tried to sponsor such research in the late 1970s. One of the trends FLOWERDEW & WHITEHEAD desired has been realized, specifically, during the past few years there have been more cost-benefit analyses and examinations of information value among cost and efficiency analyses. The reasons why extensive research of this type was not sponsored in Britain are related to the difficulty of the research task, the severe criticism of the studies done so far, and the fact that the application of the new information technology has taken the most significant part of the research interest during the past years. The report of MARTYN & FLOWERDEW evaluates the situation anew, and most of the problems that were present a decade ago still seem to await solution. For instance, the British statistics associated with information still have not been organized despite several efforts.

CRONIN & GUDIM insist on more research on the connections between information and productivity. They introduce a matrix of seven research approaches (multivariate analysis, econometric modeling, case studies, matched case studies, cost-benefit analyses, national economic comparisons, and tracer studies of the links between basic R&D and technological innovation), and of three research areas (information technology, information systems and services, and information). The third dimension is the public/private sector. The matrix is "filled" by some examples from the earlier studies, and it is hoped that the matrix could be a useful basis for future research on information and productivity.

For those who start economic investigations now it is possible and beneficial to avoid the defects and errors of previous research by conducting studies in the field. The difficulties associated with compiling information statistics are due to the character of information. While the statistics are under development and hundreds of mechanized information systems are developed and studied, more information scientists could find the most fruitful research targets both at the organizational and individual level in the case studies of information use. Future research will show generalizations can be made from the more theoretical approaches.

Case-studies are needed to deepen our understanding of the economics of information. There seems to be a need for a dual approach (REPO, 1986b): 1) information products, services, systems, and channels need to be studied by using basic economic thinking; studies on information production, information markets, and the accounting and budgeting of information activities—better known as the information resource management (IRM) approach—are needed; 2) the value of information can be studied only through its use, which means that the economics of information cannot be described without studying the users of information, the use of information, and the effects of that use.

The economic importance of information activities for individuals, organizations, and societies is increasing. Economists have not been able to offer much help despite their substantial efforts (see, e.g., REPO, 1986a). There is no doubt that information scientists have also tried to answer the need by completing numerous studies during the past few decades. There is a need to analyze these studies and to develop a sounder basis for empirical research; otherwise the efforts do not increase our common understanding of the phenomenon. Case studies, especially those done in organizational settings, are most needed when theories are under development.

CONCLUSIONS

This review has analyzed research into the economics of information from the information science viewpoint. Much research has been done during the past 20 years. Numerous theoretical discussions as well as empirical studies have been performed.

After having analyzed empirical studies, it is easy to agree with MARTYN that the studies on the economics of information should be "simple, easy to understand (both by professionals and organization management), relatively cheap, and easy to apply to local circumstances." It has to be possible to demonstrate the value of information in different contexts for individuals and groups and in organizations as well as society. The first steps should be taken by increasing the economic consciousness of librarians and information specialists.

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APPENDIX 2

THE VALUE OF INFORMATION: APPROACHES IN ECONOMICS, ACCOUNTING AND MANAGEMENT SCIENCE

THE VALUE OF INFORMATION: APPROACHES IN ECONOMICS, ACCOUNTING AND MANAGEMENT SCIENCE

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ABSTRACT

This paper reviews and analyzes research performed by economists, accounting researchers and management scientists in the field of economics of information. The main emphasis is on approaches taken to describe and measure the value of information. Economists define information as a phenomenon to reduce uncertainty and it is usually studied in terms of exchange values. Information markets and products, as well as information as a public good, are described. The approaches to the value of information favoured by economists are (1) statistical decision theory approach, (2) equilibrium theory approach, (3) multidimensional value approach, and (4) cognitive approach. These approaches are discussed and concluded with cost-benefit and value considerations of information. Some empirical studies are also presented. It is concluded that economic approaches based on 'information theory' have not achieved significant practical results in a general sense, but 'classical' economic approaches can and should be used in describing information products (and services) in terms of exchange values, as has been the case with other goods. But the cognitive approach, with analysis of the tasks performed, should be used simultaneously for describing the value-in-use of information.

1. Introduction

It is often said that information scientists should be more aware of research done by economists when studying the economic issues of information, information products and services. The failure to do so is cited as a major defect in economic studies carried out by information scientists. This article concentrates on the value of information as studied by economists, accounting researchers and management scientists. The aim is to demonstrate the range of ideas and tools economists offer for practical analyses of the value of information. For the author's own value considerations see [1]; these issues have also been analyzed in information science by the author [2].

K. E. Boulding [3] defined economics as the study of the econosphere. This was viewed as a subset of all human activity characterized by the phenomenon of exchange. The exchange of knowledge and information in the form of, for instance, books, has assigned them prices and markets. On the other hand, difficulties in measuring the quantity of knowledge and information in a book have caused problems for economists trying to define information goods in precise terms. For example, markets have been hard to determine, because the nature of the product (information in this case) forbids its presentation before the buying action. Or, imperfect markets often have made pricing complicated. A common suggestion nowadays is to price information according to marginal production and dissemination costs, and a profit. This is said to promote common wealth by ensuring the broadest use of information [4]. The question of optimal use of information remains open, however.

Many economists have attempted to define economics of information. For example, Lamberton [5] defines economics of information neutrally as the analysis of the processes by which information is produced, diffused, stored and used. Marschak [6] connected his definition to decision making by saying that economics of information is the economics of services of inquiring, communicating and deciding. This definition, widely used later, excludes areas like education and entertainment and places an emphasis on information supporting decision making or problem-solving. In this article the latter approach is followed. It can be said that we are dealing mainly with microeconomic questions and problems.

Information is needed for a variety of purposes contributing to decision making or problem-solving [7]:

- awareness or identification of the problem
- definition or collection of relevant information
- development of alternative hypotheses
- evaluation of alternatives
- selection of optimum solution or alternative
- implementation
- review of the results or performance as a consequence of the implemented decision.

Though real life situations are usually much fuzzier and more fragmented in nature, the above description provides a model for analyzing the role of information in the context of use. This approach, again, is often used in the analyses to be described. Although some of the studies examined fall outside the context provided by the foregoing model the approach is still governed by the need to relate work within the economics of information to problem-solving and support for decision making and taking.

1.1 Economics of information by Machlup

It is hardly possible to write this kind of paper without mentioning the work of Fritz Machlup on the economics of information [8, 9, 10]; Machlup's writings about basic concepts and ideas in the field give valuable background information for further analysis. However, the highly conceptual nature of his presentations are of limited application in practical situations.

"The distinctions - generation, dissemination, use - are appropriate for certain purposes, but not for any estimates of the flow of knowledge (or information) in society. It is not possible, even in the vaguest sense, to quantify the use made of any bit or piece of information." [9], p. 174)

"... stocks of knowledge are neither measurable nor comparable, whereas flows of knowledge can be quantified and appraised by the measuring rod of money applied either to what is being paid for the knowledge by those who buy it ... or to what is being give up for it to be made available." (ibid. p. 178)

"In economic theory, production implies that valuable input is allocated to the bringing forth of valuable output. The input is valued in terms of foregone opportunities - that is, by the magnitude of the sacrifice of alternative outputs that could be produced in lieu of the output actually obtained. The output is valued in terms of someone's willingness to pay for it." (ibid. p. 193)

In the first quotation Machlup distinguishes what can be studied and what cannot by stressing that only the transmission or flows of information can be investigated. Both the use of information and the 'stock of knowledge' are beyond calculating. We come back to the distinction of knowledge and information later, but briefly, knowledge is 'a stock' and information is 'a flow' (ibid. p. 175).

The second quotation calls attention to the need for economists to think of markets in terms of demand and supply. In this world of exchange the only phenomena of interest are those which can be measured and, hopefully, exchanged by using money. This approach is useful in measuring amounts of money spent in producing information products and services and in measuring what individuals spend in buying information in the market place.

In the last quotation Machlup explicates the input-output model which expresses the thought of lost opportunities when counting the value of outputs of some action. This idea is useful in showing the too often forgotten fact that costs and benefits are only sides of the same coin. This idea and that of indefinite markets for information, have led economists to write of information (or usually information systems) in terms of cost-benefit analysis which sometimes even allows non-money benefits and costs to be included (this is sometimes called cost- effectiveness analysis). On the other hand, for instance, in modern welfare economic a broad cost-benefit approach is often used. However, the final sentence in the quotation pleads for what economists prefer to do: value everything in money-terms.

Machlup devotes considerable attention to the ways in which individuals value information. In this respect his main message is that studies carried out to-date are unsatisfactory. Machlup does not accept the analogue of information goods with other goods, where "the value to an individual of any quantity of any tangible or intangible good is measured by what he would give in exchange for it."(ibid. p. 208) One reason for the impossibility of assigning value to information is that it cannot be done before one has the information. Still, Machlup's broad analysis of the use of information does not offer any positive tools for analyzing the value-in-use of information. For the conceptual analyses of the value of information see [1]. An economist Machlup pushes his analyses quite far from those of mainstream economists and seemingly comes near to the thoughts of information scientists [2]. His thoughts do not seem to have influenced much the economists in studying information.

1.2 About the literature of the value of information

For three decades, in addition to general discussions about basic concepts and ideas, there have been remarkable efforts to formulate theories and perform empirical studies in the field of economics of information. Theory building has been heavily influenced by information theory (definitions in the following section) and its modifications into forms more suitable for analyzing information and information systems.

In the journals of economics, accounting and management the subject of economics of information has been and still is a popular issue. Such journals as Journal of Economic Theory, Accounting Review, Quarterly Journal of Economics, Journal of Accounting Research, Econometrica, American Economic Review, Omega and Management Science have contained articles dedicated to treatments of problematical issues related to the value of information. Almost all the articles are theoretical, with only a few employing practical examples in describing the theories. A few articles break the ruling paradigm. These have used the cognitive approach.

Another measurement of the popularity of a research area may be found in symposia, or the collections of articles, of a subject area. For example, D.M. Lamberton [5] collected articles of the 60's under the title 'Economics of information and knowledge'. He warned readers of a too straightforward application of Shannon's information theory [11], but his advice has had little influence on later research on the economics of information. During the 70's several symposia were devoted to the subject. For example,

-Symposium on the economics of information, University of Lund, August,1973 [12] dealt mainly with market equilibrium, but the collection also included a paper dealing with the cognitive approach.

- Symposium: Economics of information in 1973 [13] dealt mainly with imperfect market information.

- Symposium on Economics of information [14] concentrated on uncertain market information under equilibrium theory.

- ASIS Meeting in 1975 on Information services: Economics, Management and Technology [15] was a meeting for economists to discuss economics of information services (most papers were written by economists).

- Information Economics and Accounting Research [16] was a workshop for accounting researchers to study theoretically the value of an accounting system.

- Economics of Information seminar for economists contained a heterogeneous collection of papers; one contributor used a cognitive approach [17].

In the above mentioned seminars the value of information was discussed in broad terms. Apart from seminars there are reviews of research related to the value of information. Hirshleifer [18] provides a valuable review of earlier research and, for instance, Lawrence [19] reviews studies done in the 70's.

1.3 The scope of the study

In this article we describe and analyze studies on the value of information as these have appeared in the fields of economics, accounting and management science. No attempt is made to include all important studies. Instead the most common approaches are described and attention devoted to the cognitive approach. It is our belief that this latter approach, even though not perhaps fully applicable in its present forms to value of information problems, offers interesting and useful additions to the basic economic approaches which deal with values only in terms of exchange. Because of the dominating role of approaches closely linked to information theory these approaches are presented fairly broadly.

On the basis of literature analysis an attempt is made to develop ideas for an approach (or approaches) which, when combined with the approaches taken in information science [2], will provide practical tools for assessing both the exchange value and the value-in-use of information [1]. The main interest is not so much in possible results of future theoretical research, but in the methods and techniques currently on offer. When practical analytical tools are not available fruitful approaches are looked for in order to find bases for further development.

2. Information, uncertainty and value

Information theory based upon the work of Shannon and Weaver [11] has fascinated economists, as well as many other scientists in different fields of science. Perhaps the main reason for this has been that in his theory Shannon gave a measurement to a piece of information. Even though Shannon himself clearly spoke only of relative frequencies among bits in the information transferring channel aiming at more technically efficient communication, his ideas were subsequently applied to a broad set of information measurement problems. They have also inspired research on the role of information in uncertain situations unrelated to Shannon's original thoughts.

Probability is vital to information theory. In thermodynamics there is a tendency for molecules to spread as randomly as possible in space, so absolute chaos is the most probable state for them. From these facts Shannon developed an idea for the measurement of information, named entropy, which is a measure of distance from chaos. To give entropy a mathematical definition Shannon stated that the entropy function H is a statistical parameter which depends solely on the probability distributions $p_1, p_2, \ldots, p_n$ involved. The entropy of a discrete probability distribution over a set is

$$H = -\sum_{n=1}^{n} p_i \log p_i \;.\; ([11],\ \text{p. } 54\ \&\ 105)$$

2.1 Some contradictory thoughts

As already mentioned Shannon concentrated in developing theories for efficient coding principles to solve some fundamental problems in communication engineering, for instance, efficiency measurement and noise in channels. These basic ideas have inspired Jeremy Campbell [20] to much broader thought. For example -

"Serious difficulties arise when scientists try to separate the idea of probability from the idea of information, because the first cannot be defined without the help of the second. In Shannon's theory, entropy is a probability distribution, assigning various probabilities to a set of possible messages, but entropy is also a measure of what the person receiving a message does not know about it before it arrives. Entropy is an index of his uncertainty as to what to expect." ([20], p. 62)

Campbell is fully conscious of the fact that Shannon himself said nothing about understanding a message , or, the interconnections of a set of messages. However, he believes that the approach can be broadened to these areas as well as to describing human life from DNA to the understanding of languages. He seems to think that uncertainty and redundancy can be used in understanding, for example, the problems of language in describing the world (connections between symbols and substance). And by referring to Shannon once again Campbell concludes that "there is no information without uncertainty, and no information worth having without redundancy, under which ever of its various manifestations redundancy may choose to appear." (ibid. p. 253)

At the end of his book Campbell refers to Aristotle's intention to find meaning for everything that is happening in the human world. Campbell states that it is 'the ever increasing intentional complexity', the generating of which takes energy from surrounding world, for which we all must struggle. These thoughts are fascinating in describing and explaining the connections of different parts of human life, but this holistic view does not seem very powerful when attempting to analyse practical issues. Still, these thoughts can be helpful in avoiding useless theorizing in isolation.

By constrast there are many who have serious doubts as to the possibility of broadening the scope of Shannon's information theory [5, 21, 19, 10]. While Machlup denies the whole concept of information theory (it should be called 'mathematical theory of communication or signal transmission', ibid. p. 658) Lawrence ([19], p. 61) only warns that "since entropy is a function of the probability of states but not the consequences of states, it cannot usually serve as a measure of the value of an information source." Belkin ([21], p. 49) follows the same lines by emphasizing that Shannon was not interested in the contents of the message, but rather in probabilities assigned by the potential recipient to the set of messages, the least probable message having the highest information value. This means that Shannon's approach is not useful in information science and thus it cannot be used in assessing the value-in-use of information.

So there are arguments for and against broadening the scope of the information theory approach. A fundamental question arises – does information theory offer practical means to measure the value of information? On this abstract level the answer must be no. However, to answer the question properly we have to look more closely at the definitions of economists theories for measuring the value of information based on information theory.

2.2 About the views of economics

In his review Hirschleifer [18], p. 31) defines (micro)economics of information as an outgrowth of the economic theory of uncertainty. Where uncertainty is the dispersion of individuals' subjective probability distributions over possible states of the world. Information consists of events tending to change these probability distributions. The same kind of ideas are also presented by Lawrence [19] though he also expressed doubts about the usefulness of Shannon's information theory as explained earlier. He makes important additions by saying that information must be new to the individual, and it must be understood:" It is only after the message has been received, the impact analyzed, the appropriate action taken and the true state of the world obtained that one can put a value on the message." (ibid., p. 17) According to this definition the value of information can only be determined retrospectively, while Carter [22] gives three points for determining of the value of management information:

- before information seeking
- before the use of information
- after the *consequences* of use are examined.

An accounting researcher, Joel Demski [23] also connects information with information theory. According to his views uncertainty must be present in one's formal thinking, and one's behavioral assumptions must accommodate the use of information. Information has value only in a world of uncertainty and even further Demski seems to think that information actually is a given probability distribution (as in Shannon's original theory).

The concept of relevance is also sometimes used as a synonym for the value of information among information theorists. An amount or degree of relevance of a piece of information is the effect that piece of information has on reducing uncertainty associated with a particular event or set of events [24].

From these examples it can be seen that information theory is used in defining information and its economic value in varying ways. It is often referred to in articles using more detailed approaches presented later in section 4. These definitions include also both process (Hirshleifer) and condition (Demski) interpretation of information as well as subjective (Hirshleifer & Lawrence) and objective (Carter) evaluation. At this level it is difficult to say much about the usefulness of such definitions. One can only wonder how practical it is to start collecting information on the probability distributions of hundreds of individuals or events.

2.3 Some mediating views

We have already mentioned Machlup's attack on information theory in an economic context. In addition to this, he has offered positive definitions of information. It is not possible to explore his ideas fully here, but some points especially valuable for our study are examined (for more detailed discussions see Machlup [8, 9, 10].

The distinction of knowledge and information plays a central part in Machlup's analysis.

"Information as the act of informing is designed to produce a state of knowing in someone's mind." ([9], p. 56)

"The contents of the information received may be the same as the contents of what is known as a result, but not necessarily so, because the merging of the new inflow with the pre-existing stock of knowledge may result in a re-ordering, restructuring, or revised understanding of the latter. It may not be possible to compare the changed and the added knowledge ... not in quantity but in kind." (ibid. p. 57)

"If information is something that reaches a mind ... it ought to be clear that the whole does not have a mind of its own and can neither receive nor process the information that has reached its members." ([10], p. 656)

The above definitions take Machlup near to the cognitive approach by emphasizing the fundamental role of an individual in the transformation of information into knowledge (for the presentation of the cognitive approach see e.g. [25e]). The idea of new information is included in the information theory approach, but the radical difference here is that the information does not necessarily have to bear any new knowledge if it only stimulates some changes in existing knowing. Further, the thoughts contain some features of the processes of information use (see value-added approach to information, [26] which cannot be explained by probability distributions.

To broaden the scope of the concept of information Machlup defines information as the act of telling or that what is being told. He also describes a set of restrictions to his all- inclusive definitions made by other scientists: information has to be previously unknown to the recipient; it has to ensure knowing; it affects what is previously known; it has to be raw data; it has to be useful for a subject or a task; it reduces uncertainty; ... ([10], p. 651). Many of the above restrictive definitions have been used to focus interest on valuable information for the specific problems at hand. Machlup rejects these restrictions because they fragment the concept of information making it harder for non-economists to understand (ibid., p. 660). In his approach Machlup tries, through broad definitions, to get a holistic view of information phenomena, but at this level he is unable to find the right tools to describe economics of information at the practical level. We still remember what he said about the impossibility of studying the value-in-use of information.

Our aim here is not to argue against holistic views as such. Those views are needed to reject rational, but isolated, thoughts which may be threat to the totality. More detailed and restricted definitions make it possible to describe and study practical situations. For concrete results we have thus to be able to derive useful models and techniques from those holistic definitions.

To us the idea of information reducing uncertainty generates general thoughts of an individual living in an always expanding world of uncertainty. Science, by producing new information, does not reduce the uncertainty of an individual trying to cope with all his concerns. As a matter of fact information has a major role in his ever increasing uncertainty, but usually the new information has reduced uncertainty to someone in some particular situation.

But how can an individual learn to live in the world of uncertainty? Is it possible to derive practical models from this uncertainty approach? One way of seeking solutions was described by Campbell [20]: he explained the world in terms of uncertainty and information reducing it. The book may give new insights to some readers and in some instances the ideas presented can reduce their subjective uncertainty as well. If this does not happen to an individual for a particular reason, for example, failing to understand Campbell's message, it can possibly do so to an other. But this is uncertain. It seems that we cannot get much further with these ideas of uncertainty due to their abstract nature. The thoughts have power in describing the world but they do not reach the level of understanding.

The discussion in this chapter is meant to describe the starting points of economists in their analyses of the value of information. It is perhaps worth mentioning that economists usually do not pay much attention to these matters, which may be one explanation of the broad use of an apparently quite unfruitful approach. The probable conclusion, tentatively advanced because of our acceptance of the uncertain nature of the world, that more concrete surroundings are needed to test these thoughts more precisely.

3. Information as an economic concept

In economic terms it is possible to analyze and describe information in a market context by supply and demand. Hirsleifer ([18], p. 32-33) supplies a useful model for describing the situation. There are supposed to be two actors in information markets: possessors of information and seekers (or users) of information. They are supposed to act rationally by supplying and demanding valuable information. Possessors have four possibilities of action:

1) Private use of information to produce something valuable to be sold in the markets.
2) Direct sale of information to the seekers.
3) Gratuitous dissemination of information in the hope that this would promote the buying of other goods the possessor has.
4) More particular deception and authentication information related to products for sale.

The information user or seeker also has four corresponding possibilities when acting economically in his information acquisition task:

1) Production of information by 'direct inquiry of Nature' (research)
2) Purchasing of information in the market.
3) Monitoring free information in the market.
4) Evaluation of supplied information.

The literature of economics of information consists of two main branches where individuals are assumed subject to either 'technological' or 'market' uncertainty according to Hirshleifer ([18], p. 33). 'Technological' uncertainty refers to uncertain resource endowments and/or productive opportunities. Market uncertainty deals with imperfect information about supply and demand offers. The studies are presented and analysed in the next section, but before that we characterize information as an economic concept in some detail.

3.1 Information as a public good

A product is a public good if it conveys benefits directly to individuals with no interdependence in consumption. These goods are jointly supplied to the community as a whole in the sense that benefits accrue collectively to society (a group of individuals). They are not appropriated by individuals. That is, they are not divisible into units that can be sold separately.

Consumption by one person does not reduce the amount available to others ([27], p. 55; [9], p. 218). Common examples of public goods are streets and roads, national security and public libraries. Though it is hard to define exactly where the borderline between public and private goods lies, it is obvious that many available information products and services have some characteristics of public goods. Despite many attempts to privatise information, for instance patenting and copyright, it remains that most of the stock of valuable information is produced and/or financed by governments. Often only the modes of dissemination invest information with private features.

This characteristic of information has given rise to much discussion among economists (e.g. [28]; [29]). Much support has been given to the thought that information is only partly a public good and its markets can be developed, and seemingly are developing, towards a more private mode. Arguments for avoiding this development include an idea of social or external benefits gained from the wide use of information which again supports the public good approach. Although it is impossible to come to any definite conclusion in the matter, the previous description is adequate for determining the characteristics of information as a product. There are also other special features, like shareability, compressibility and substitutability, which characterize information products and give rise to doubts upon the treatment of information products as other commodities (see [30] and [2] for broader discussions).

3.2 Information as a product

The distinction of information and information product is vital for this study though it is seldom made by economists. Following common thoughts of economists information products here are understood as the products, services, systems and channels which carry information. No stress is placed upon the difference between information products and services because only a few economists have paid attention to this distinction. However, the latter distinction is important due to the special attention that has to be paid to human information intermediaries.

Information itself is the content of these products (or messages in terms of information theory). This point contains the core problem of information assessing. The idea of product is closely connected to the concept of economic exchange, and information is exchanged through information products (in more or less developed 'markets'). Information in an information product gives value to the user, or the value arises from the process when new information joins the recipient's former knowledge for the task at hand [1].

Classical economists, and even many modern economists do not make the distinction between exchange and use, supposedly being faithful to the idea of exchange, one of the corner-stones of economics. They often use the phrase value of information, but they actually mean value of information products, most often information systems (see e.g. [31, 32]). Hilton ([32], p. 57) states explicitly that the value of an information system is equivalent to the information provided by the system. This is especially remarkable proof of the lack of distinction between system (product) and content, because Hilton studies the 'usefulness of information for the decision maker' and on the other hand gives exchange values to the pieces of information the information system provides.

On the other hand some of those economists who have studied information services have noted the difference.Sassone [33] distinguishes clearly the value of information and the information product when studying the value of an Information Analysis Centre using a classical supply and demand model. He points out that in the presence of competing information delivery systems the demand for the services offered do not mirror the demand for information. But still, the model gives valuable information for fixing prices and mix of services in the market place. Though the prices charged in the competitive market do not depend on the value of information but on the prices other suppliers set.

Interesting ideas about information products are presented also by Feinman [27]. He renames an information product as a knowledge-information-communication package to describe better its characteristics and develops fascinating ideas of information industry by using banking as an analogy. Money is defined as analogous to information, and it is suggested that information could be treated as money in societies. Feinman's idea of the central information bank controlling the value and the life span of information and even knowledge seems to be rather dangerous, because it denies the varying importance of information to individuals according to their ability, motivation and intention to use it. However, this thinking process is a valuable demonstration of the results of trying to describe information purely as a product.

Among information scientists most recent efforts to define information products are presented by Taylor [34, 35]. Many information scientists do not like the product idea of information (e.g. [36, 37]). Unlike economists who are defining information products as exchangeable good in the market, Taylor isolates a piece or a set of information in a value-added process, that is, a process in which information becomes more valuable as it is 'organized, synthesized and judged' [1, 34]. Taylor seems to aim at a general definition for information product, but he fails to convince a critic with his achievements in describing both the exchange value and value-in-use of information. In the end his ideas seem to support more the value-in-use approach. He wants future research to concentrate on the knowledge processes which information supports instead of information as an output of efficient systems. He also speaks of the methods of measuring the benefits of the use of information.

The gap between information product and information content seems to be unavoidable. Economists are doing valuable research in describing the product side. The last example of this kind can be taken from Thomas [38] who deals with selling of information products. According to him it is not very important for an information provider to study the needs of the user. In practice the decisions of whether to use an information service or not are usually made by representatives of users in the user- organizations. These people tend to think in terms of 'organizational needs for information' (which at their best are derived from organizational goals and the needs of those who try to fulfil these goals), and, of course, also in terms of competitive possibilities in the market if there are any. There are also alternatives to buying.

3.3 A model of use and information markets

In principle there are four issues to discuss when describing the markets and use of information. We have an individual or a group performing an information task. The demand for information can be met either from tradition, the existing body of human knowledge, or from Nature by new research. The conventional procedure is that the presentation of an information task first motivates an examination of tradition and then, if necessary, new research is performed. The results are then added to the tradition. This self-evident model does not help much in understanding the use and markets of information. However, it can serve as a starting point for a more complex model, the only purpose of which is to organize thoughts of exchange and use values of information, as well as other ideas presented so far. In Figure 1 some complexities of the basic model are displayed.

Information work is not performed in a vacuum into which needed information is bought, or received free of charge always in the same way. The level of order of that part of the tradition needed for a particular task means a lot to the efforts and expenses that have to be incurred for information acquisition. Levitan [39] describes the reorganization of tradition by a 'life cycle' scheme where tradition is first described as a set of information sources. Some of these sources are institutionalized as information resources and offered as services and products in the market. But much of the information needed in varying information tasks is not in the evident form of products and services. This means that often information seekers have to wander almost randomly among information sources or they may receive assistance from, for instance, secondary information services.

Information work is always performed by an individual (or individuals). Although computers can be used to perform some routines and, nowadays, even fairly complex tasks independently, they are still products of human intention. The settings of information work have an important role in describing the economics of information seeking because the closer to the seeker the needed information is found, the greater the added value. The tradition can be seen, from the point of view of an information worker (and task), as an ever widening set of circles around the head of an individual: - former knowledge and information, advice and information from colleagues, tradition institutionalized within the organization, information products and services in the market and finally the entire tradition.

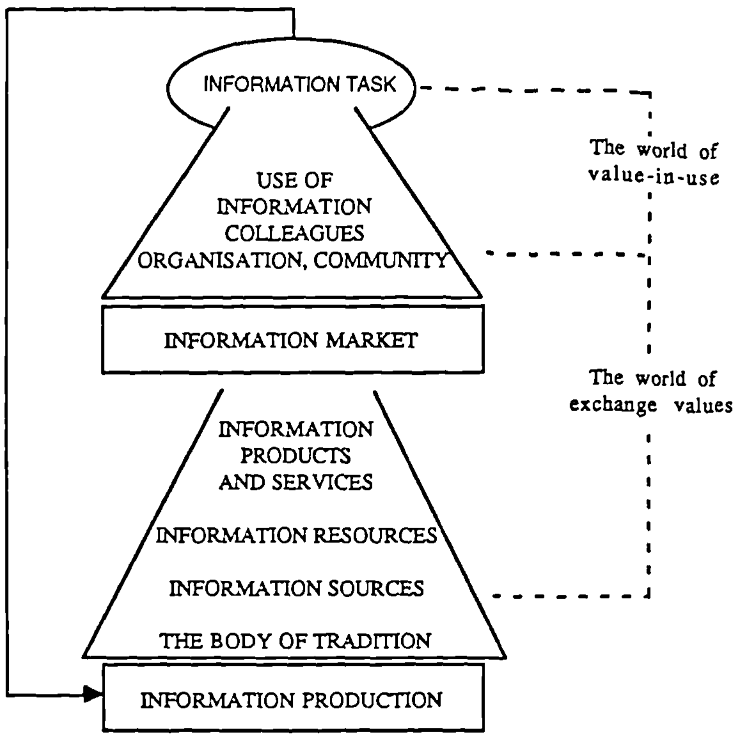

Figure 1. Information use and markets, an economic view (Note2).

The market for information is not well developed, and it is hard to see that it ever will be, in the same sense as markets for raw materials or money. The obvious reasons lie in the special characteristics of information. The public good features, and social benefits, derived from the use of information, make information markets quite fuzzy if the markets of information products and services, and the effects of the use of information, are not separate clearly.

Many modern economists discuss the nature of growing information markets. Melody [40], [41], for example, characterizes information markets by dividing them into two categories:

(1) maximum market value by maximum sale, and
(2) maximum market value by scarcity and monopoly.

In his analysis Melody emphasizes that there have always been information markets, but the broadening use of new information technology has increased the economic importance of this sector remarkably. Information technology has also made it simpler to introduce marketable information products. However, Melody also emphasizes the important role of governments in producing and controlling of 'public information'.

In certain areas of secondary information services there is quite a selection of products available for an information seeker, or his representative, selecting information channels for use in an organization. It seems obvious also that broadening demands for productivity, effectiveness and efficiency in information activities increase the need for the measurement of exchange values of information products available in the market.

The information production side also deserves a comment though it is of marginal interest for our information-use-oriented approach. The production of information is usually studied in terms of efficiency and productivity, especially within an organization where the whole cycle from production, organization to product and use are evaluated. The economics of societally new information can be looked at through, for example, patents and copyrights (see references e.g. in [18]).

Most of the value of information phenomenon can be explained by exchange values where information products are to be studied (see Figure 1). As already mentioned there are clear signs that economic pressures will strengthen interest in this area. The classical economic approach provides tools for these analyses. Value-in-use is only realized in the information-need and use situations of individuals while performing an information task, and from the effects the use of information has had. However, in these situations are to be found the ultimate reasons for the efforts put into information production, setting the tradition in order, and developing the information market. Otherwise, these efforts would only result in increasing budgets, not producing anything new and productive. These observations provide arguments for keeping both value-categories in mind while studying the value of information.

4. Economic studies on the value of information

In this section some of the approaches adopted by economists, accounting researchers and management and commented scientists while studying the value of information are reviewed. We start with approaches heavily influenced by information theory and then turn to cognitive approaches. The section is concluded with cost-benefit considerations of information. Although this rewiev includes theoretical literature, it has been written while searching for useful approaches to assess the value of information in practice.

4.1 The equilibrium approach to information

Equilibrium in the market has been the starting point for many formal economic theories. The application of information theory introduced the concept of uncertainty of market information to developed formalisms. This idea is used broadly in later theory building. Market information is studied also by collecting empirical data on markets (see e.g. [17]), but the main emphasis has been on theoretical studies.

The equilibrium position of a market can be described and calculated when one has unlimited computational capacity for studying uncertain situations. Radner ([42], p. 33) explains that

"An equilibrium is a set of prices, together with acts of consumers and producers, such that each consumer maximizes his preferences within his consumption possibility set, subject to his wealth constraint; each producer maximizes profits within his production possibility set; and total demand equals total supply, at every date and every state of nature."

The basic idea in the equilibrium approach under uncertainty is that if people in the social system do not have perfect information about opportunities available, they may allocate resources to search until they have enough information to make a consuming decision. Price information and quality information are then studied by trying to describe the role of imperfect information ([19] p. 62-63; [13], [14]). The formalisms presented describe very specific situations useful only in theory building. Thus, in Radner's [42] example there are two consumers, one producer and two commodities. If there is any practical use for these theories seemingly they have to be in describing the logic of valuing market information from the point of view of a consumer when the attitudes and actions of other consumers are uncertain.

While theory formulation still continues criticisms are presented also. Hirshleifer ([18], p. 36) pointed out that in the analysis of price information it is generally assumed that genuineness is manifest - even though deceptive ways of quoting price are not unfamiliar in reality. This simplification, together with the measurability of price , has permitted rigorous mathematical solutions of some outstanding questions. More generally, for instance, Lichtenstein [43] points out that the equilibrium approach is too specific to be useful outside theoretical market information studies.

For us, seeking useful approaches in valuing information in practice this approach was a disappointment. First, it has not provided tools for measuring the value of information (even market information) in practice. The approach also lacks power to describe real life situations. It is very unlikely that people behave according to equilibrium theory when seeking information in general because it is usually impossible for an individual to realize what constitutes perfect information relative to the information task at hand.

4.2. The statistical decision theory approach

Another approach having connections with information theory is the statistical decision theory approach. This theory applies probabilities and expectations especially to support decision making. The approach is widely experimented in valuing information.

In valuing information to be collected about the future one applies statistical information of similar events. Perhaps the most useful statistical theory here is the Bayesian theorem:

"Given that the event A can occur only if one of the mutually exclusive events $B_1, B_2, \ldots, B_n$ has occurred before it. The B's may precede A in time or may occur simultaniously.

$B_1, \ldots, B_n$.

$$P(B_i/A) = \frac{P(B_i) * P(A/B_i)}{\sum_{j=1}^{n} P(Bj) * P(A/Bj)} \text{ ."}$$

[44], p. 70.

The Bayesian theorem is useful in chaining the probabilities of several uncertain events. It gives a simple formula for calculating dependent probabilities from independent probability sets. To be useful in practice we need, in addition to probabilities, numeric values for the results of the decisions studied. Although the formula is simple, most practical situations are so complex that much calculation is needed. For a simple example of the use of Bayesian approach see Carter [45[. The decision tree is used also to keep the logic of the decision process clear. When combining this approach with decision simulation models powerful tools for evaluating decision alternatives are developed (see also Carter [44], p. 240- about some doubts regarding the expense of simulation).

In the literature of economics, accounting and management science the Bayesian approach is often presented and used to describe imaginary examples. Lawrence [19] uses the approach when describing the decision problem of a farmer when thinking what to sow next year. Kihlström [46] used the Bayesian approach in describing the demand for information about product quality. Optimal information demand is measured in relation to the costs and benefits of information seeking: the better, but more costly, information is a result of a more accurate statistical sample. We return to practical examples in section 5.

In accounting it was Feltham [31] who first mentioned the concept of value of information while providing a framework for determining the value of change in the accounting information system. He also used realized probabilities in the past to predict future events, but also presented doubts about the mathematical models being too complex to handle when trying to describe real accounting systems. Later Demski [16] developed Feltham's formalisms emphasizing the viewpoint of use of information, but again value is examined in connection with probabilities.

For the conclusion of this section we take Hilton's [32, 47, 48] formal presentation of the value of information. According to Hilton this is a theory based on economic and statistical decision theory. The value of information U(h) (equivalent to information system) is described by a formula [32], p.57

$$U(h) = \int_{y_h \in Y_h} \max_{x \in X} \int_{s \in S} u(w(x,s)) \; p(s/y_h) \; p(y_h) -$$

$$\max_{x \in X} \int_{s \in S} u(w(x,s)) \; p(s).$$

Where

h denotes information system h,

$y_h = Y_h$ denotes the set of signals for system h,

S denotes the set of uncertain states of nature,

X denotes the set of actions,

w denotes the outcome function mapping act-state pairs into outcomes, here $z = w(x,s)$,

u denotes the utility function mapping outcomes for function w,

$p(s)$ denotes the prior probability distribution over states,

$p(s/y_h)$ denotes the posterior distribution over states given signal y_h from information system h,

$p(y_h)$ denotes the prior distribution over signals from system h, and

$\int$ denotes a general summation operator.

Though the formula may look complicated for non-mathematician at the first glance it actually gives only a formal description of the value of an information system where the former sum of the utility function is subtracted from the maximum utility after the use of information. The probability coefficients determine the distribution of the values of information ('signals') for a particular set of action. The utility u is a function of results from possible action-state pairs. The use of the formula in practice would require there to be information available on all possible actions and their probabilities; pay-offs from each action; prior probabilities and actions without the ' influence of an information system; and the nature of information system itself. At this point it is easy to see that the usefulness of the statistical decision theory approach diminishes when the list of data needed is itemized. Lacava and Tull [49] noticed the problems in the approach both in data collection and application. They described the Bayesian analysis as a method of determining the value of information that is almost universally prescribed but seldom practised. Curiously, they emphasize that this expensive method is useful in analyzing the value of marketing studies.

This approach revealed, at a more practical level, the problem already noticed while studying the information theory approach at a general level: fascinating ideas are almost useless in practice. The decision theory approach is valuable in certain situations where information is available of past actions taken and their probabilities and effects and so on. The approach does not have any possibility of offering a general framework for assigning value to information.

But what of the situation where value can be measured using this approach? For instance, when there is a value for a market study of a new product. Is this value-in-use, or exchange value, or can we here forget this annoying distinction? The analysis gives us hypothetical money-value for a study, to decide whether to do it or not before actually performing it. So, the approach produces exchange values because the basis for the analysis is in the exchange values of the earlier market studies. The value-in- use of information is not explained by this approach. We do not get values of the earlier market studies. The value-in- use of information is not explained by this approach. We do not get answers to such questions as 'what is a role of a market study to a production scheme?' or 'what does the value x pounds mean for a manager?'. This example gives us hints for categorizing value-in-use more strongly as a 'motive', or stimulating value and exchange value as 'real' or money-value, whenever the last mentioned is possible to be measured.

4.3 About multidimensional value of information

In the literature of economics there are a number of analyses where, in addition to formalisms, descriptive characteristics of information are also presented. In his review article Hirshleifer [18] listed five economically significant information attributes:

1) Certainty
2) Diffusion affecting the scarcity value
3) Applicability (particular vs. general information)
4) Content (several subclasses, e.g. behavioral vs. environmental
5) Decision-relevance.

Although these attributes are supposed to be 'economic' the two last mentioned are actually tied to individuals using the information. So, with the introduction of these personal

Carter [44], ten years later, suggests six attributes, but characteristic of 'theory' discussion, they differ from those proposed by Hirshleifer. In Carter's list we have timeliness, prior knowledge, prior information, accuracy, quantity and power (information as a tool against, or for ruling, other individuals). Carter uses these attributes in relation to other analyses of management information using, for example, the Bayesian approach. These attributes do not fit into the formal approaches describing exchange values due to the totally different approach ('value-in-use approach') represented by these attributes. However, Carter appears unaware of this problem, perhaps because he relies so heavily on the overall power of his formal approaches (see [24] for a brief presentation of his approaches).

Elsewhere Epstein and King [50, 51, 73] have studied attributes of management information more thoroughly and introduce a multi-dimensional value concept. Tens of attributes are presented and analyzed based on the review of the literature. A study where the approach is used in practice is examined more closely here [51].

The objective of this study was to test hypotheses related to the value placed on management information by managers in different functional areas and at different hierarchical levels in a business organization. The ten attributes selected for study were - reporting cycle; sufficiency; understanding; freedom from bias; reporting-delay; reliability; decision-relevance; cost-efficiency; compatibility; quantitativness. Through the use of questionnaires managers gave relative satisfaction percentages to those attributes related to the management information system at the planning stage. Some additional analysis was also performed. The result was that the functional areas and hierarchical levels of respondents had no influence on answering patterns. The dimensions used were derived from an extensive set of conceivable attributes, and for the purpose they were used they obviously gave a broad enough description of the information received through the management information systems. But what about the value of information? Information was provided on the relative differences (or similarities in this study) of individuals valuing information. The value of information was described by attributes of value-in-use. For describing the value-in-use one should study the actual use contexts more thoroughly.

The multidimensional value approach is used quite often in describing the use situations of information or information systems [52, 53, 54]. It focusses attention upon the use of information, but it does not provide tools or 'theory' to determine attributes in each particular situation. They are 'found' or 'invented' from the vast variety of synonyms for the concept of value or usefulness. Exchange value is usually ignored, evidently because of empirical surroundings. The multidimensional value approach is only used in connection with information use within organizations, or within areas where information markets are not developed or are not of interest (the latter is the case in the studies of Morehead [54]). However, the approach does offer some ideas to describe the value-in-use of information in practice using the statistical analysis of empirical data. The use of this approach for determining the value of information would mean that more attention should be paid on the actual tasks for which the information is used. It is interesting also to notice that, although relying in part upon the non-economic approach, economists do not seem to have noticed this fact; or, at least, it is not explicated in the studies.

4.4 Criticisms and the cognitive approach

Criticisms of the earlier mentioned approaches have often taken their arguments from cognitive sciences. The cognitive approach has its roots in psychology, but it has recently gained interest among a variety of scientists trying to understand the dynamics of scientific thinking. Marc De Mey [25] defines 'cognitive science' as a study of knowledge; what knowledge is, how it can be represented; how it can be handled by transforming it from one form to another. This approach has traditionally emphasized the role of a subject in scientific activities. The approach may be broadened by definition - "any form of information processing, whether natural or artificial, requires a device that has in some way or another, an internal model or representation of the environment in which it operates." (ibid., p. xv). Although we are not interested in artificial intelligence in this study this quotation takes us outside an individual's head while dealing with the cognitive view of knowledge and information.

It is self-evident that the cognitive approach emphasizes the use of information in the communication process, and on the other hand pays no attention to the 'product' side. The close relation between this approach and the approach often taken in information science can be observed for instance in Belkin's [21] quotation when he is defining a needed concept of information for information science:

"... a concept of information which is based on a relevant communication system, which takes cognizance of the effect of information on its recipient without identifying information with that effect, and which relates some externally observable phenomenon to internal events in a predictable and generalized way." (ibid., p. 79)

Although one may express doubts whether one such concept can be 'found' the general idea of the viewpoint is broadly approved by information scientists. One can also find some studies in the literature of economics which have taken a cognitive approach. For instance, while studying the relation of tradition and innovation McCain [55] proves that tradition has an important role in individual innovations, but the relation is difficult, or even impossible, to describe in economic terms. He tries macroeconomic valuations of tradition through time-series.

These thoughts direct one to ideas of the rich information surroundings conducive to innovative information work. When criticizing the exchange-oriented economic approach Urquhart [36] speaks of geese, some of which sometimes lay golden eggs, if they have adequate accommodation and food. But should we be satisfied just with promoting these rich information surroundings and give up trying to uncover the value of information? At this point we note the need to take Urquhart's comment into account in future, and as an additional argument for the need for a dual approach when valuing information.

Also, Roberts [56] presents criticism of classical economic thought by noting that some modern economists believe that:

"... economic laws are only generalizations about tendencies ... economics may be unlike many of the physical sciences which have an appeal for the man who likes an answer to every question, but it is in the same boat as most other subjects that deal with human behaviour and are unable to reduce it to the kind of inexorable scientific laws that govern the behaviour of atoms." (ibid., p. 255)

So, the earlier described economic approaches have been criticised from the cognitive viewpoint. The core of the criticism is the insufficient analysis of the human factor in the 'economic' approaches. In addition to this type of general discussion, there are studies which apply a cognitive approach and deal also with those economic approaches we have presented earlier in this section.

In a Nordic symposium, held more than a decade ago, there was a paper among studies of market information which took a critical attitude towards uncertainty-reduction oriented approaches. Nyström [57] was not satisfied with the statistical decision theory approach when describing complex decision situations. He believed that the cognitive model was justified in changing situations to supplement ordinary statistical approaches in decision making. However, the latter approach can be successful in relatively stable and predictable circumstances and in analyzing continuous behaviour. In his cognitive model of decision-making Nyström uses uncertainty in a slightly different way to that encountered normally. Subjective uncertainty is due to the lack of understanding of the cognitive structure of a problem at hand, not so much to lack of information. A cognitive structure is defined as a set of partially ordered cognitive elements -notions and ideas- which are viewed by the decision- maker as relevant for determining the outcome of a contemplated decision.

Nyström's model emphasizes the role of a decision maker's uncertainty gap between the 'objective' cognitive structure and the subjective beliefs of the structure of a problem at hand, and how the new information influences these structures. Without going into a detailed description of the model, which presents only some general ideas related to the assessment of the value of information, one is able to see the difference compared to the statistical decision theory approach. Now we have to deal with subject- and situation-orientation instead of 'only' struggling with problems of data-collection about probabilities. Still, Nyström does not offer any positive suggestions of how the valuing of information could take place in his model. He leaves us with his superficial conclusion that the role of individuals should be taken into account more fully in organizational decision-making development.

In the literature of accounting research we find another interesting theoretical approach by Theodore Mock [58, .59, 60, 61]. The starting point of Mock's work arises from dissatisfaction with research performed on the value of accounting information:

"... the greatest majority of studies have been based upon a formal or modelling approach. These investigations tend to exhibit little external validity and thus provide few measures that may be extrapolated. Recently more research has relied upon experimental and field study methodologies. Such studies progressively seem to exhibit greater external validity but less ability to apply the information economics approach." [59]

Mock had published, a couple of years earlier, an article where he took a much broader view of the value of information than in the previously presented economic approaches. Then he dealt with circumstances in which information is valued according to its contribution to learning, appreciation and control. According to him, an accounting system can be seen giving answers to three types of questions:

1) Score Card Questions
2) Attention-Direction Questions
3) Problem-Solving Questions. ([58], p. 768)

The first category, which deals with facts, can be 'solved' by using the Bayesian approach. The second needs knowledge of the right questions to be asked, and the third can only be studied as learning processes. This means that an accounting information system has to be flexible and evolutionary from the point of view of an individual user. Mock [60] believed that accounting information systems ought to focus upon the learning value of accounting feedback. A gaming/ simulation methodology was used in recognizing the effects of learning in connection with budget information structures. Later Mock and Vasarhelyi [61] tried to develop connections between economic and cognitive approaches with inconclusive results. They ended with doubts about the usefulness of these more complex theoretical models which employed a joint approach.

Hilton [62] draws some conclusions regarding the nature of these two approaches which he viewed as being mutually supportive. The economic approach has concentrated on modelling the selection and use of information systems by rational information appraiser and decision makers. Cognitive, or descriptive studies, as he calls them, have used various deductive and empirical methods in attempts to develop a positive theory of information production and use. Unfortunately these efforts have so far remained at the level of theoretical discussion with little practical impact or significance.

Recent research in the area has moved away from explicit value considerations towards determinants of optimum use situations of accounting information systems. Pratt [63] comes quite near to the thoughts of Nyström when studying the relationships between the user's cognitive structure, accounting information system, and the user's predictions. It has been proved that individuals, based on their genetic endowments and past experiences, may have complex cognition in some domains but simple cognition in others. Pratt proved in his tests the fairly self-evident fact that accounting information systems influence the cognitive structures of their users, but again there was not much else to say except,

"the future research in this area should continue to focus on the determinants of domain-oriented post-cognitive structure as well as those aspects of post-cognitive structure which relate to human information-processing variables and effective decision making. Such studies should be conducted across many decision settings, examining various elements of post-cognitive structure, information processing, and decision performance as well as various characteristics of information systems. Further research must also be conducted at a conceptual level attempting to integrate the relationships among cognition, information systems, human information processing and decision performance." (ibid., p.204)

The above quotation comes near the ideas of how value-in-use of information could be studied [1], but cautious attention must be paid to the fact that Pratt does not distinguish between information and information system (or onformation and knowledge).

It is established that cognitive studies in economics and accounting contain ideas similar to those in information science. However, there are also doubts as to the usefulness of the cognitive approach. Hubert [64] expresses strong criticism when using the approach in MIS and DSS design. After a review of the literature he concludes that

1) The current available literature on cognitive styles is an unsatisfactory basis for deriving operational guidelines for MIS and DSS design, and

2) Further cognitive style research is unlikely to produce these guidelines.

The well argued key-point in Hubert's analysis is that cognitive research studies individuals and their personal characteristics only and that they should rather pay attention to the characteristics of the task the individuals are involved in. We would like to add here that, while the task gives the 'objective' basis for the study, the role of an individual is vital for real situations because only they, by their intentions and acts, actually use the information. Anyhow, Hubert's observation is very important for avoiding subjectivism in cognitive analyses.

The cognitive approach offers valuable criticisms of information theory approaches, but it also suffers from the lack of practical means to describe the value of information. There is obvious need to study the use of information not only through individuals but also through their work. On the other hand the cognitive approach alone, even with the above characteristics, does not allow of a full assessment of the value of information. It does not comprehend the values of information products in the market.

4.5 From cost-benefit analysis to value considerations

To conclude this section cost-benefit analyses of information and practical value considerations are briefly discussed. The reason for this is that cost-benefit analysis is the most used tool for economists when studying information, or merely information systems in practice.

Costs and benefits are always of interest when making rational decisions. They are also often linked to each other:the more benefits we want, the greater the cost we have to bear. In economics cost-benefit analysis (CBA) becomes important whenever market prices for certain goods or services either do not exist, or are regarded as irrelevant or even misleading as the only guides for decisions aiming at an efficient allocation of resources. In the case of information, CBA is used for planning and evaluating varying possibilities in information acquisition, processing, transmitting and use (for broader background see e.g. [9], p. 217-224).

In information science CBA has been be used in a broad sense to describe almost any microeconomic study of information [2]. Economists usually restrict their study to costs and benefits measurable in terms of money [65]. For our purposes it is necessary to broaden the scope to all costs and benefits which can be identified. Although in practical decision situations it is often not necessary to measure all the influencing factors, usually only those which are different among possibilities considered need to be examined, it seems misleading to measure only money costs and benefits. Still,the common economic use of CBA concentrates, faithful to basic economic principles, on exchange values and so ignores the value-in-use of information.

Selected examples serve to relate CBA with approaches described earlier. Williamson [66] uses CBA with the Bayesian approach. He emphasizes that information is a commodity the acquisition of which should be subject to CBA:

"Some information is worthless in a particular decision making context because its inclusion or exclusion in the information set has no effect on the decision. Other information is valuable (it would change the decision) but its acquisition cost is higher than its expected value. Only that information which has an expected value greater than its acquisition cost should be acquired." (ibid., p. 414)

Here CBA is used only to formalize the logic of the use of Bayesian data and, as noted previously, these data are in practice seldom available.

Carter [24] uses CBA in valuing management information. He has the management's information needs, which are determined by interviewing the managers, as a starting point for the analysis. He then turns to assigning money-values to the needed data in some special situations by using, for instance, the Bayesian and 'cost of not having information' approach. After the cost- calculations one is ready for the comparison. Again CBA is used as a overall frame. Although the use of information is taken as a start-up for the analysis valuation is done purely in terms of exchange values. This is so, in spite of extensive, detached, discussions of the characteristics of value-in-use already referred to.

Keim and Janaro [67] take a somewhat more practical approach when studying the CBA of MIS. They come to the conclusion that the complexity of the various designs of information systems preclude the application of valuation approaches presented. Still, it is possible, and even desirable, to use CBA as part of the information system design process. CBA is especially useful as a framework in analysing varying possibilities to develop an information system, but it can be used in various parts of the process for emphasizing the economical issues of the design sub-processes.

It seems obvious that there is not a single theory available which fully explains to the value of information. It does not even seem probable that one can develop such a theory easily. This is because of the empirical fact that individuals give different values for the same information depending on context. On an abstract level one can see the dual approach needed (economic and cognitive, or exchange and use values; [1]), but in practice these approaches or paradigms only provide frameworks for studies. The actual individuals and, even more importantly, the tasks individuals are performing, constitute the core meaning for the value-in-use concept. There may be very little to be generalized as detailed theory from these concrete settings.

5. About empirical studies on the value of information

In this section examples are given of empirical studies of information value to give an idea of the level of achievement.We concentrate here on studies presented in the literature of economics, accounting and management science only.

Dissertation Abstracts contained 12 theses explicitly mentioning the value of information in the title and including some empirical analysis, or, at least, some trial theory applications. The following areas were studied:

- information retrieval (multidimensional value study)
- "variable precision data to delineate wheat expansion areas Syria" (sample size study)
- the role of cash and futures markets in fat cattle production (willingness to pay for extra information on markets)
- pest management for potatoes (savings from the use of information)
- water sampling and alternative pollution abatement strategies (Bayesian approach used)
- quantification of decision information (e.g. Bayesian approach)
- competitive bidding (e.g. Bayesian approach)
- private value of information in exchange markets
- cost, volume and profit decision (Bayesian approach)
- sealed bidding (optimal use of information)

- market information and the consumer(product information study)
- monitoring and forecasting of air pollution (statistical modelling)

All the dissertations were completed after 1974 and most of them are fairly theoretical. The role of empirical analyses is to give some expression of the possible practical usefulness of ideas presented. Although it may be dangerous to say much based on dissertations only they do give tentative hints of the general interest distribution of such studies. It seems that the statistical decision theory approach is used most often and that sample size studies (studies for optimizing the sample size) give most exact, and perhaps most useful empirical measures also, for (exchange) values.

Scanning of the literature in general supports the impression gained from the dissertations. There are no good reviews of empirical studies available. It is possible to obtain some idea of the important research, for instance, from Hilton's [32] article where he classifies studies according to their characterization of the value of information. Lawrence [19] and Hirshleifer [18] give examples of empirical studies.

If we look further at examples of empirical studies through the approaches presented in the preceding section additional evidence is provided of the poor results such approaches have produced in practice. Sassone [33] exemplifies those studies using 'classical' economic approach. This author tested models describing the exchange value of the services of an Information Analysis Centre. He found it difficult to identify all the legitimate costs and benefits; to construct conceptual measurement schemes; and to gather appropriate data. Still, he demonstrated that the calculation of supply and demand produces valuable information for an information provider. For example, for price fixing and the amount of demand which makes a certain information product profitable. Sass [68] studied the role of intermediaries in economic terms; empirical studies were performed among estate agents. The study sought an answer to the question what are the transaction costs which lead to the use of brokers and determine the fees brokers can charge? Statistical data about selling actions was gathered through questionnaires, and a descriptive model of influential factors was developed. A simplified mathematical model was supposed to provide a probable estimate for the use of a broker in a certain situation. Problems arose when deciding which factors influenced buying-selling actions; complex models needed simplifications; and data collection proved expensive.

The statistical decision-theory approach was demonstrated recently in connection with, for example, uncertain quality information about products for the consumers [46]; selection of tenants by profit maximization [66]; valuing some subproblems of a banker (e.g. loan demand and investment demand) [19] and value of a market study and a decision problem dealing with timing of a change to a new machine in production surroundings [44]. There are serious problems when one really tries to use the approach in practical situations as seen in Carter's [44]) Concord Insulator Ltd. case. Real problems are simply too complicated to handle with this kind of approach. The sample size problems (e.g. [69, 70] where the costs of more detailed data for statistical analysis are compared to the benefits from more reliable results seem to be the only type of problems which so far have really been able to give useful results in practice. But these situations are not so much solved by the statistical approach as by using plain economic calculations of costs and profits with varying error rates.

There is even less to say about the other approaches. The studies of market equilibrium are entirely theoretical; studies of market information in practice have used classical approaches. The multidimensional value approach is merely used in describing factors influencing the value-in-use of information and their internal relations tested statistically, not the value as such [50, .54]. And the cognitive approach has only been tested in practice as a basis for criticizing other approaches. Apart from these studies there is much useful empirical research closely related to Shannon's basic ideas of information theory. In the field of information science these ideas are used, for instance, in text compression [71, 72].

This review of empirical research has revealed little of use for us. Even though there are interesting empirical studies not reviewed here it is possible to say, based on the literature review performed, and the examples presented, that the value of information approaches taken have resulted in conclusions of very limited practical value. The only approach which has some practical value is 'classical' which measures exchange values of information products. The others have value only in presenting justified doubts that the 'classical' approach is not able to fully describe the phenomenon of the value of information.

6. Summary and conclusions

Information and its value is a fairly new research area in economics, accounting and management science. After the area came into prominence some three decades ago it has been the subject of quite broad interest. Interest has been developed on the theoretical side, and most of the scientists have taken their basic ideas from information theory. Though the idea of information as a means of reducing uncertainty sounds reasonable, economic approaches using probabilities have not been successful in producing practical means for measuring the value of information. Only some case studies have been able to offer empirical evidence of the value of information. So far, extensive theoretical research does not seem productive in practical terms. The classical idea in economics, to discuss of values in terms of exchange, has meant also that the value of information is mostly studied in this respect. Though many studies explicitly speak of value of information they usually mean the value of an information system or product. The difference between exchange value and value-in-use is not noticed. This is surprising because there are studies which have clearly adopted a value-in-use approach. These latter studies seem to arise from the need for empirical results. For instance, some scientists studying the multidimensional value of information for decision makers adopt use values without realizing the implications of the change. The cognitive approach is used by scientists dissatisfied with the poor practical results of formal studies. They also skip from exchange values to value-in-use without distinction.

The review provided no new, useful, tool for measuring the value (exchangeor use value) of information in practice. But some general ideas of the economic approaches are worth repeating:

1) Information reduces uncertainty; usually uncertainty is described in terms of probabilities. Useful as a general framework, but not productive in practice because of the problems of getting data for the formulations developed. One should perhaps abandon mathematical formulae and collect statistical or descriptive data for empirical studies and then see if there is anything to generalize.

2) The idea of perfect and optimal information; used in connection with market information. Optimal gathering of information products becomes more important because of the deluge of information (products!).

3) The role of learning in the use of information. Especially important in connection with problem-solving information. This gives a point of reference for looking at types of information separately while valuing information.

6.1 Dual approach to practical values

When appraising this review and research in information science [2] it seems inevitable that we have to leave the information theory approach and its derivations and start seeking solutions elsewhere. One possibility is to start organizing research using the' dual approach to the value of information' [1]:

1) The exchange value of information products (service, channel, system) should be studied using 'classical' economics methods. Still, the value of an information service needs special attention when the role of a human intermediary is fully explored.

2) The value-in-use of information should be studied using the cognitive approach which takes the user, the use and the effects of the use of information into consideration.

The value concept in philosophy forms the basis for the analysis of the value of information, see Figure 2.

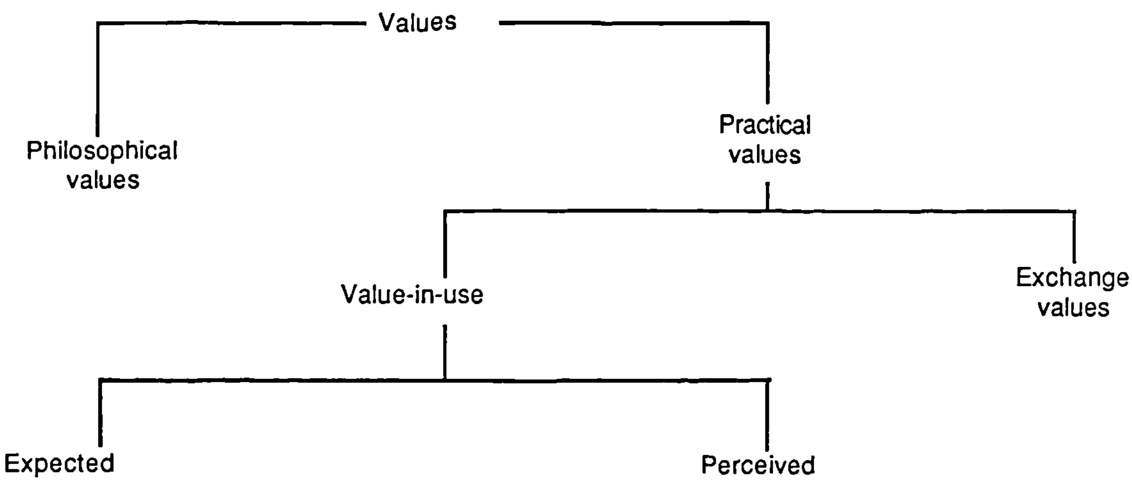

Figure 2. A taxonomy of practical values

It must be emphasized that the above classification is developed for practical purposes. It does not fully explore the important role of philosophical values (emotional, spiritual, social, etc.). This is so, because in practice those values can only be studied through individuals and their importance is reflected in the value-in-use statements of individual information users. The part of practical values which can be described in exchangeable terms is the area economists have been working on (information as a product), information scientists have mostly been interested in value-in-use described by individuals. It is useful to make a further distinction between expected and perceived values. Expected value-in-use is of importance because the use or non-use of information is almost always decided on the expectations of individuals. Perceived value-in-use describes the actual experiences of information use in particular use-situation. This value is the core of assessing the value of information. It can sometimes be made objective using such measures as time and money savings and then there is a possibility of comparing the exchange values of an information product and the value-in-use of its content. Still, more often this can be done only partly and the value-in-use can only be characterized by qualitative measures.

6.2 A framework for research

General model of the role of exchange values and value-in- use in information flow were presented in Figure 1. Value-in-use and exchange values have clearly separated areas in the flow but they both are needed to describe the value of information. Figure 1 also shows that emerging information market emphasizes two levels: that of information products and services which have economic character and that of information contents which have cognitive character. It is of course true that a lot of information does not follow the path presented, there is free and important information around which does not have exchange value, and the use of information introduces social values etc. When our model is used these issues must be remembered, and once more, our model is provided for practical purposes to give as holistic approach as possible to monitor the value of information in practical situations.

The research interests can be directed to two separate areas where the value of information has different meaning, see Figure 3.

The figure is a simplification from the viewpoints of individuals and organizations, and does not consider the role of societies in supporting information flow.

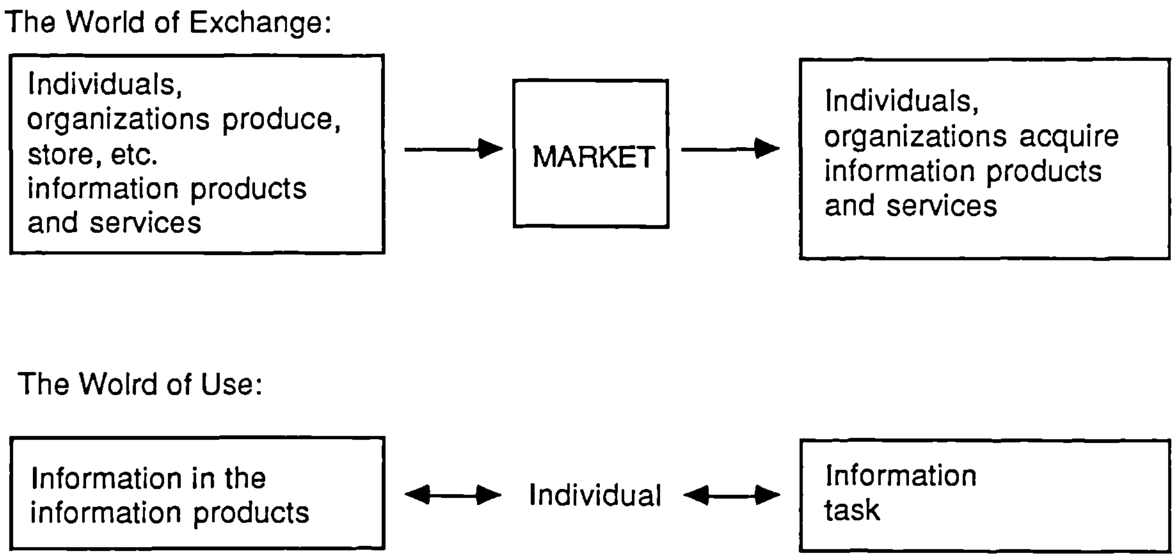

Figure 3. Two worlds of the value of information.

Much research has concentrated upon one of the above worlds. The information life-cycle runs across both worlds and it seems that it is most interesting to study the value of information by following information flow through these worlds which often takes place in an organizational setting where the acquired information product is 'opened' and possibly used in a particular information work with possible consequences, see Figure 4.

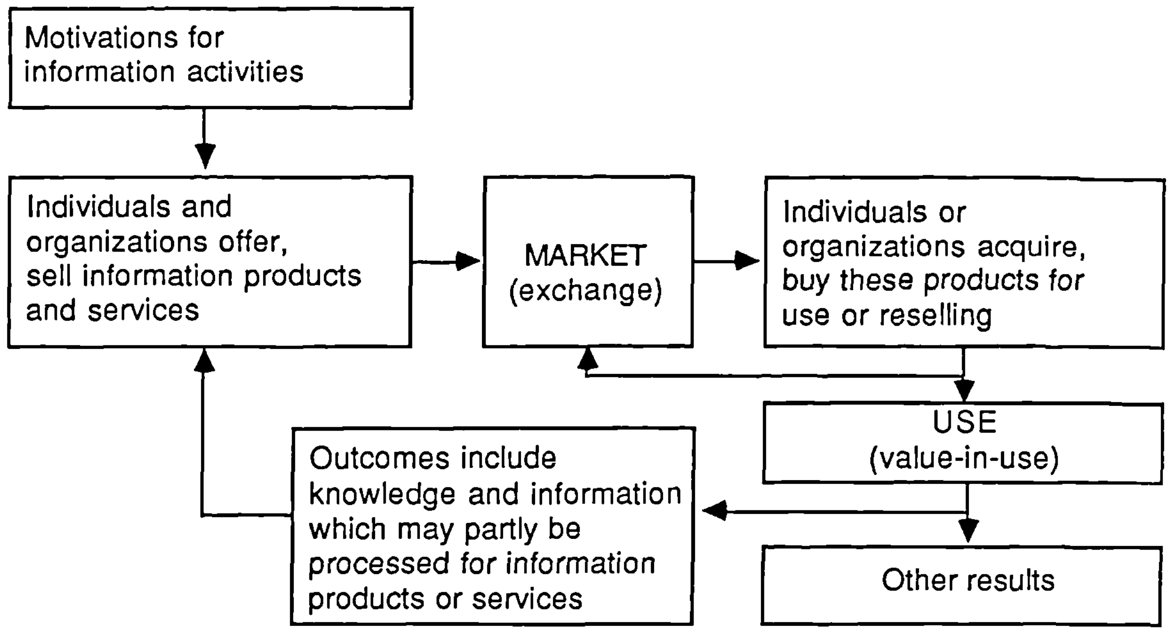

Figure 4. Information flow and the value of information

Information is acquired as information products and services. The value of information is fully explicated in its use. This means that the cognitive processes of individuals involved in information tasks, and such issues as time and learning for different types of information have to be studied. Descriptive statistical data have been collected using multidimensional approach which have given means to compare, for instance, the value of information systems but this approach does not offer any means to find the hierarchy for the dimensions Snavely [74] has introduced one in connection to accounting information systems) which must be 'found' from the empirical data.

It seems that the case-study approach is the only means at the moment available for studying the value of information deeply enough. Data have to be collected from information work and individuals performing the work using several collection techniques (interviews, questionnaires, diaries, content analysis etc.). For instance, successful or unsuccessful research processes could be studied both retrospectively and longitudionally. Tests on providing a lot of information to information tasks and following the consultation of information problems could also produce useful data on the value of information. The action research approach could be used in developing information use in organizations.

It is not possible to develop general model for studying the value of information. We have developed the framework which can be used to analyze the past research and guideline studies in future. More detailed methods and techniques for assessing the value of information must be developed for the particular research task at hand. It is hoped that the framework helps in setting up research or development work for more productive information work. For a minor test of the framework in connections to secondary information see [77].

It is apparent that information as a product will be under extensive research due to economic pressures on information activities. It is also as inevitable that it is not possible fully to explain the value of information in terms of exchange values. The key point in assessing value is in the use of information. Although concrete surroundings and intentions of the study will determine the main interests the awareness of this 'duality' helps in finding practical results in the research.

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Notes

Note 1. Marc Porat [75] is another economist performing general studies on the economics of information; mainly macroeconomic studies. For reviews of economic studies in information science see, for instance, [65, 76] and]2].

Note 2. Figure 1 is supposed to describe the roles of exchange values and value-in-use in information generation, not to model information economy.

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APPENDIX 3

PILOT STUDY OF THE VALUE OF SECONDARY INFORMATION: DISCUSSIONS FROM THE VIEWPOINTS OF INFORMATION PROVIDERS AND USERS

Pilot study of the value of secondary information: discussions from the viewpoints of information providers and users

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In this paper the value of secondary information services is discussed from the viewpoints of service-providers and a small group of scientists as users of current awareness services. A selection of earlier studies on the subject is briefly reviewed. The exchange value of secondary information services is demonstrated from the viewpoint of a service-provider. Users usually see the services in the light of their value-in-use though the services often have exchange values as well. In conclusions the problem of assessing the value of secondary information is discussed.

Introduction

The aim of this paper is to study some of the earlier developed ideas of the value of information[1,2,3]. The key issue here is to examine whether there is practical support for the dual approach (exchange value vs. value-in-use) to the problem of value of information. In spite of doubts about the quality of earlier studies we wanted to use somewhat similar methods for gaining further arguments for or against our theory-based critique[3].

The subject of the pilot-study is the value of current awareness information. The original idea was to study the exchange value and the value-in-use of the current awareness bulletins of the Sheffield University Biomedical Information Service (SUBIS) by interviewing a small set of subscribers and then sending a brief questionnaire to all of them. It was expected that this method would provide a picture of the exchange value of the service supported by value-in-use. SUBIS Bulletins were selected because they seemed to be clear information products in a fairly established, competitive market. Scientists in biomedicine were also known to have a constant need for following research done elsewhere. The third reason was that the providers of the service were willing to co-operate in defining the terms of the pilot-study. This willingness to co-operate, although limited, was unusual, as we discovered when contacting other, potentially competing, service-providers.

In the event it proved impossible to interview users of SUBIS Bulletins. It was feared that the interviews could harm business relations. Increased familiarity with the SUBIS products also strengthened the belief that questionnaires to the users could probably not offer detailed enough information for modelling how the users assessed the service. It was decided

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to focus attention on a small group of senior scientists in biomedicine and their use of current awareness information in general. For convenience, scientists were selected from the Annual List of Publications 1984-85 of the University of Sheffield, Faculty of Medicine and Dentistry.

Interviews with six scientists as users of current awareness information, and three senior members of the SUBIS staff elicited empirical data for modelling the value of current awareness information. These few interviews gave quite homogeneous results; no further data collection seemed to be necessary.

In section 2 some of the earlier studies on current awareness services are introduced. Section 3 is dedicated to exchange values and section 4 to value-in-use. In the last section the results of the pilot-study are placed within the broader context of our research. In the appendix the interview schedules are briefly described.

Studies on the value of current awareness services: a selective review

The value of current awareness services has been continuously under the investigation of information scientists and practitioners. In this section a few British studies are examined as background to the pilot study. When the studies are selected quite randomly the substantial interest of private industry in this academically problematic issue is evident: there is a clear practical need for information officers to prove the economic justification of their information services.

To start with academics. Hawgood and Morley[4] studied, among other things, the value of a current awareness service for a small group (29) of economists. Questions were asked about changes in behaviour of the academics after a new current awareness service was introduced; the number of relevant references found; further actions dealing with references; personal and departmental willingness to pay for the service; and time savings from the use of the service. The results of the study were unconvincing. Only one person was able to estimate time savings from the use of the service (one hour per week). There was no correlation between answers to willingness to pay of individuals and what they thought the organisation would be willing to pay. Could this be a supportive argument for the warnings of survey textbooks about the problematic hypothetical questions[5]?

In the private sector, studies have often been much more straightforward. Nightingale[6] asked the users of the in-house current awareness service how many journals the users estimated it would be necessary to see if the service studied was unavailable. The range of variation was from 0 to 42 and the median was 6. The median was used as the basis for time saving estimates and the result was that the 'value' of the service was over ten times the cost. This single measurement was seen as useful evidence of the value of the service[7] but the hypothetical nature of the question casts doubts on the findings. Later studies have used several measurements to describe value.

Dammers[8] attempted to analyse the exchange value (money-value) of SDI-profiles to their users and, further, to model the costs of current awareness related activities, like journal acquisition, loan activities and user time involved in current awareness activities. His basic data were collected by questionnaires to a set of users who gave estimates of annual time and money savings from the use of the SDI-service. Quite surprisingly all 22 respondents were able to give money-values to annual savings (range from £50 to £1,500) and the value of the service was rated about three times the cost.

There has been quite a lot of discussion about the validity of the studies on the economics of information services and products[1,3] and at one stage it directed research away from value analysis. Associated with current awareness services, for instance, Blick emphasised that 'one cannot put a value on information itself ... therefore ... one must do the next best thing which is to show that an information service is being developed on a clear-cut, positive, sensible basis and that its systems and services are cost-effective'[9].

Blick[9,10] studied the economics of an in-house current awareness service to its users and in comparison to bought-in services. The value of the current awareness service was studied using a relevance study (the amount of requests based on references) and a user survey (e.g. about the importance of the service in comparison to other means, its timeliness, and time savings in scanning). Descriptive data were produced to demonstrate the value of the service to its users: the exchange value was 4.6 times the cost and the value-in-use was described, for example, by the finding that 59 per cent of the vital items and 50 per cent of important items would have escaped customers' notice without the service. Further, this in-house service was compared with other possible solutions by giving weights to the following measurements: timeliness, relevance, cost, customer convenience and suitability for large numbers of customers.

The recent study of Whitehall[11] can be seen as a summary of common approaches to the value of current awareness services. The value of *Education News* of Trent Polytechnic to its 29 users was studied by six indicators in comparison to its costs:

1. the alternative cost of keeping up with the literature[6].
2. the alternative costs of a purchased bulletin; a hypothetical question to the user of the market value of the service.
3. what clients would pay for their copy of *Education News* from department funds[4].
4. clients' time spent in making use of the service[12].
5. items from the bulletin which were useful to the clients[9,10].
6. cash value of the contribution made by the bulletin to clients' work[12].

Users found it difficult to answer most of the questions but, a lot of descriptive data (sets of examples) were gathered. The study proved its usefulness because it convinced the chief executive at the Polytechnic that value for money was being obtained.

The above studies have been useful in the evaluation of current awareness services. They have concentrated on the exchange value of the services, but some fractions of the value-in-use issue have also been studied[10]. Wilson[13] goes further in this direction when studying the value of a current awareness service in local government. Data were gathered by questionnaires and interviews[14] about the general usefulness of the *Social Work Information Bulletin* and the usefulness of the example articles ordered through the Bulletin. A majority of the respondents found the Bulletin useful because it was convenient. It increased awareness, was good in sifting, offered new ideas, had good coverage, helped in reference collection etc. The usefulness of documents received (1-3 ordered documents) was in providing background information (51%), contributed to a specific task (16%), personal use (11%), passed to colleagues (9%), and others (13%) – about 16% were not useful. In the more detailed analysis of the responses about 25% of the users reported 'emotional or affecting use' of articles (e.g. reduces the feeling of isolation and sustain one's position), and a list of different types of 'cognitive use' was also produced.

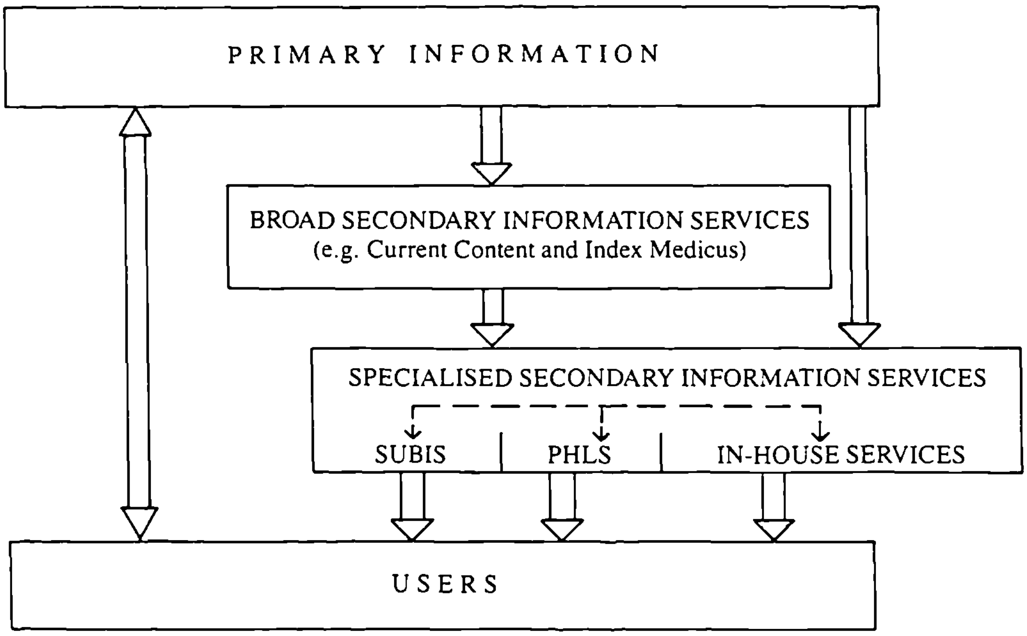
To summarise, when studying the value-in-use of current awareness information services it is necessary to examine the information transmitted[12]. On the other hand, the exchange value of these services could be studied using their market value. In between, there has been a lot of hypothetical questioning and opinion collecting about the services. Could we close or bridge the gap by approaching the problem from both sides at the same time? But perhaps we still need hypothetical questions in assistance.

The exchange value of secondary information: the case of SUBIS bulletins

Secondary information services have been developed to support information seeking when the number of primary information sources has grown beyond the capacity of individuals to encompass. Although direct scanning of journals is still an important means of following ongoing research there is an increasing need to support scanning with less time consuming secondary services.

In the field of biomedicine there are a number of secondary services available but, typically of information products, each is aimed at different user groups or is intended for different use. For instance, Current Content Life Science Bulletin is mainly for general and comprehensive awareness in the field (and in practice it is mainly used in libraries), whereas the ISI online databases offer dedicated service at a fairly high price. Index Medicus and representative Medline database are also for retrospective and SDI searches but they lag behind in timeliness (but also in price). In addition, there are several dedicated services produced almost totally from the above broad services. These services offer some advantages in costs and convenience for their users: SUBIS bulletins, roughly speaking, are examples of cheap specialised service as the Public Health Laboratory Service (PHLS) Bulletin is an example of general service to a specific group of scientist (microbiology). Finally, there are in-house services produced by the user-organisations which come fairly near to the services like SUBIS and PHLS. For the market situation see Figure 1.

FIGURE 1.



The history of SUBIS Bulletins

The first SUBIS Bulletin was produced in 1966. Since then the number has grown to 54 Express Bulletins and 85 Economy Bulletins at the beginning of 1986. From a handful of scientists within the University of Sheffield the number of subscribers has increased to about 2,000 all around the world. There are up to 300 users per bulletin and the set of bulletins keeps changing following the needs of the subscribers.

Economic thinking has been behind the service right from the beginning. It was realised that scientists at the University used much time in scanning Current Contents (CC) and many found it frustrating. It was calculated in 1966 that when CC cost about £100 the additional cost of scanning would be a further £100. This was based on the assumption that a scientist with an average salary of £7,000 would spend 0.5 hours a week scanning CC. It was estimated that about ten scientists used a copy of CC. By offering an individualised service at the price of £4 the benefit for the users would be over twice the cost and, in addition, the service would be more convenient to the users and the time savings in use could be substantial.

Now that the service has established its position in the market the idea has broadened from reading CC for subscribers. The price of an Express Bulletin is 15-20% of the price of CC, being about £45 in average. The development has been possible by increasing number of subscribers of this non-profit service.

Production of the bulletins

Papers for SUBIS Bulletins are selected from a variety of original articles and abstracting journals. About 80% are from *Current Contents Life Science*; about 5 per cent from other abstracting journals, and 15% from about a dozen journals (*Science, Nature, British Medical Journal, Lancet,* etc.) and varying free sources. References are then assigned by code to individual bulletins and details are typed and corrected using textprocessors. Each month all the references for a particular bulletin are extracted and edited. Edited references are formulated into camera ready copy, printed and copies are sent to subscribers. At the moment the total SUBIS-staff is 16, of whom two scientists select the references.

Feedback from the subscribers is collected continuously for developing the quality of the bulletins and monitoring the need for changes in the selection of the bulletins. Such issues as the need for abstracts and indexes, sufficient print-out, the need for machine readable versions and demands for improvements in the speed of publication have been evaluated. Recently, the need for new bulletins has been studied.

Administratively the service is a part of the University. There are no profit making demands but the service must be self-supporting which means that it broadens or diminishes as income from subscribers fluctuates. Subscribers per produced page of each bulletin is the measure used to monitor whether a bulletin is profitable or not. Although the service providers do not want to see themselves purely as followers of economic factors the case is quite clear. The fact that there are nearly 150 individual products gives some flexibility in developing products according to the expressed needs of the users but in the end the real 'vote' is given by subscribing.

Market situation

The subscribers of SUBIS Bulletins come from 30 – 40 countries around the world. About 60% of some 2,000 subscribers are Europeans (20% in Britain and 1% in Finland), about 35% from the United States and 5% from the rest of the world, mainly from Japan. Most of the users (90-95%) are individual scientists or small groups but there are also libraries and information services among the subscribers.

The basic market situation was described in Figure 1. It is important to follow the development of Current Contents Life Science service because its role is so vital in the production of SUBIS Bulletins. Similarly Index Medicus and Medline database are somewhat competing services but the main idea is to avoid identical service for the same clients. For the new services there seems to be a market in filling the gaps which existing services have left, sometimes the 'old' services notice new-comers by offering similar competing services. When the market share is established it seems to be quite stable. For large orders there are discounts to discourage in-house services but this is mainly prevented by specialised bulletins.

Concluding remarks

SUBIS is a successful service which is valuable to its subscribers by saving time in scanning journals and also in practice mainly, in scanning more general current awareness services. One could easily imagine that the users also see its value in exchange terms but in practice this is not the case because the users seem to think in terms of value-in-use. There is certainly a need for training scientists to think their current awareness practices in economic terms and this would obviously advance the use of secondary information services. And further, when there are so many non-profitable services around this would also mean better services. The questions remain. What would be the value of the time saved? Could scanning be needed 'therapy' or 'relaxing' for scientists in between other research tasks? In any event, the more priced services there are available, the more often there is a need for scientists to think of their information seeking patterns in terms of exchange values.

There were also efforts to study some other related secondary services but, quite surprisingly, the providers were not willing to take part in our pilot study. The reason for this could be that there may be competitive thoughts and attitudes among service providers because most services use the products of others.

About the value-in-use of secondary information in biomedicine

The value-in-use of secondary information is discussed here on the basis of interviews of a small group (6) of scientists in biomedicine at the University of Sheffield. (See appendix for the description of the interview schedule). Senior scientists from the publishing list of the Faculty of Medicine were selected because they were believed to have established comprehensive current awareness patterns. In order to attempt some conclusions even with this small sample scientists were selected from two departments (Medical Microbiology and Biochemistry). The research strategy proved to be rewarding because surprisingly identical behaviour was found. The only major obstacle was that scientists working in basic research were not able to isolate their current awareness activities dealing with individual research projects. A more general view had to be taken[15].

Use of current awareness services

The interviewed scientists spent 25 - 80% of their time in research activities. Their work was mainly basic research, though they also had connections with practical development work (e.g. developing new antibiotics). Their information-seeking profiles were very homogeneous. They had numerous personal contacts with other scientists working in their field (maintained by visits, conferences, exchange of publications, etc.). They scanned tens of journals (a couple of personal journals, a few in the department and main scanning in the library); they used several current awareness services (scanned occasionally CC in library. Two used PHLS as their main awareness service, relevant SUBIS Bulletins were used occasionally in the library, etc.); they ordered a retrospective search approximately twice a year (when starting new research or writing review articles).

Scanning journals was said to be the most important method of following ongoing research. Personal contacts were next in importance. There are three stereotypes in the attitudes towards current awareness information services: (1) 'scanners' and occasional users of secondary services (2) broad service supporters (3) dedicated service supporters. The respondents seemed to have slightly varying attitudes towards the stereotypes, for instance, although they all scanned the journals some found it frustrating and scanning secondary index journals was found even more frustrating. There also seem to be conflicting objectives. The ideal service should be brief and dedicated, but also broad enough to give a feeling of general awareness. This may be the reason for the emphasis on scanning – it gives a feeling of awareness through physical effort. People seem also to have firm opinions that the adopted pattern was the best which means that use of services is staunch.

Two of those interviewed had followed regularly one current awareness service (PHLS Library Bulletin) and they were able to give more detailed descriptions about the value-in-use of the service. They spent some 15 minutes with this weekly bulletin and found some 5 – 10% of the references important for their work and some 20% generally interesting. In the last issue there was about ten out of 100 important references but only the other scientist looked for the original four articles. The bulletin was seen mainly as a very good means for general awareness and for producing new research ideas. It was not so much for seeking particular information. These users preferred this service to the occasionally used SUBIS Bulletins of their interest because PHLS was 'cheap and broad enough'.

Market behaviour

The scientists did not seem to have a clear idea of the current awareness service market. The pattern of use had been developed over several years using trial-and-error methods with those services which happened to be available, and the use had continued if any value-in-use had been found. Although the prices of any services available here are reasonably low compared to other research facilities used, scientists are not ready to make much effort to have a particular service even though their experiences of the service were good (this was especially a case with two potential SUBIS Bulletins users). This follows the common understanding that the economics of research work is not developed in the area of information. It also seems that scientists rely (or have to rely in present circumstances) on what librarians make available for them, and try to use everything instead of thinking of the most cost-effective pattern of use for their individual purposes.

The scientists used one to five hours per week on current awareness activities (excluding reading). They found it hard to analyse the time savings and the use of several current awareness services offered. This kind of question seems to be useful when there is only one main service in use, as was the case with the two PHLS users. They estimated that the bulletin could save 15 minutes per week in library use and about the same time in browsing literature, although they said that there may be savings in, for instance, better organised reading and maintaining own files. They could not indicate any measures of these. When the use of the service takes less time than the estimated savings one could say that there is weak evidence that the value of the service is at least twice the cost – the price of the service can be excluded from calculations because it is only 40 pence per issue. On the other hand, only 5 – 25% of the time used on current awareness went to the use of this service.

It was even more difficult to obtain measures of the benefits from readings found by current awareness services. The only example mentioned would probably have been found by scanning as well. In one example an article reported similar research results elsewhere which saved about a month's work in testing the researcher's own results (this is an objective value-in-use measure). At the general level, it was easier to recall situations where some new ideas of research methods and research topics were found through current awareness services, but when something new is undertaken it is often impossible to imagine what would have been done otherwise.

The interviews supported the idea that the reason for problems in attaching exchange values to information is that users only think of value-in-use when they use information, or, even, an information service, not its exchange value. The users find it difficult to answer the questions dealing with the exchange values. Although one could easily declare that current awareness services like PHLS or SUBIS have only exchange value because the same information can also be found by other means the insufficient economic thinking of scientists makes pure exchange value studies difficult, if not impossible. Therefore, it is reasonable to describe the subjective value-in-use of these information services along with exchange value considerations, and to find examples of the objective value-in-use whenever it is possible. Still, there is a practical task for future development to educate the users of current awareness services (and the users of secondary services more generally) for the economic comparison of the services available for them to aim at more effective use of information.

Discussions

The pilot study gave support for a dual approach to the value of information problem but it also demonstrated the differences that exist between primary and secondary information considerations. The value of secondary information can be studied in terms of exchange by comparing the service to other, more or less identical, services. The problems of hypothetical questions can be reduced by asking users detailed questions about the way savings could be achieved. Answers to time saving questions seem to be much more reliable than answers to questions about willingness to pay. Because of the lack of economic awareness of subscribers of the services descriptive data about subjective value-in-use is often the best means to evaluate the services in practice and even in a more clear exchange value context the value-in-use descriptions are significant, if not at cognitive, then at 'affecting' level. It is possible to find measures of the objective value-in-use of secondary information services by time and money savings in some situations but, in practice, this is very seldom the case.

The pilot study produced data which formed the basis for a critique of some earlier studies. Subscribers of secondary information services use several services at the same time, and they are mainly interested in the information references offered. Therefore, they are seldom able to answer hypothetical questions of the value of the secondary information. More concrete questions are needed for reliable answers. 'How much money or time service x saves annually?' or, 'How much would you pay for service x ?' Such questions are unlikely to add usefully to existing knowledge. Although it is possible to advance the above mentioned recommendations for useful questions to ask, in comparison of the results one has to remember that value giving situations vary considerably. For example, such factors as the nature of the field (e.g. engineering or science), and the nature of the work (e.g. basic research or contract projects), greatly influence abilities of giving answers to the valuing questions.

There are those who advocate abandoning studies of individual users of secondary information in favour of concentrating upon markets. Thomas[16] writes about organisational buying as the decision-making process by which formal organisations establish the need for purchased products and services and identify, evaluate, and choose among alternative brands and suppliers. On the other hand, for instance, Wilson[13] emphasises the use of qualitative data about individuals in valuing information. In a study it is possible, and often necessary, to concentrate on a particular end of these extremes but it is still useful to realise that both ends exist and are of importance.

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APPENDIX

THE INTERVIEW SCHEDULE I:

The value of current awareness information for some scientists in biomedicine

1. INTRODUCTION
General information of the study, confidentiality, etc.

2. ABOUT THE RESEARCH ACTIVITIES AND THE USE OF CURRENT AWARENESS SERVICES
The research activities of the respondent and his general information·

seeking pattern was explored; special attention was paid for the use of current awareness services.

Comment: This section gave valuable data, no problems.

3. THE MAIN RESEARCH PROJECT AND THE MOST USED CURRENT AWARENESS SERVICE

The idea was to discover how much useful information was found for a particular research project by using the main current awareness service. We were looking for examples of important primary information found by the service, time and money savings from the use, qualitative benefits, willingness to pay, etc.

Comment: This section had to be discarded because respondents were all working with a set of projects and it was not possible to concentrate on a particular project. General information was obtained but the connection between research work and the information used was too weak for the resulting data to be useful.

4. MARKET SITUATION

The respondents were asked to describe how they see the service they mainly use in comparison to other similar services.

Comment: Valuable information was obtained but respondents did not really seem to think of possibilities in economic terms.

5. THE DETAILED USE PATTERN OF THE MAIN CURRENT AWARENESS SERVICE

The use pattern of a particular bulletin was questioned. The idea was to obtain information of the value-in-use of the bulletin. For example the following questions were asked:

What are the general savings, if there are any, from the use of the bulletin in terms of time or money monthly?

(1) in the library use ________
(2) in browsing literature ________
(3) in reading ________
(4) in maintaining own files ________
(5) other, what ________

Do you recall any examples of the information use chain where a bulletin had the vital role (e.g. a new technique saved efforts remarkably, some experiments already done, a particularly good review found, . . .)?

Comment: Useful information was obtained though it was hard for most of the respondents to separate the role of the main current awareness service from other services and from scanning journals.

THE INTERVIEW SCHEDULE II:

The value of SUBIS bulletins – providers' view

1. HISTORY OF THE SERVICE
2. PRODUCTION AND THE CONTENT OF THE BULLETINS
3. PRODUCTION COSTS AND PRICES
4. MARKET SITUATION
5. SUBSCRIBERS AND EVALUATION OF THE SERVICE

APPENDIX 4

CASE STUDY OF A SET OF RESEARCH PROJECTS AT VTT
- FIRST INTERVIEW

This interview aims at describing the histories of the projects studied at general level. The heads of the projects are interviewed. The questions consentrate on the inputs and the outputs of the projects. After the interview some documentation of the project is collected for further analysis.

In order to save space only the questions asked are listed, the original interview schedule was in Finnish with spaces for notes in connection to each question. The list of questions were sent to those interviewed a couple of days before the interview took place.

1. GENERAL DATA

-Research program
-Project
-The person interviewed
-Time and duration of the interview.

2. BACKGROUND OF THE PROJECT

-Documented goal of the project

-Importance of the project to the research program

-Previous knowledge in the area at VTT and in Finland when the project was started.

3. INPUTS OF THE PROJECT

-Project staff; changes, if any; reasons for the selection of each individual to the project

-Equipment, materials, software, etc. How the decisions were made?

-Information seeking at general level

-Other inputs.

4. OUTCOMES OF THE PROJECT

-Were the goals of the project fulfilled?

-Outcomes of the project

--Documents

--Equipment and devices

--Software, handbooks, manuals etc.

--Patents, standards

--New knowledge and abilities

-Have outcomes already been used? How?

-Estimates of the economic benefits from the projects now and in future.

5. ASSESMENTS OF THE PROJECT

-Did the project produce results value for the money put into it?

-Any feedback received from people outside the project group.

6. DOCUMENTATION OF THE PROJECT

The following documentation of the project was collected for further analysis:

- -project plan as it was when the project began
- -minutes of the project group and other possible supporting and advicing groups which took part in the project
- -published documents of the project and other reports
- -economic report of the project (produced for each project at VTT)

APPENDIX 5

A CASE STUDY OF INFORMATION USE IN A SET OF RESEARCH PROJECTS AT VTT

Information seeking and use of a set of research projects at VTT are studied in this interview. The project-documentation is analyzed and the findings tested in the interview in order to find evidence for major changes in the course of the project. Information seeking and use are studied by analysing the sources and contents of information used. The information use of key-tasks is studied more thoroughly. Those who had major responsibility of the projects are interviewed (1-2 scientists per project).

List of questions:

1. Project
2. Person interviewed
3. Date and duration of the interview

4. Tasks of the project

5. Major changes in the course of the project (detailed questions for this question are based on the analysis of the project documents; additions are made in the interview)

6. Reasons for the major changes in the project. Special attention is paid to the situations where new information was the reason for a change.

7. Information use in the project
(This part of the interview is carried out by scanning the project records with the respondent)

7.1 The amount of information acquired

-articles, books, other documents (amount and distribution)
-contact with experts and techniques used (-"-)

7.2 The portion of earlier knowledge and acquired information and knowledge asked to be given, not in amounts, but in terms of the relational contribution to the results achieved.

-earlier knowledge of the project group	____%
-acquired information and knowledge	
--domain information and knowledge	____%
--problem information and knowledge	____%
--method information and knowledge	____%

--general technical information and knowledge ____%

--other, what ____%

In total	100 %

7.3 Nature of the project in relation to the use of information

-produced new knowledge ____%

-used information from outside ____%

-used existing knowledge alone ____%

-combined existing knowledge with outside information ____%

-other, what ____%

In total	100 %

7.4 The use of documentation acquired

-scanned but not useful ____%

-read but not useful ____%

-partially useful ____%

-generally useful ____%

-other, what ____%

In total	100 %

8. Personal comments on the following statement:

A scientist prefers to use a found or given procedure to solve a problem on hand and uses more theoretical approaches if there are no practical procedures available.

9. Was there enough time available for the project? Describe the project as a learning project.

10. Information need and use of the key-task
(The respondents were asked to name the key-task from the list of tasks in the project-plan).

10.1 Brief description of the information needs

10.2 How the information was sought

-project-group already had the knowledge	____%
-sought from the laboratory	____%
-produced in the project	____%
-personal contacts with experts	____%
-from literature	____%
-other, what	____%
In total	100 %

10.3 Experiences from information seeking and use

10.4 Assessment of what should have been done in order to gain savings in time and money.

APPENDIX 6

EXPERTS' EVALUATIONS OF A SET OF PROJECTS AT VTT

In this interview a set of projects are evaluated by experts. The quality of the projects is assessed in relation to using and producing new information and knowledge.

List of questions:

1. Research programme

2. Project

3. Importance of the results achieved in the project

   3.1 At national level
   3.2 At VTT-level
   3.3 Economic success (whether value for the money was gained or not).

4. Importance of the project in producing new information and knowledge in Finland

(Circle appropriate number below, 0=no importance; 10=very important)

0 1 2 3 4 5 6 7 8 9 10.

5. Nature of the project in relation to information and knowledge

-New information and knowledge produced	____%
-International information and knowledge used	____%
-Existing knowledge used	____%
-Existing and outside information combined	____%
-Other, what	____%

In total	100 %

Comments:

APPENDIX 7

USE OF INFORMATION IN A SET OF ONGOING PROJECTS

Information use of the project studied is described in this interview from the beginning of the project or since the last interview.

List of questions:

1. Project

2. Person interviewed

3. Date and duration of the interview

4. What has happened in the project since the last interview

5. Inputs to the project except for information inputs

6. Information sought

7. Experiences of information use

8. New plans for the near future of the project

9. Nature of the information needed

-Create new information and knowledge	____%
-Use information and knowledge from outside	____%
-Use one's own information and knowledge	____%
-Combine outside and ones's own information	____%

	In total 100 %

APPENDIX 8

QUESTIONNAIRE ON INFORMATION SEEKING AND USE AT VTT

(The actual questionnaire is compressed for this presentation)

The aim of this questionnaire is to study information seeking and use patterns of scientists at VTT. The questionnaire is a part of a broader study on the costs and benefits of information seeking and use at VTT. The results of the questionnaire are used in developing present means to support information seeking and use as well as in developing new services. The idea is to develop information seeking and use as a whole which includes personal contacts, information use from documents and education. The results are dealt with in strict confidence and only aggregates are presented. The questionnaire has been sent to a group of scientists (100) at VTT.

Please mail the completed form to Repo/Information Service within seven days.

1. BACKGROUND INFORMATION

1.1 Name:

1.2 Laboratory:

1.3 Education (highest degree):

1.4 Age:

1.5 Working experience as a scientist ____, and at VTT ____

2. INFORMATION SEEKING PROFILE

Please find below a set of statements with which you are asked to agree (true) or disagree (false). The statements are based on earlier studies on information seeking patterns of scientists. Give your answers based on your present behaviour although you would like to behave differently. The information seeking profiles of scientists at VTT are formed by using this data. Please comment on your answers whenever you think it necessary, especially when you find answering difficult.

Statement	True(Agreed)	False(Disagreed)
1. Working hours are not enough for reading needed for the projects.		
2. I follow regularly ____ periodicals and I am satisfied with my knowledge of new research in my field.		

3. The continuous following of important journals in the field is essential.

4. In the beginning of my career I read more journals.

5. Literature is essential when going into new fields of research.

6. I order online search ____ times per year and I am satisfied with the results.

7. I follow regularly ____ abstract journals. They are a good means for following fields of interest.

8. I occasionally get reviews which are important for my projects from my colleagues.

9. I receive too much information which does not have relevance to my work.

10. New information is over-emphasized, everything not known previously, is new.

11. Personal contacts are the best means for gathering the latest research information.

12. I often use personal contacts
outside VTT for my research.

13. International contacts are essential
in following the latest developments
in my research field.

14. Information can be received from the
experts only if one's own knowledge
is at a high level.

15. Conferences abroad should be attended
regularly in order to follow the latest
developments. I have travelled abroad on
business ____ times during the 12 months.

16. National conferences are seldom useful.

17. Colleagues at VTT do transfer information
they have adopted efficiently to others.

18. Joint efforts in the research groups are
important for information seeking and use.

19. The use of information is a learning
process which takes time.

20. I visit the library ____ times a month and

I am satisfied with my library usage.

21. The information service should analyze information for project needs.

22. I use my own reference files for my ongoing research-projects.

23. I am satisfied with the efforts made at VTT for supporting my information seeking.

---

3. SOURCES OF INFORMATION

The list of information seeking sources and tools is given below. You are asked to say how often you use each source by using four categories: No use; Seldom used; Sometimes used; and Often used. Indicate also when did you last use each source. Answer 'No' if you have not used the source within the past two months. Notice that the list included overlaping sources. Please answer to every part.

	How often used			
Source	Often	Sometimes	Seldom	No

Published literature:

1. Periodicals
2. Research reports
3. Books
4. Patents
5. Standards
6. Trade literature
7. Theses and dissertations

Unpublished material:

8. Internal research reports
9. One's own research notes
10. Correspondence
11. Drawings, maps
12. Software

Tools for information seeking:

13. Abstract journals
14. Online-search
15. Handbooks
16. Textbooks
17. Ones's own indexes

Organizations and contacts
in information seeking:

18. Government departments

19. Other research organizations

20. Professional societies

21. Industry

22. Universities

23. Consultants

24. Clients

25. Library of the laboratory

26. VTT's information service

27. Other library, what ___________

Discussions with colleagues:

28. Discussions within VTT

29. Other contact in Finland

30. International contacts

(In connection with each source it was also asked when the source was last used)

Please rank by putting numbers in the margin representing the five most important sources and tools (1. meaning the most important source). Which five means are most important in seeking information for your research? Make sure that you have given an answer for each source.

4. DEVELOPING INFORMATION SEEKING AND USE

Supporting information seeking and use is a high priority activity at VTT. The task of the Information Service at VTT is to support information seeking for research work, especially from literary sources. Education and training advances international contacts (e.g. foreign exchange of scientists).

How should one develop information seeking and use at VTT? Mention development tasks and rank them afterwards.
From earlier studies one knows that previous experience and availability of sources are important in deciding which sources to use in a particular search-situation. There are other influencing factors as well, like economic factors. Which are the most important factors influencing your behaviour in information seeking?

Rank the factors according to their importance.

What kind of mistakes or failures do you recall happening recently in connection with your information seeking?

Economics of information seeking is an issue when information is sought by travelling or from online databases. What kind of discussions are there in your laboratory about economics of information seeking in general?

Is there enough discussion?

The benefits from the use of information are hard to measure but the costs are easier to deal with. Are you able to recall a fairly recent occasion where information sought introduced a benefit easy to measure (time savings, saved efforts, etc.)?
Describe briefly.

5. CONCLUDING REMARKS

Thank you for your time, our aim is to develop information seeking at VTT. Are there any further comments you would like to put forward after completing this questionnaire?

Please send the form to Aatto J. Repo, Information Service.

APPENDIX 9

STUDY OF TIME ALLOCATION IN A SAMPLE OF PROJECTS AT VTT

We ask you to follow the time you use for the given project using the enclosed form during the week ____. This study is a part of a research project where costs and benefits of information seeking and use are examined at VTT. The aim of our efforts is to develop information seeking and use at VTT. This time allocation study produces data on how time is used within the projects. The form has been sent to a representative set of project heads at VTT. If you are merely a project manager could you please pass this form to a scientist who has a central role in the actual project work?

Please return the form after the given week to Aatto J. Repo, Information Service. Return the form even though you did not do anything for the given project during the monitoring week. If you have any questions, please contact Aatto J. Repo/4409.

Yours sincerely,

Administrative Director

Pentti Grönberg

REPORTING FORM

TIME ALLOCATION STUDY AT VTT

Project:

Reported by:

The time used for the given project during the week ____.

Please note your time used in the project using given categories. You may comment on the hours in the margins (this is especially necessary if you find it difficult to decide into which category some particular activity falls). There are examples of what each category is meant to include on the enclosed sheet. If you use the category Other, please, define the content.

Activity\Day	Mon	Tue	Wed	Thu	Fri
Information seeking					
Reading					
Communication/VTT					
Communication /other					
Research					
Bureaucracy					
Documentation					
Other (*)					
In total					

(*) Definition of Other, if used:

Thank you for your co-operation, please return to Aatto J. Repo, Information Service.

DEFINITIONS OF THE CATEGORIES USED

INFORMATION SEEKING

-information seeking and acquisition from literary sources

-online searches

-scanning periodicals (only for the project followed)

-visits to library, information service etc.

READING

-reading for the project

-include the appropriate reading while travelling and at home.

COMMUNICATION/VTT

-communication within VTT

-discussions with colleagues, experts etc.

-telephone discussions, face-to-face contacts, meetings, seminars, conferences etc. for that part which belong to the particular project in question

-travelling for that part which belongs to the project, if you do other activities during the trip (e.g. reading) put that time into the appropriate category.

COMMUNICATION/OTHER

-communication with people outside VTT, as above.

RESEARCH

-actual research (theoretical and empirical research,

testing, making prototypes, programming etc.)
-note that in the case of literary study, data collection by interviews and questionnaires, data manipulation etc. belongs to this category.

BUREAUCRACY
-project-bureaucracy, like completing of forms
-the economics of the project and acquiring and managing resources
-project-meetings for that part which does not advance the research work in the project.

DOCUMENTATION
-documentation of the results
-verbal presentations of the results
-preparing presentations and publications.

OTHER
-other activities in the project, define in the form.

APPENDIX 10

INTERVIEW SCHEDULE

EFFECTIVE USE OF INFORMATION - MANAGERS' VIEWPOINT

(compressed version of the interview schedule)

The aim of this interview is to study information seeking and use in the laboratories at VTT from the viewpoint of managers. The brief summary of the earlier study of information seeking and use of scientists at VTT has been delivered to the managers well before the interview. The economics of information seeking and use in the laboratory is discussed at first. The developed model of optimal information use is explored. The problems and development ideas of information seeking and use are then discussed.

Person interviewed and the laboratory:

Time and duration of the interview:

1. ECONOMICS OF INFORMATION SEEKING AND USE

1.1 When you are setting up a project, or maintaining an ongoing one, how much thought is given to the cost of finding and using information to support the project workers?

(A broad definition of information seeking is used: information services, communication, education etc.)

-Any cost-benefit considerations?

-Who helps in making decisions about how information is sought for the research projects? Levels: manager, project head, scientist

-Nature of the information markets in the field?

1.3 How do you rate the quality of present information seeking and use patterns in the laboratory (from 0 to 10).

Why?

2. A MODEL FOR INFORMATION SEEKING AND USE IN THE RESEARCH PROJECT

The model is an extension of an input-output model of a research project. It was 'found' from the interviews of the scientists and other data that the following six areas seem to be of importance when one tries to develop the effectiveness of information seeking and use for optimal results of the research projects.

INPUTS =======> RESEARCH PROJECT ======> OUTPUTS

A) Inputs

1) Information environment
2) Joint efforts in information seeking
3) Seeking of methodological information

B) Research project

4) Time used for information seeking and use
5) The use of sought information

C) Outputs

6) Publishing the results of the project

We now study the parts of the model and collect comments on the need for each part and how it should be developed.

2.1 Information environment

Indicators in ranked order (VTT-level average in parantheses):

1) Important contacts in Finland (10/project)
2) International contacts (10/project)
3) Travelling abroad (2/scientist/year)
4) Periodicals followed (13/scientist)
5) Visits to library (2/scientist/month)
6) Abstract journals followed (3/scientist)
7) Online searches (1.4/scientist/year)

Comparisons to the laboratory, need for rich information environment, surprises in the averages.

2.2 Joint efforts in information seeking and use

Indicators:

1) Size of the project (active and passive information seekers together)
2) Senior and junior scientists together

Situation in the laboratory, development needs.

2.3 Seeking of method information

Indicators (optimum being rich channels to this information):

1) Colleagues

2) Contacts (national/international)

3) literature.

Problems in the laboratory.

2.4 Time used for information activities in the projects

Indicators (VTT-level averages/heads of the projects in parantheses):

1) Information seeking (9% of the time used)

2) Reading (12%, 60 000 FIM/project)

3) Communication within VTT (8%)

4) Communication/out (18%, 90 000 FIM/project)

5) Documentation (17%)

(Project bureaucracy 8%; experimental research 28%; average project 16 man months and 500 000 FIM)

Comparisons to the laboratory, surprises.

2.5 Use of acquired information

Indicators:

1) Ammount of article copies acquired

2) Usefulness of acquired articles (VTT-data in the parantheses)

-scanned, not useful (20%)
-read, not useful (25%)
-partially useful (40%)
-generally useful (15%)

Comments.

2.6 Publishing of the results of the project

Indicators (levels):

1) International article
2) International presentation
3) Article in Finland
4) Presentations, demonstrations in Finland
5) Other (reports etc.)

Discussions in the laboratory, goals.

2.7 Any other important areas to follow in information seeking and use.

2.8 Rate the importance of the parts of the model, indicate the three most important areas to follow for management purposes.

2.9 Would you be willing to use the model for monitoring the effectiveness of information seeking and use in your laboratory? If yes, in what form?

Example (modifications needed asked):

Data collection	Indicator
All the projects ended in the year 1987, questionnaire to the heads of the projects	Contacts in the project Project staff Seeking of method inf. Use of articles Publishing data
All the scientists at the laboratory, questionnaire	Foreign travelling Periodicals reading Visits to library Abstract journals Online searches
All the projects at the laboratory time allocation study, scientists	Information and other activities

All scientists at the laboratory	Ideas for developing information seeking and use

3. DEVELOPING INFORMATION SEEKING AND USE IN THE LABORATORY

3.1 What are the main problems in the present information seeking and use support at VTT? And what shoud be done?

(If necessary the ideas presented by the scientists are elaborated here)

Thank you for your co-operation.
